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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	02074-24012.NP
First Inventor	Chien-Min Sung
Title	CMP Pad Dresser Having Leveled Tips and A
Express Mail Label No.	electronically filed

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. ☐ **Fee Transmittal Form** (e.g., PTO/SB/17)
2. ☑ **Applicant claims small entity status.** See 37 CFR 1.27.
3. ☑ **Specification** [*Total Pages* 33]
   Both the claims and abstract must start on a new page
   (For information on the preferred arrangement, see MPEP 608.01(a))
4. ☑ **Drawing(s)** (*35 U.S.C. 113*) [*Total Sheets* 2]
5. **Oath or Declaration** [*Total Sheets* _____]
   a. ☐ Newly executed (original or copy)
   b. ☐ A copy from a prior application (37 CFR 1.63(d))
   (for continuation/divisional with Box 18 completed)
   i. ☐ DELETION OF INVENTOR(S)
   Signed statement attached deleting inventor(s) name in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
6. ☐ **Application Data Sheet.** See 37 CFR 1.76
7. ☐ **CD-ROM or CD-R** in duplicate, large table or Computer Program *(Appendix)*
   ☐ Landscape Table on CD
8. **Nucleotide and/or Amino Acid Sequence Submission**
   (if applicable, items a. – c. are required)
   a. ☐ Computer Readable Form (CRF)
   b. Specification Sequence Listing on:
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      ii. ☐ Paper
   c. ☐ Statements verifying identity of above copies

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ACCOMPANYING APPLICATION PARTS

9. ☐ **Assignment Papers** (cover sheet & document(s))
   Name of Assignee_____
10. ☐ **37 CFR 3.73(b) Statement** *(when there is an assignee)* ☐ **Power of Attorney**
11. ☐ **English Translation Document** *(if applicable)*
12. ☐ **Information Disclosure Statement** (PTO/SB/08 or PTO-1449)
    ☐ Copies of citations attached
13. ☐ **Preliminary Amendment**
14. ☐ **Return Receipt Postcard** (MPEP 503)
    (*Should be specifically itemized)*
15. ☐ **Certified Copy of Priority Document(s)**
    (if foreign priority is claimed)
16. ☐ **Nonpublication Request** under 35 U.S.C. 122(b)(2)(B)(i). Applicant must attach form PTO/SB/35 or equivalent.
17. ☐ Other:_____

18. If a CONTINUING APPLICATION, *check appropriate box, and supply the requisite information below and in the first sentence of the specification following the title, or in an Application Data Sheet under 37 CFR 1.76:*

☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No.: .....

Prior application information: *Examiner* _____ *Art Unit:* _____

19. CORRESPONDENCE ADDRESS

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This collection of information is required by 37 CFR 1.53(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

PRIORITY DATA

This application claims the benefit of United States Provisional Patent Application Serial no. 61/489,074, filed on May 23, 2011, which is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

The semiconductor industry currently spends in excess of one billion U.S. dollars each year manufacturing silicon wafers that must exhibit very flat and smooth surfaces. Known techniques to manufacture smooth and even-surfaced silicon wafers are plentiful. The most common of these involves the process known as Chemical Mechanical Polishing (CMP) which includes the use of a polishing pad in combination with an abrasive slurry. Of central importance in all CMP processes is the attainment of high performance levels in aspects such as uniformity of polished wafer, smoothness of the IC circuitry, removal rate for productivity, longevity of consumables for CMP economics, etc.

SUMMARY OF THE INVENTION

The present disclosure provides CMP pad dressers and associated methods thereof. In one aspect, for example, a CMP pad dresser can include a matrix layer and a monolayer of a plurality of superabrasive particles embedded in the matrix layer, where each superabrasive particle in the monolayer protrudes from the matrix layer. The difference in the protrusion distance between the highest protruding tip and the next highest protruding tip of the monolayer of superabrasive particles can be less than or equal to about 20 microns, and the difference in protrusion distance between the highest 1% of the protruding tips of the monolayer of superabrasive particles are within about 80 microns or less. In one specific aspect, a rigid support is coupled to the matrix layer.

In another aspect, the difference in protrusion distance between the highest protruding tip and the next highest protruding tip of the monolayer of superabrasive

particles is less than or equal to about 15 microns. In yet another aspect, the difference in protrusion distance between the highest protruding tip and the next highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 10 microns. In a further aspect, the difference in protrusion distance between the highest 10 protruding tips of the monolayer of superabrasive particles are within about 30 microns or less. In another aspect, the difference in protrusion distance between the highest 100 protruding tips of the monolayer of superabrasive particles are within about 50 microns or less. In yet another aspect, the difference in protrusion distance between the highest 1% of the protruding tips of the first monolayer of superabrasive particles are within about 50 microns or less. In another aspect, the difference in protrusion distance between the highest protruding tip and the second highest protruding tip is less than or equal to about 10 microns. In yet another aspect, the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip is less than or equal to about 20 microns. In a further aspect, the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip is less than or equal to about 40 microns. In another aspect, the highest protruding tip protrudes from the matrix layer to a height greater than or equal to about 50 microns.

In another aspect, a CMP pad dresser is provided. Such a dresser can include a first monolayer of superabrasive particles disposed on one side of a metal support layer and a second monolayer of superabrasive particles disposed on the metal support layer on an opposite side from the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer, and a rigid support is coupled to the second monolayer of superabrasive particles opposite the first monolayer.

In yet another aspect, a method of making a CMP pad dresser includes disposing a first monolayer of superabrasive particles on a metal support layer and disposing a second monolayer of superabrasive particles on the metal support layer on a side opposite the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer.

The method further includes bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the metal support layer such that symmetrical forces due to the substantially similar distribution between the first monolayer and the second monolayer precludes substantial warping of the metal support layer. In one aspect, the method can further include coupling the second monolayer of superabrasive particles to a rigid support.

In one aspect, the bonding of at least one of the first monolayer and the second monolayer is by brazing with a braze material. In another aspect, the bonding of at least one of the first monolayer and the second monolayer is under heat and pressure. In one specific aspect, the heat and pressure bonds at least one of the first monolayer and the second monolayer directly to the metal support layer. In another specific aspect, the bonding of at least one of the first monolayer and the second monolayer further includes disposing a sintering compound on the metal support layer in contact with at least one of the first monolayer and the second monolayer and sintering the sintering compound to bond the at least one of the first monolayer and the second monolayer to the metal support layer. In one specific aspect, the method further includes infiltrating the sintering compound with a braze material during bonding.

In yet another aspect, a method of minimizing warpage of a CMP pad dresser during manufacture is provided. Such a method can include substantially equalizing warping forces on opposing sides of a metal support layer during bonding of a plurality of superabrasive particles thereto, wherein warpage of the support layer is minimized during bonding due to the equalized forces on opposing sides. In one aspect, substantially equalizing forces includes arranging the plurality of superabrasive particles on opposing sides of the support layer such that the plurality of superabrasive particles has substantially the same distribution on either side of the support layer to substantially equalize warping forces during bonding.

In a further aspect, a CMP pad dresser is provided. Such a dresser can include a plurality of superabrasive particles arranged as a working surface, wherein the difference in protrusion distance between the highest protruding tip and the second highest

protruding tip is less than or equal to about 10 microns, the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip is less than or equal to about 20 microns, the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip is less than or equal to about 40 microns, and the highest protruding tip has a protrusion distance of greater than or equal to about 50 microns.

There has thus been outlined, rather broadly, various features of the invention so that the detailed description thereof that follows may be better understood, and so that the present contribution to the art may be better appreciated. Other features of the present invention will become clearer from the following detailed description of the invention, taken with the accompanying claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention;

FIG. 2 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention;

FIG. 3 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention;

FIG. 4 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention; and

FIG. 5 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention;

It will be understood that the above figures are merely for illustrative purposes in furthering an understanding of the invention. Further, the figures are not drawn to scale, thus dimensions, particle sizes, and other aspects may, and generally are, exaggerated to make illustrations thereof clearer. Therefore, departure can be made from the specific dimensions and aspects shown in the figures in order to produce the heat spreaders of the present invention.

DETAILED DESCRIPTION

Before the present invention is disclosed and described, it is to be understood that this invention is not limited to the particular structures, method steps, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

It must be noted that, as used in this specification and the appended claims, the singular forms "a," "an" and, "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a diamond particle" includes one or more of such particles and reference to "the layer" includes reference to one or more of such layers.

Definitions

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

As used herein, the terms "conditioner" and "dresser" can be used interchangeably, and refer to a tool used to condition or dress a pad, such as a CMP pad.

As used herein, "dressing segment" refers to a dressing or conditioning element of a CMP pad dresser. Dressing segments are utilized in the present invention to carry superabrasive particles having leveled tips. Thus superabrasive particles are introduced into a CMP pad dresser by the incorporation of multiple dressing segments. It should be noted that a variety of techniques of attaching the dressing segments to the substrates, and a variety of techniques of attaching the superabrasive particles to the dressing segments, are discussed herein. It is to be understood that all of these various attachment mechanisms can be used interchangeably herein: that is, if a method of attaching a dressing segment to a substrate is discussed herein, the method of attachment discussed can also be used to attach a superabrasive particles to a dressing segment. For any particular CMP pad dresser being discussed, however, it is understood that attachment methods of the

superabrasive particles to the dressing segments can differ from, or can be the same as, the method used to attach the dressing segments to the pad conditioner substrate.

As used herein, "superabrasive" may be used to refer to any crystalline, or polycrystalline material, or mixture of such materials which has a Mohr's hardness of about 8 or greater. In some aspects, the Mohr's hardness may be about 9.5 or greater. Such materials include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), polycrystalline cubic boron nitride (PcBN), corundum and sapphire, as well as other superabrasive materials known to those skilled in the art. Superabrasive materials may be incorporated into the present invention in a variety of forms including particles, grits, films, layers, pieces, segments, etc. In some cases, the superabrasive materials of the present invention are in the form of polycrystalline superabrasive materials, such as PCD and PcBN materials.

As used herein, "organic material" refers to a semisolid or solid complex or mix of organic compounds. "Organic material layer" and "organic matrix" may be used interchangeably, and refer to a layer or mass of a semisolid or solid complex or mix of organic compounds, including resins, polymers, gums, etc. The organic material can be a polymer or copolymer formed from the polymerization of one or more monomers. In some cases, such organic material can be adhesive.

As used herein, the process of "brazing" is intended to refer to the creation of chemical bonds between the carbon atoms of the superabrasive particles/materials and the braze material. Further, "chemical bond" means a covalent bond, such as a carbide or boride bond, rather than mechanical or weaker inter-atom attractive forces. Thus, when "brazing" is used in connection with superabrasive particles a true chemical bond is being formed. However, when "brazing" is used in connection with metal to metal bonding the term is used in the more traditional sense of a metallurgical bond. Therefore, brazing of a superabrasive segment to a tool body does not necessarily require the presence of a carbide former.

As used herein, "particle" is as used herein in connection with diamond particles, and refers to a particulate form of diamond. Such particles may take a variety of shapes,

including round, oblong, square, euhedral, etc., can be either single crystal or polycrystalline, and can have a number of mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes. All mesh sizes referred to herein are U.S. mesh unless otherwise indicated. Further, mesh sizes are generally understood to indicate an average mesh size of a given collection of particles since each particle within a particular "mesh size" may actually vary over a small distribution of sizes.

As used herein, "sharp portion" means any narrow portion to which a crystal or particle may come, including but not limited to corners, apexes, ridges, edges, obelisks, and other protrusions. In some cases, corners and/or apexes are formed at the convergence of more than two faces of the particle or crystal, or other body, disposed in intersecting planes. In other aspects, edges and/or ridges may be formed at the convergence of two or at least two faces of the particle or crystal, or other body, disposed in intersecting planes. In some aspects, "sharp portion" can include a portion that is broken, chipped, cracked, jagged, and the like. In some aspects, degrees of sharpness can be correlated with the geometric angle formed by the particle, crystal, or other body, at the location in question. In some aspects, an angle of 90 degrees or less can be considered sharp. In other aspects, an angle of 60 degrees or less can be considered sharp. In yet other aspects, and angle of 45 degrees or less, or 30 degrees or less can be considered to be sharp.

As used herein, "peripherally located," "peripheral location" and the like, mean any particle of a dresser that is located in an area that originates at the leading edge or outer rim of a dresser and extends inwardly towards the center for up to about 90% of the radius of the dresser. In some aspects, the area may extend inwardly from about 20% to 90% of the radius. In other aspects, the area may extend in to about 50% of the radius. In yet another aspect, the area may extend in to about 33% of the radius of a dresser (i.e. 66% away from the center).

As used herein, "working end" refers to an end of a particle which is oriented towards the CMP pad and during a dressing operation makes contact with the pad. Most

often the working end of a particle will be distal from a substrate to which the particle is attached.

As used herein, "attitude" means the position or arrangement of a superabrasive particle in relation to a defined surface, such as a substrate to which it is attached, or a CMP pad to which it is to be applied during a work operation. For example, a superabrasive particle can have an attitude that provides a specific portion of the particle in orientation toward a CMP pad.

As used herein, "sintering" refers to the joining of two or more individual particles to form a continuous solid mass. The process of sintering involves the consolidation of particles to at least partially eliminate voids between particles.

The term "metallic" refers to both metals and metalloids. Metals include those compounds typically considered metals found within the transition metals, alkali and alkali earth metals. Examples of metals are Ag, Au, Cu, Al, and Fe. Metalloids include specifically Si, B, Ge, Sb, As, and Te. Metallic materials also include alloys or mixtures that include metallic materials. Such alloys or mixtures may further include additional additives. In the present invention, carbide formers and carbon wetting agents may be included as alloys or mixtures, but are not anticipated to be the only metallic component. Examples of such carbide formers are Sc, Y, Ti, Zr, Hf, V, Nb, Cr, Mo, Mn, Ta, W, and Tc. Examples of carbon wetting agents are Co, Ni, Mn, and Cr.

As used herein, "infiltrating" refers to a situation where a material is heated to its melting point and then flows as a liquid through the interstitial voids between particles.

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained.

The use of "substantially" is equally applicable when used in a negative

connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. For example, a composition that is "substantially free of" particles would either completely lack particles, or so nearly completely lack particles that the effect would be the same as if it completely lacked particles. In other words, a composition that is "substantially free of" an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.

As used herein, the term "about" is used to provide flexibility to a numerical range endpoint by providing that a given value may be "a little above" or "a little below" the endpoint.

As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

Concentrations, amounts, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc., as well as 1, 2, 3, 4, and 5, individually. This same principle applies to ranges reciting only one numerical value as a minimum or a maximum. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present disclosure generally provides CMP pad dressers and associated methods that can be utilized in conditioning (e.g., smoothing, polishing, dressing) a CMP pad. Pad conditioners of the present invention can be advantageously utilized, for example, in dressing CMP pads that are used in polishing, finishing or otherwise affecting semiconductor materials. Specifically, the present disclosure concerns CMP pad dressers having superabrasive particles with substantially leveled tips. Traditional CMP pad dresser manufacturing methods, even many of those describing techniques for leveling superabrasive particle tips prior to fixation, generally contain significant variation in tip height across the surface of the dresser. Often, the superabrasive particles are affixed to the CMP pad dresser support in a manner that disrupts any leveling that has occurred. For example, fixation techniques that utilize high heat and/or pressure can cause warping of the dresser support as the dresser cools. Thus, unless steps are taken to avoid such warpage, superabrasive particles are not maintained in their leveled state following cooling of the dresser. This can be particularly problematic with brazing techniques.

Accordingly, minimizing the warpage of the metal support layer can maintain a greater degree of leveling of superabrasive particle tips in the finished tool. When heat and/or pressure are used to make a superabrasive tool, warpage of the metal support layer can cause great variations in tip height level, even for those particles that were leveled prior to heating and/or applying pressure. By distributing the warpage forces equally or substantially equally on both sides of the metal support layer through the arrangement of the superabrasive particles, these forces effectively cancel each other with respect to the degree of warping occurring in the metal support layer, thus also minimizing the relative height movement of the superabrasive particles relative to one another.

The present CMP pad dressers include a layer of superabrasive particles having substantially leveled tips across the working surface of the finished CMP pad dresser. A variety of techniques can be utilized to maintain tip leveling, and any such technique is considered to be within the present scope. A few non-limiting examples of such techniques are described below.

In one aspect, as is shown in FIG. 1, a CMP pad dresser 10 includes a monolayer of a plurality of superabrasive particles 12 embedded in a matrix layer 14, such that each superabrasive particle in the monolayer protrudes from the matrix layer. The difference in protrusion distance 16 between the highest protruding tip 17 and the next highest protruding tip 18 of the monolayer of superabrasive particles is less than or equal to about 20 microns. In some aspects, the protrusion difference may be less than or equal to about 50 microns. Additionally, the difference in protrusion distance between the highest 1% of the protruding tips of the first monolayer of superabrasive particles are within about 80 microns or less. In other words, for the 1% of the plurality of superabrasive particles that have the highest protruding tips, the variance in protrusion distance for that 1% is less than or equal to about 80 microns. Thus, the two highest protruding superabrasive particle tips protrude to within about 20 microns or less of each other, and in addition, the highest protruding 1% of superabrasive particle tips protrude to within about 80 microns or less of each other. In another aspect, the difference in protrusion distance between the highest protruding tip and the next highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 15 microns. In yet another aspect, the difference in protrusion distance between the highest protruding tip and the next highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 10 microns. In a further aspect, the difference in protrusion distance between the highest 1% of the protruding tips of the first monolayer of superabrasive particles are within about 70 microns or less. In yet another aspect, the difference in protrusion distance between the highest 1% of the protruding tips of the first monolayer of superabrasive particles are within about 50 microns or less. In another aspect, and in addition to the protrusion variance of the highest two protruding tips, the difference in

protrusion distance between the highest 10 protruding tips of the monolayer of superabrasive particles are within about 30 microns or less. In yet another aspect, the difference in protrusion distance between the highest 100 protruding tips of the monolayer of superabrasive particles are within about 50 microns or less. Additionally, in one aspect, the rigid support can be coupled to the matrix layer (not shown).

In another aspect, the difference in protrusion distance the difference in protrusion distance between the highest protruding tip and the second highest protruding tip is less than or equal to about 10 microns. In yet another aspect, the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip is less than or equal to about 20 microns. In a further aspect, the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip is less than or equal to about 40 microns. In yet a further aspect, the highest protruding tip protrudes from the matrix layer to a height greater than or equal to about 50 microns. In another aspect, the highest protruding tip has a protrusion distance of greater than or equal to about 50 microns.

It is noted that the recited protrusion distances can include a distribution across the entire monolayer surface or a discrete area or segment of the monolayer. For example, the highest 1% of protruding tips can be located around the periphery of the monolayer. In another example, discrete regions of leveled superabrasive particle tips can be located within a larger area of superabrasive particles having a lower protrusion distance than the leveled portion. It is also contemplated that the monolayer can include multiple regions or segments of superabrasive particles that are leveled as described, within a larger area of superabrasive particles having a lower protrusion distance.

Various methods can be utilized to measure superabrasive particle tip height to determine the difference in protrusion distance between tips. As such, any method for making such a determination is considered to be within the present scope. It should be noted that for the purposes of the present disclosure, the term "protrusion" refers to the height of a particle relative to some reference point. Techniques for such measurements can include direct measurements of the tip heights relative to a reference point such as, for

example, the highest particle tip, a surface of a rigid support, the bottom surface of the matrix, etc. Measurements of particle height from the surface of the matrix material can be problematic, however, due to the irregular nature of such materials due to wicking around the superabrasive particles. In those cases whereby the matrix material is uniform, such a surface may be used to determine particle height. Additionally, a relative protrusion or height difference between two particles would be the difference in the heights between these particles measured from a common reference point. Furthermore, in some cases the superabrasive particles may lie along a slope, curvature, or some other arrangement that is not parallel to the metal support layer. In these cases, the protrusion height would be normalized against the slope, curvature, or other arrangement so that the relative protrusion height difference between particles can be measured in the absence of the slope, curvature, etc. It should be noted that superabrasive particle tip height leveling can, in some cases, be independent from the positioning or patterning of the superabrasive particles across the surface of the dresser.

One example of a direct measurement technique can include an optical scanning process to evaluate superabrasive particle tip positions. In one such process, an optical scanner can scan the surface of the CMP pad dresser to determine the height of the superabrasive particle tips relative to a fixed point. For example, the scanner can scan downward in space toward the dresser until the highest tip is located. The highest tip can then be set to the reference point, and the scanner can continue scanning in a direction toward the dresser measuring the distance from the reference point to each superabrasive particle tip across the surface of the dresser. Accordingly, the difference in protrusion distance between all of the superabrasive particles across the dresser can be directly measured.

Furthermore, measurement techniques can also include indirect measurements, such as, for example, applying the diamond monolayer to a deformable substrate that deforms relative to the protrusion distance of the particle tips. The diamond monolayer can be pressed into the deformable substrate and/or moved across the deformable

substrate to form a scratch pattern therein. Tip height can thus be extrapolated from such indirect measurements.

A variety of materials are contemplated for use as superabrasive particles. Any superabrasive known that can be utilized in a CMP pad dresser should be considered to be within the present scope. Non-limiting examples of such materials include diamond materials, nitride materials, ceramics, and the like. In one aspect, the superabrasive particles include diamond materials. Such diamond materials can include natural or synthetic diamond, single crystal, polycrystalline, and the like. In another aspect, the superabrasive particles include cubic boron nitride materials. Additionally, various diamond particles sizes can be used, including mesh sizes such as 10/20, 30/40, 80/90, 90/100, 100/120, 120/140, 140/170, 170/200, 200/230, 230/270, 270/325, and 325/400.

Additionally, the plurality the superabrasive particles can be oriented so as to affect dressing performance of a CMP pad. Orienting the superabrasive particles in a specific attitude in relation to the CMP pad to be dressed creates different asperities in the pad surface, thus altering the performance of the CMP pad. Different asperities retain slurry in different manners and thus polish a workpiece differently according to asperity depth, width, density, etc. The superabrasive particles of a CMP pad dresser can be oriented according to the desired polishing characteristics of the CMP pad. For example, if the superabrasive particles predominantly have an apex oriented towards the CMP pad, the asperities of the pad will be narrow and deep. The advantages of narrow and deep asperities are that the pad can better retain the polishing slurry, and thus the polishing rate of the wafer increases. However, the increased polishing rate may also increase the wear rate of the superabrasive particles. As such, wear rate may vary depending on the attitude of the superabrasive particles, and therefore, the orientation of each superabrasive particle may be considered when designing a device with desired performance characteristics. Generally speaking, superabrasive particle attitudes that provide higher dressing rates (i.e. deeper penetration into a pad) also wear particles out at a higher rate.

In contrast, if the superabrasive particles are oriented with a face towards the pad, the resulting asperities may polish at a lower rate. The face of the particle is generally

thought to be more durable, but does not typically cut deep and narrow asperities in the pad, but rather asperities that are shallow and broad. Therefore the face portion of a particle will dress a CMP pad at a reduced rate compared to the apex portion of a particle, but the superabrasive particle will wear at a much lower rate.

The edge portions of a superabrasive particle have dressing and wear characteristics that are between those of the face and apex portions. It has been thought that if the edge portion is utilized to dress a CMP pad, the asperities are not as deep or narrow as those dressed with an apex portion, but may provide asperities having desirable intermediate characteristics. Further, the edge portion of the particle does not wear at such a high rate as that of an apex.

In one aspect, the plurality of superabrasive particles are substantially all configured in an attitude having either an apex portion oriented toward a pad to be dressed. In another aspect, the plurality of superabrasive particles are substantially all configured in an attitude having either an edge portion oriented toward a pad to be dressed. In yet another aspect, the plurality of superabrasive particles can be configured in an attitude having a sharp portion oriented towards a pad to be dressed.

A CMP pad dresser having such substantially leveled tip arrangements can have a low scratch rate because superabrasive particles are less likely to pull out of the matrix layer due to their more uniform protrusion distribution compared to traditional dressers. Additionally, the more uniform protrusion distributions of such a dressers allows the conditioning of CMP pads in such a manner as to facilitate good polishing rates while at the same time extending the effective working life of the dresser. These benefits can be affected by, for example, uniform asperity spacing and size distribution in the CMP pad.

In one aspect of the present disclosure, superabrasive tip leveling can be accomplished by manufacturing the CMP pad dresser in such a way that the effects of warpage are minimized. For example, in one aspect a CMP pad dresser can be made in at least a two stage process, where the first stage is performed in a manner that minimizes perturbations of the leveled tips in a process that would normally significantly move the superabrasive tips out of a leveled arrangement, such as, for example, by brazing. The

second stage of the process can further enhance the leveling of superabrasive particle tips across the CMP pad dresser.

Various exemplary configurations of CMP pad dressers having substantially leveled tips are contemplated. In one aspect, for example, a CMP pad dresser can include a first monolayer of superabrasive particles disposed on one side of a metal support layer and a second monolayer of superabrasive particles disposed on the metal support layer on an opposite side from the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer. A rigid support is coupled to the second monolayer of superabrasive particles opposite the first monolayer to provide support to the dresser.

As is shown in FIG. 2, a first monolayer of superabrasive particles 22 is arranged on a surface of a metal support layer 24. A second monolayer of superabrasive particles 26 is arranged on the metal support layer 24 on a side that is opposite to the first monolayer. As is discussed further below, in some cases the first and second monolayers of superabrasive particles can be arranged such that corresponding superabrasive particles across the metal support layer are in substantial alignment, as is shown in FIG. 2. In other cases, the superabrasive particles of the first and second monolayers can be arranged in a substantially similar distribution, but may or may not be substantially aligned with one another across the metal support layer.

The metal support layer can be any material capable of supporting the diamond monolayer during tool formation. Such materials can include, without limitation, metal materials, metal alloy materials, braze alloy materials, ceramic materials, composites, and the like.

In one aspect, the superabrasive particles can be arranged into a predetermined pattern. Such a pattern can be a uniformly distributed pattern or a non-uniformly distributed pattern. Additionally, a variety of techniques are contemplated to facilitate the arrangement of superabrasive particles into a predetermined pattern. Predetermined is understood to mean a non-random pattern that has been determined prior to arranging the superabrasive particles. In one aspect, a predetermined pattern can also apply to a

predetermined spacing between particles. Non-limiting examples of such techniques include arrangement by a template, arrangement using spots of adhesives, arrangement on a first substrate followed by a pattern specific transfer from the first substrate to the metal support layer, and the like, including combinations thereof. The superabrasive particles from either of the monolayers can be temporarily held in position in the predetermined pattern using a variety of techniques, including, without limitation, adhesives, dimpled locations on the metal support matrix, a supporting compound such as, for example, a wax, and the like, including combinations thereof. In one specific aspect, the superabrasive particles can be temporarily coupled to the metal support layer using an adhesive that then volatilizes away and is eliminated during construction of the dresser.

In one aspect, the predetermined pattern can be a uniformly distributed grid. In another aspect, the predetermined pattern can be an annular configuration having a central region devoid of superabrasive particles. In one specific aspect, the annular configuration can include an annular ring. In another specific aspect, the annular configuration can include a portion of an annular ring. In yet another aspect, an annular configuration can include one or more concentric annular rings nested inside one another. In other aspects, the monolayer distribution can be discrete radial regions, spiral regions, and the like.

The disposition of a monolayer of superabrasive particles on each side of the metal layer thus moderates the thermal shrinkage from the brazing temperature that would otherwise buckle a distribution of superabrasive particles arranged on just one side. By applying a monolayer to each side of the metal support layer, warping forces such as thermal movement and pressure can be equalized or substantially equalized on both sides. As such, the warpage of the metal support layer can be minimized. In other words, the forces responsible for warping are applied substantially equally to each side of the metal layer and can thus at least partially cancel one another out, thus minimizing warpage that can otherwise occur. In some aspects, the superabrasive particles making up the monolayers on each side of the metal layer can have matching configurations, patterns, or orientations to one another. In this way there can be a substantially matching spatial arrangement of superabrasive particles on each side of the metal layer. In another aspect,

the configurations, patterns, or orientations can be different or varied from one another, or may be partially matching. In yet another aspect, the patterned placement of the superabrasive particles on one side of the metal support layer can be substantially aligned with the pattern of superabrasive particles on the other side of the metal layer so that particle locations match one another. In some aspects, there can be a direct correspondence between the spatial positioning of superabrasive particles on one side of the metal support layer and the spatial positioning of superabrasive particles on the other side of the metal support layer. In another aspect, the patterns of superabrasive particles may match or substantially match one another, but may be offset on opposite sides of the metal support layer so that particle locations do not match one another.

In another aspect, as is shown in FIG. 3, a first monolayer of superabrasive particles 32 is arranged on a surface of a metal support layer 34. A second monolayer of superabrasive particles 36 is arranged on the metal support layer 34 on a side that is opposite to the first monolayer. A bonding material 38 secures the first monolayer and the second monolayer to the metal support layer 34. The bonding material can be any material capable of securing the first and second monolayer to the metal support layer. In some aspect, the bonding material can be the same for securing the first monolayer and the second monolayer, while in other aspects, the bonding material can be different for securing the first monolayer and the second monolayer.

The bonding material can be any material capable of securing superabrasive particles therein. Non-limiting examples of bonding materials include metal brazes, metal braze alloys, organic matrix materials, sintered materials, electroplated materials, and the like, including combinations thereof.

In one aspect, for example, the superabrasive particles can be brazed to the metal support layer, and thus the bonding material can be a metal braze or metal braze alloy. Metal brazing techniques are known in the art. A green braze material can be applied to the metal support layer on or around the superabrasive particles. The metal braze can be applied in any know configuration, including braze sheets, powders, pastes, sprays, and the like, including combinations thereof. Once applied to the metal support layer, the

braze can be heated and melted to coat at least a portion of the metal support layer and to bond the superabrasive particles. The heating temperature can vary depending on the braze material used, but in one aspect can be from about 700°C to about 1200°C. The superabrasive particles in the first and second monolayer are thus arranged such that thermal forces exerted on the metal support layer during heating and cooling are substantially equalize in order to minimize warping.

In one non-limiting example, the superabrasive particles can be bonded to the metal support layer by brazing with a nickel-based alloy containing chromium. In another example, the brazing can include pressing the superabrasive particles with a flat ceramic material that cannot be bonded to the braze in order to level the superabrasive particle tips. Various braze alloys are contemplated, including non-limiting examples such as BNi_2, BNi_7, and the like.

Additionally, in one aspect at least one of the first and second monolayers of superabrasive particles can be coupled to the metal support layer by an electrodeposition process, and thus the bonding material can be an electrodeposited metal material. As an example of a suitable method for positioning and retaining abrasive materials prior to and during the electrodeposition process, a mold can be used that includes an insulating material that can effectively prevent the accumulation of electrodeposited material on the molding surface. Superabrasive particles can be held on the molding surface of the mold during electrodeposition. As such, the accumulation of electrodeposited material can be prevented from occurring on the particle tips and the working surface of the pad conditioner substrate. Such techniques are described in U.S. Patent Application Serial No. 11/292,938, filed December 2, 2005, which is hereby incorporated herein by reference.

In another aspect, the superabrasive particles can be bonded to the metal support layer by sintering, and thus the bonding material can include a sintering material. For example, the bonding of the superabrasive particles to the metal support layer can include disposing a sintering compound on the metal support layer in contact with at least one of the first monolayer and the second monolayer and sintering the sintering compound to bond the at least one of the first monolayer and the second monolayer to the metal support

layer. Suitable sintering methods will be readily appreciated by one of ordinary skill in the art having possession of this disclosure. Basically, a sintering compound is applied around the superabrasive particles and in contact with the metal support layer. The sintering compound can be any known sintering material that can be used to secure superabrasive particles to a substrate. Non-limiting examples of such materials can include metal and metal alloy powders, ceramic powders, and the like. One specific non-limiting example of a sintering compound is cobalt powder.

Once the sintering compound has been applied around the superabrasive particles and to the metal support substrate, heat and in some cases pressure can be applied to cause sintering to occur. In some aspects, a braze or braze alloy can be infiltrated into the sintering compound during bonding to further strengthen the bonding material matrix.

In another aspect, as is shown in FIG. 4, heat and pressure can be applied to bond the first monolayer of superabrasive particles 42 and/or the second monolayer of superabrasive particles 46 directly into the metal support layer 44. Thus, upon the application of heat and pressure, the metal support layer 44 is softened or partially melted. The superabrasive particles in one or more of the monolayers are then pressed into the metal support layer. A planar leveling surface can be used to apply pressure to the monolayer and thus maintain the level nature of the superabrasive particle tips as the superabrasive particles are pressed into the metal support layer. Upon cooling, the distribution of superabrasive particles on either side of the metal support layer at least partially equalizes the thermal forces acting on the metal support layer, thus minimizing warping.

In yet another aspect, as is shown in FIG. 5, a CMP pad dresser can include a first monolayer of superabrasive particles 52 and a second monolayer of superabrasive particles 56 coupled to a metal support layer 54. The superabrasive particles can be coupled to the metal support layer directly or via a bonding material. The second monolayer of superabrasive particles 56 is coupled to a rigid support 58. A portion of the rigid support 58 is shown removed in FIG. 5 to expose the second monolayer. The rigid support 58 can facilitate handling and use of the CMP pad dresser. By bonding the superabrasive

particles of the second monolayer to the rigid support, the first monolayer of superabrasive particles remains exposed for CMP pad conditioning operations.

The rigid support can be made from any material compatible with the abrading or dressing process. Such materials can include polymeric materials, metal materials, ceramic materials, glasses, composites, and the like. In one aspect, the rigid support can be a polymeric material and the second monolayer of superabrasive particles can be embedded therein using heat, pressure, adhesives, etc. In some aspects, the rigid support can be a non-polymeric material such as a metal layer. In such cases, the superabrasive particles can be bonded to the rigid support by adhesive attachment, soldering, brazing, electroplating, and the like. For brazing techniques, care can be taken to minimize or eliminate warpage in the metal layer during the heating and cooling process. In another aspect, one or more magnetic elements can be placed into the rigid support to attract and hold the CMP pad dresser in place, thus forming a temporary attachment. An optional locking mechanism can be utilized to further immobilize the CMP pad dresser to the rigid support during use. In some aspects the rigid support can include surface features to hold the dresser in place during rotational movement against a CMP pad. The rigid support can have approximately the same diameter as the metal support layer, a larger diameter than the metal support layer, or, in some cases, a smaller diameter than the metal support layer.

In another aspect, a CMP pad dresser can be comprised of a plurality of dressing segments having a plurality of leveled superabrasive particles tips, where the plurality of dressing segments are held in place by a rigid support. Such a design allows a plurality of smaller dressing segments to be manufactured having precisely leveled tips. Smaller diameter metal support layers in these dressing segments can be made by processes involving heat and/or pressure with less warpage due to their smaller size. For example, a 4 inch diameter metal disc can exhibit greater warping due to brazing as compared to a 0.5 inch diameter metal disc. Thus thermal distortion and particle floating problems are decreased. A plurality of such dressing segments can then be coupled to a larger diameter rigid support by processes that do not introduce significant warpage, such as bonding in an

organic material. Such dressing segments can have one or more layer(s) of superabrasive particles coupled to a support layer. In one aspect, a segment can have a single layer of superabrasive particles coupled to a metal support layer. In another aspect, a segment can have a layer of superabrasive particles coupled to each side of a metal support layer, as has been described herein. Thus, this process allows the manufacture of CMP pad dressers that can have precise tip protrusion tolerances. Additionally, in one aspect, each dressing segment can have at least three superabrasive particles that protrude to the greatest extent. If the three highest protruding superabrasive particles on every dressing segment are leveled across the entire rigid support, a CMP pad dresser is made having very precise tip leveling across the entire surface. If, for example, ten dressing segments are used to make the CMP pad dresser, then the highest protruding thirty superabrasive particles in the tool will have effectively the same protrusion distance and be substantially leveled. Various additional details regarding dressing segments are detailed in U.S. Patent Application No. 13/034,213, filed February 24, 2011, which is hereby incorporated herein by reference.

Various organic materials are contemplated for use as a rigid support and/or to be used to secure the second monolayer of superabrasive particles and/or the dressing segments to the rigid support. Examples of suitable organic matrix materials include, without limitation, amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof. In one specific aspect, the organic material can be an epoxy resin. In another aspect, the organic material can be a polyimide resin. In yet another aspect, the organic material can be a polyurethane resin.

Additionally, so-called "reverse casting" methods can be used to accurately orient and attach the dressing segments to the rigid support. Such methods can include initially securing the plurality of dressing segments to a substrate using a "mask" material. The portions of the dressing segments protruding from the mask material can then be attached

to the rigid support using the methods discussed herein, after which (or during which), the masking material can be removed.

When an organic material is utilized, methods of curing the organic material can be a variety of processes known to one skilled in the art that cause a phase transition in the organic material from at least a pliable state to at least a rigid state. Curing can occur, without limitation, by exposing the organic material to energy in the form of heat, electromagnetic radiation, such as ultraviolet, infrared, and microwave radiation, particle bombardment, such as an electron beam, organic catalysts, inorganic catalysts, or any other curing method known to one skilled in the art.

In one aspect of the present invention, the organic material can be a thermoplastic material. Thermoplastic materials can be reversibly hardened and softened by cooling and heating respectively. In another aspect, the organic material layer may be a thermosetting material. Thermosetting materials cannot be reversibly hardened and softened as with the thermoplastic materials. In other words, once curing has occurred, the process can be essentially irreversible, if desired.

As a more detailed list of what is described above, organic materials that may be useful in embodiments of the present invention include, but are not limited to: amino resins including alkylated urea-formaldehyde resins, melamine-formaldehyde resins, and alkylated benzoguanamine-formaldehyde resins; acrylate resins including vinyl acrylates, acrylated epoxies, acrylated urethanes, acrylated polyesters, acrylated acrylics, acrylated polyethers, vinyl ethers, acrylated oils, acrylated silicons, and associated methacrylates; alkyd resins such as urethane alkyd resins; polyester resins; polyamide resins; polyimide resins; reactive urethane resins; polyurethane resins; phenolic resins such as resole and novolac resins; phenolic/latex resins; epoxy resins such as bisphenol epoxy resins; isocyanate resins; isocyanurate resins; polysiloxane resins including alkylalkoxysilane resins; reactive vinyl resins; resins marketed under the Bakelite™ trade name, including polyethylene resins, polypropylene resins, epoxy resins, phenolic resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, ethylene copolymer resins, acrylonitrile-butadiene-styrene (ABS) resins, acrylic resins, and vinyl resins; acrylic resins; polycarbonate resins;

and mixtures and combinations thereof. In one aspect of the present invention, the organic material may be an epoxy resin. In another aspect, the organic material may be a polyimide resin. In yet another aspect, the organic material may be a polyurethane resin.

Numerous additives may be included in the organic material to facilitate its use. For example, additional crosslinking agents and fillers may be used to improve the cured characteristics of the organic material layer. Additionally, solvents may be utilized to alter the characteristics of the organic material in the uncured state. Also, a reinforcing material may be disposed within at least a portion of the solidified organic material layer. Such reinforcing material may function to increase the strength of the organic material layer, and thus further improve the retention of the individual abrasive segments. In one aspect, the reinforcing material may include ceramics, metals, or combinations thereof. Examples of ceramics include alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof.

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of a superabrasive material to facilitate the retention of the superabrasive particles in the organic material via chemical bonding. A wide variety of organic and organometallic compounds is known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive materials and the organic material, thus increasing the retention of the superabrasive materials therein. In this way, the organometallic coupling agent can serve as a bridge to form bonds between the organic material and the surface of the superabrasive material. In one aspect of the present invention, the organometallic coupling agent can be a titanate, zirconate, silane, or mixture thereof. The amount of organometallic coupling agent used can depend upon the coupling agent and on the surface area of the superabrasive material. Oftentimes, 0.05% to 10% by weight of the organic material layer can be sufficient.

Specific non-limiting examples of silanes suitable for use in the present invention include: 3- glycidoxypropyltrimethoxy silane (available from Dow Corning as Z-6040); γ-methacryloxy propyltrimethoxy silane (available from Union Carbide Chemicals Company

as A-174); β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, γ- aminopropyltriethoxy silane, N-(β-aminoethyl)-γ-aminopropylmethyldimethoxy silane (available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.). Specific non-limiting examples of titanate coupling agents include: isopropyltriisostearoyl titanate, di(cumylphenylate)oxyacetate titanate, 4-aminobenzenesulfonyldodecylbenzenesulfonyl titanate, tetraoctylbis (ditridecylphosphite) titanate, isopropyltri(N-ethylamino-ethylamino) titanate (available from Kenrich Petrochemicals. Inc.), neoalkyoxy titanates such as LICA-01, LICA-09, LICA-28, LICA-44 and LICA-97 (also available from Kenrich), and the like. Specific non-limiting examples of aluminum coupling agents include acetoalkoxy aluminum diisopropylate (available from Ajinomoto K.K.), and the like. Specific non-limiting examples of zirconate coupling agents include: neoalkoxy zirconates, LZ-01, LZ-09, LZ- 12, LZ-38, LZ-44, LZ-97 (all available from Kenrich Petrochemicals, Inc.), and the like. Other known organometallic coupling agents, e.g., thiolate based compounds, can be used in the present invention and are considered within the scope of the present invention.

In other aspects of the present disclosure, superabrasive particle tips can be leveled by reducing the protrusions of particles that are outside of the desired tolerance range. Once such particles are identified, various techniques can be utilized to reduce such protrusions. In one aspect, for example, mechanical abrasion of the dresser can reduce the protruding particles. In another aspect, a vibration tool can be used to individually break such particles. In yet another aspect, a laser such as a Nd:YAG laser can be used to disrupt such particles.

In another aspect of the present disclosure, a method of making a CMP pad dresser can include disposing a first monolayer of superabrasive particles on a metal support layer, and disposing a second monolayer of superabrasive particles on the metal support layer on a side opposite the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer. The method can further include bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the metal support layer such that symmetrical forces due to the substantially

similar distribution between the first monolayer and the second monolayer precludes substantial warping of the metal support layer.

In yet another aspect, disposing at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles can include adhering a plurality of superabrasive particles to an adhesive transfer sheet in a predetermined pattern established by apertures in a template, and removing the template from the adhesive transfer sheet such that the plurality of superabrasive particles remain adhered to the adhesive transfer sheet in the predetermined pattern. The plurality of superabrasive particles is then transferred with the adhesive transfer sheet to the metal support layer, and the adhesive transfer sheet is removed from the plurality of superabrasive particles to form at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles.

In a further aspect of the present disclosure, a method of minimizing warpage of a CMP pad dresser during manufacture can include substantially equalizing warping forces on opposing sides of a metal support layer during bonding of a plurality of superabrasive particles thereto, wherein warpage of the support layer is minimized during bonding due to the equalized forces on opposing sides. In one aspect, substantially equalizing forces includes arranging the plurality of superabrasive particles on opposing sides of the support layer such that the plurality of superabrasive particles has substantially the same distribution on either side of the support layer to substantially equalize warping forces during bonding.

In yet a further aspect of the present disclosure, a CMP pad dresser can include a plurality of superabrasive particles arranged as a working surface, where the difference in protrusion distance between the highest protruding tip and the second highest protruding tip of the first monolayer of superabrasive particles is less than or equal to about 20 microns, and where the difference in protrusion distance between the highest 1% of the protruding tips of the first monolayer of superabrasive particles, excluding the highest protruding tip, are within about 80 microns.

In another aspect, a CMP pad dresser can include a plurality of superabrasive particles arranged as a working surface, where the difference in protrusion distance between the highest protruding tip and the second highest protruding tip is less than or equal to about 10 microns, the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip is less than or equal to about 20 microns, the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip is less than or equal to about 40 microns, and the highest protruding tip has a protrusion distance of greater than or equal to about 50 microns.

It is noted that, while the above disclosure refers primarily to CMP pad dressers, other precision grinding and/or abrading tools are considered to be within the present scope. As such, the techniques and teaching disclosed herein can additionally be applied to such tools.

Additionally, it is noted that traditional CMP processing techniques, including pad dressing, has limited the critical dimension of integrated circuits. The presently disclosed CMP dressing devices and techniques can, however, allows processing of wafers having integrated circuit critical dimensions of less than or equal to 45nm, 32nm, 28nm, or 22nm.

Of course, it is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use may be made without departing from the principles and concepts set forth herein.

CLAIMS

What is claimed is:

1. A CMP pad dresser, comprising:

a matrix layer;

a monolayer of a plurality of superabrasive particles embedded in the matrix layer, wherein each superabrasive particle in the monolayer protrudes from the matrix layer, and wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 50 microns and the difference in protrusion distance between the highest 1% of the protruding tips of the monolayer of superabrasive particles are within about 80 microns or less.

2. The dresser of claim 1, wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip is less than or equal to about 10 microns.

3. The dresser of claim 2, wherein the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip is less than or equal to about 20 microns.

4. The dresser of claim 3, wherein the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip is less than or equal to about 40 microns.

5. The dresser of claim 4, wherein the highest protruding tip protrudes from the matrix layer to a height greater than or equal to about 50 microns.

6. The dresser of claim 1, further comprising a rigid support coupled to the matrix layer.

7. The dresser of claim 1, wherein the plurality of superabrasive particles are arranged in at least one annular configuration having a central region devoid of superabrasive particles.

8. The dresser claim 1, wherein the plurality of superabrasive particles are configured in an attitude having a sharp portion oriented towards a pad to be dressed.

9. The dresser of claim 1, wherein the plurality of superabrasive particles are substantially all configured in an attitude having either an apex or an edge portion oriented toward a pad to be dressed.

10. A CMP pad dresser, comprising:

a first monolayer of superabrasive particles disposed on one side of a metal support layer;

a second monolayer of superabrasive particles disposed on the metal support layer on an opposite side from the first monolayer, wherein the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer; and

a rigid support coupled to the second monolayer of superabrasive particles opposite the first monolayer.

11. The dresser of claim 10, wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip of the first monolayer of superabrasive particles is less than or equal to about 10 microns.

12. The dresser of claim 11, wherein the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip of the first monolayer of superabrasive particles is less than or equal to about 20 microns.

13. The dresser of claim 12, wherein the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip of the first monolayer of superabrasive particles is less than or equal to about 40 microns.

14. A method of making a CMP pad dresser, comprising:

disposing a first monolayer of superabrasive particles on a metal support layer;

disposing a second monolayer of superabrasive particles on the metal support layer on a side opposite the first monolayer, wherein the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer; and

bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the metal support layer such that symmetrical forces due to the substantially similar distribution between the first monolayer and the second monolayer precludes substantial warping of the metal support layer.

15. The method of claim 14, wherein the bonding of at least one of the first monolayer and the second monolayer is by brazing with a braze material.

16. The method of claim 14, wherein the bonding of at least one of the first monolayer and the second monolayer is under heat and pressure.

17. The method of claim 16, wherein the bonding of at least one of the first monolayer and the second monolayer further includes:

disposing a sintering compound on the metal support layer in contact with at least one of the first monolayer and the second monolayer; and

sintering the sintering compound to bond the at least one of the first monolayer and the second monolayer to the metal support layer.

18. The method of claim 17, further comprising infiltrating the sintering compound with a braze material during bonding.

19. The method of claim 16, wherein the heat and pressure bonds at least one of the first monolayer and the second monolayer directly to the metal support layer.

20. The method of claim 14, wherein the superabrasive particles of the second monolayer are positioned to substantially align with the superabrasive particles of the first monolayer.

21. The method of claim 14, further comprising coupling the second monolayer of superabrasive particles to a rigid support.

22. The method of claim 21, wherein the coupling of the second monolayer of superabrasive particles to the rigid support is accomplished by a member selected from the group consisting of hot pressing, brazing, sintering, soldering, electroplating, and combinations thereof.

23. The method of claim 21, wherein the coupling of the second monolayer of superabrasive particles to the rigid support is accomplished by polymeric bonding.

24. The method of claim 14, wherein disposing at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles includes:

adhering a plurality of superabrasive particles to an adhesive transfer sheet in a predetermined pattern established by apertures in a template;

removing the template from the adhesive transfer sheet such that the plurality of superabrasive particles remain adhered to the adhesive transfer sheet in the predetermined pattern;

transferring the plurality of superabrasive particles with the adhesive transfer sheet to the metal support layer; and

removing the adhesive transfer sheet from the plurality of superabrasive particles to form at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles.

25. A method of minimizing warpage of a CMP pad dresser during manufacture, comprising:

substantially equalizing warping forces on opposing sides of a metal support layer during bonding of a plurality of superabrasive particles thereto, wherein warpage of the support layer is minimized during bonding due to the equalized forces on opposing sides.

26. The method of claim 25, wherein substantially equalizing forces includes arranging the plurality of superabrasive particles on opposing sides of the support layer such that the plurality of superabrasive particles has substantially the same distribution on either side of the support layer to substantially equalize warping forces during bonding.

27. A CMP pad dresser, comprising:

a plurality of superabrasive particles arranged as a working surface, wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip is less than or equal to about 10 microns, the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip is less than or equal to about 20 microns, the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip is less than or equal to about 40 microns, and the highest protruding tip has a protrusion distance of greater than or equal to about 50 microns

ABSTRACT

CMP pad dressers having leveled tips and associated methods are provided. In one aspect, for example, a CMP pad dresser can include a matrix layer and a monolayer of a plurality of superabrasive particles embedded in the matrix layer, where each superabrasive particle in the monolayer protrudes from the matrix layer. The difference in the protrusion distance between the highest protruding tip and the next highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 20 microns, and the difference in protrusion distance between the highest 1% of the protruding tips of the monolayer of superabrasive particles are within about 80 microns or less.

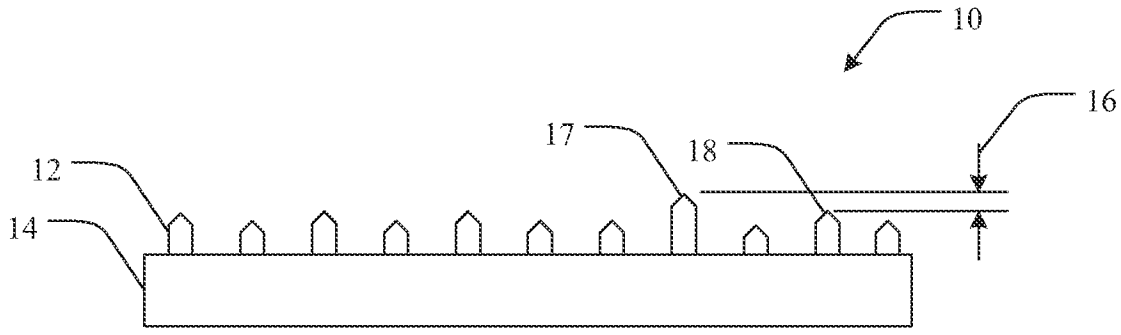


FIG. 1

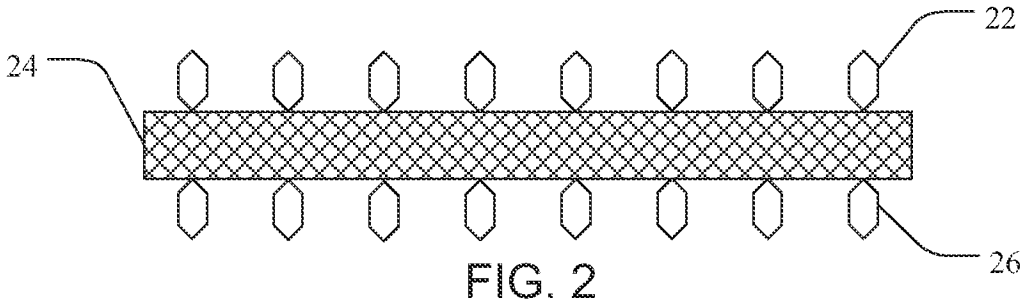


FIG. 2

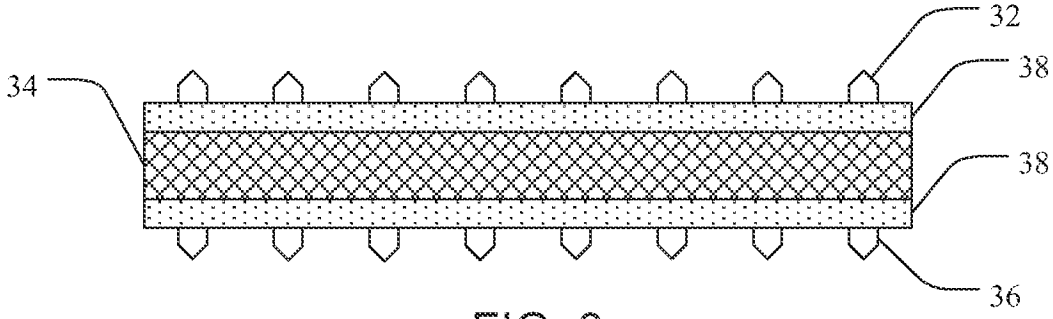


FIG. 3

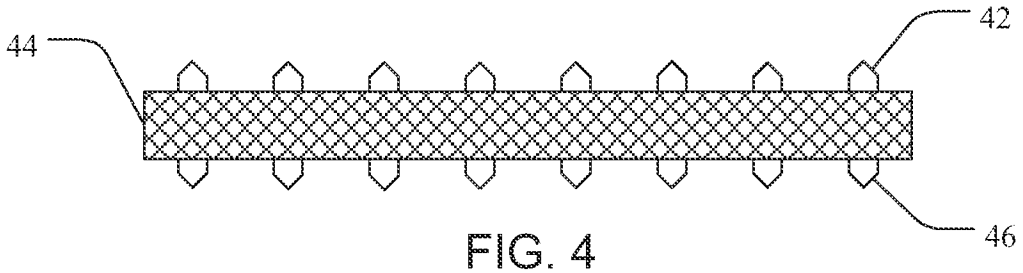


FIG. 4

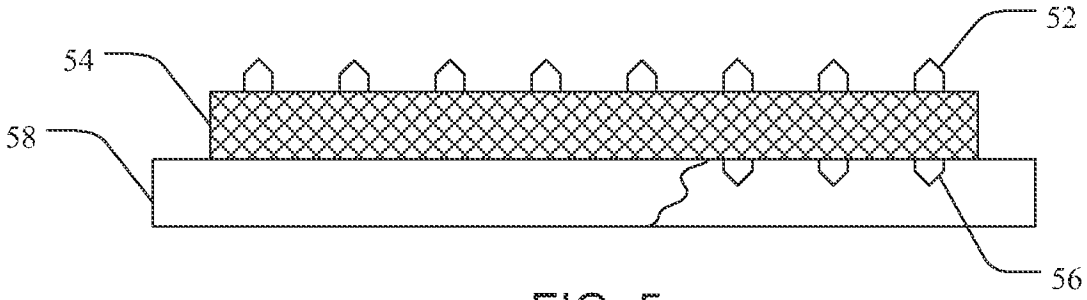


FIG. 5

Electronic Acknowledgement Receipt

EFS ID:	12851767
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Nicole Solomon
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	23-MAY-2012
Filing Date:	
Time Stamp:	19:33:47
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal of New Application	24012NPtransmittal.pdf	190008 edba9b6f3d78e66587024e78869cca5b30c2a6f0	no	1

Warnings:	
Information:	

2		24012NPapplication.PDF	317029 5945bf74fc439aa0b3556d7dde3258dcd1c0d4a1	yes	33

Multipart Description/PDF files in .zip description		
Document Description	**Start**	**End**
Specification	1	27
Claims	28	32
Abstract	33	33

Warnings:

Information:

3	Drawings-only black and white line drawings	24012NPdrawings2.pdf	23162 52765c4d4443e235b76019bfe80b8dea2bf2c301	no	2

Warnings:

Information:

Total Files Size (in bytes):	530199

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If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/479,148	Filing Date 05/23/2012	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	

AMENDMENT

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.

** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".

*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".

The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/KIMBERLY WHITE/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP

CONFIRMATION NO. 7248

20551
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

FORMALITIES LETTER

OC000000054641827

Date Mailed: 06/07/2012

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

An application number and filing date have been accorded to this application. The item(s) indicated below, however, are missing. Applicant is given **TWO MONTHS** from the date of this Notice within which to file all required items below to avoid abandonment. Extensions of time may be obtained by filing a petition accompanied by the extension fee under the provisions of 37 CFR 1.136(a).

- The statutory basic filing fee is missing.
  *Applicant must submit $**95** to complete the basic filing fee for a small entity.*
- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The applicant needs to satisfy supplemental fees problems indicated below.

The required item(s) identified below must be timely submitted to avoid abandonment:

- Additional claim fees of $**460** as a small entity, including any required multiple dependent claim fee, are required. Applicant must submit the additional claim fees or cancel the additional claims for which fees are due.
- A surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $**65** for a small entity in compliance with 37 CFR 1.27, must be submitted.

SUMMARY OF FEES DUE:

Total fee(s) required within **TWO MONTHS** from the date of this Notice is $**1055** for a small entity

- $**95** Statutory basic filing fee.
- $**65** Surcharge.
- The application search fee has not been paid. Applicant must submit $**310** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit $**125** to complete the examination fee for a small entity in compliance with 37 CFR 1.27.

- Total additional claim fee(s) for this application is $**460**
  - $**250** for **2** independent claims over 3.
  - $**210** for **7** total claims over 20.

Replies should be mailed to:

Mail Stop Missing Parts
Commissioner for Patents
P.O. Box 1450
Alexandria VA 22313-1450

Registered users of EFS-Web may alternatively submit their reply to this notice via EFS-Web.
https://sportal.uspto.gov/authenticate/AuthenticateUserLocalEPF.html

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/afessehaye/

Office of Data Management, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/479,148

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	95		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	310		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	27 minus 20 =	* 7	x 30 =	210	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	5 minus 3 =	* 2	x 125 =	250			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	990		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
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P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/479,148	05/23/2012	3723	0.00	02074-24012.NP	27	5

CONFIRMATION NO. 7248

20551
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

FILING RECEIPT

OC000000054641826

Date Mailed: 06/07/2012

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Chien-Min Sung, Residence Not Provided;

Power of Attorney: None

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/489,074 05/23/2011

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 06/04/2012

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/479,148**

Projected Publication Date: To Be Determined - pending completion of Missing Parts

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****

Title

CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

Preliminary Class

451

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

Since the rights granted by a U.S. patent extend only throughout the territory of the United States and have no effect in a foreign country, an inventor who wishes patent protection in another country must apply for a patent in a specific country or in regional patent offices. Applicants may wish to consider the filing of an international application under the Patent Cooperation Treaty (PCT). An international (PCT) application generally has the same effect as a regular national patent application in each PCT-member country. The PCT process **simplifies** the filing of patent applications on the same invention in member countries, but **does not result** in a grant of "an international patent" and does not eliminate the need of applicants to file additional documents and fees in countries where patent protection is desired.

Almost every country has its own patent law, and a person desiring a patent in a particular country must make an application for patent in that country in accordance with its particular laws. Since the laws of many countries differ in various respects from the patent law of the United States, applicants are advised to seek guidance from specific foreign countries to ensure that patent rights are not lost prematurely.

Applicants also are advised that in the case of inventions made in the United States, the Director of the USPTO must issue a license before applicants can apply for a patent in a foreign country. The filing of a U.S. patent application serves as a request for a foreign filing license. The application's filing receipt contains further information and guidance as to the status of applicant's license for foreign filing.

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For information on preventing theft of your intellectual property (patents, trademarks and copyrights), you may wish to consult the U.S. Government website, http://www.stopfakes.gov. Part of a Department of Commerce initiative, this website includes self-help "toolkits" giving innovators guidance on how to protect intellectual property in specific countries such as China, Korea and Mexico. For questions regarding patent enforcement issues, applicants may call the U.S. Government hotline at 1-866-999-HALT (1-866-999-4158).

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NOT GRANTED

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DECLARATION, POWER OF ATTORNEY AND PETITION

As a below named inventor, I hereby declare: that my residence, post office address, and citizenship are as stated below next to my name; that I verily believe I am the original, first, and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS, the specification of which was filed on May 23, 2012, as THORPE NORTH & WESTERN, LLP Docket No. 02074-24012.NP, and given United States Application No. 13/479,148, (Assignee's attorney is hereby authorized to insert the specified data, when known); and was amended on _____ (if applicable); that the subject matter of the attached amendment or amendment filed on _____ was part of my invention and was invented before the filing date of the original application, above identified for such invention; that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to above; and that I acknowledge the duty to disclose information which is material to patentability of this application as defined in §1.56 of Title 37 of the Code of Federal Regulations.

I hereby claim the benefit of the earlier filed patent application(s) filed with the United States Patent and Trademark Office as:

Application Number 61/489,074 filed May 23, 2011, status pending;

and insofar as the subject matter of each of the claims of this application is not disclosed in the earlier filed pending application in the manner provided by the first paragraph of §112 of Title 35 of the United States code, we acknowledge the duty to disclose information which is material to this application, as defined in §1.56 of Title 37 of the Code of Federal Regulations, which occurred between the filing date of the earlier filed application and the filing date of this application.

I declare further that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under §1001 of Title 18 of the United States Code, and that such willful, false statements may jeopardize the validity of the application or any patent issuing thereon.

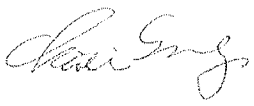
I hereby appoint as my attorneys and/or agents all registered patent practitioners/attorneys associated with Customer Number **20,551**; all with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

All correspondence concerning this application should be directed to **David W. Osborne** at the address associated with the above-mentioned Customer Number. (Even though an attorney is listed, please associate the above-mentioned Customer Number with this case.).

Wherefore, I pray that Letters Patent be granted to me for the invention or discovery described and claimed in the foregoing specification and claims, declaration, power of attorney, and this petition.

Signed at Hsin Chu, TAIWAN (City, State), this 7th day of August, 2012.

INVENTOR(S):



Chien-Min Sung

Residence:	Tansui, Taipei County
Citizenship:	US
Post Office Address:	4, Lane 32, Chung-Cheng Road Tansui, Taipei County 251 TAIWAN, ROC

document in prolaw

Electronic Patent Application Fee Transmittal

Application Number:	13479148
Filing Date:	23-May-2012
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Nicole Solomon
Attorney Docket Number:	02074-24012.NP

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility filing Fee (Electronic filing)	4011	1	95	95
Utility Search Fee	2111	1	310	310
Utility Examination Fee	2311	1	125	125
Pages:				
Claims:				
Claims in excess of 20	2202	7	30	210
Independent claims in excess of 3	2201	2	125	250
Miscellaneous-Filing:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Late filing fee for oath or declaration	2051	1	65	65
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1055**

Electronic Acknowledgement Receipt

EFS ID:	13441740
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Nicole Solomon
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	07-AUG-2012
Filing Date:	23-MAY-2012
Time Stamp:	19:40:21
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$1055
RAM confirmation Number	6087
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Oath or Declaration filed	24012NPdeclaration.pdf	87084 931d2504c6696187ad213ece0f61969f9ff13e24	no	2
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	40129 97044d683024bd4a564abbf674f24195a58a902d	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	127213	

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PATENT APPLICATION FEE DETERMINATION RECORD

Substitute for Form PTO-875

Application or Docket Number: 13/479,148

APPLICATION AS FILED - PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY FEE($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	95		N/A	
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	310		N/A	
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	125		N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	27 minus 20 =	* 7	x 30 =	210	OR		
INDEPENDENT CLAIMS (37 CFR 1.16(h))	5 minus 3 =	* 2	x 125 =	250			
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			0.00			
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				0.00			
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	990		TOTAL	

APPLICATION AS AMENDED - PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE($)	SMALL ENTITY ADDITIONAL FEE($)	OR	OTHER THAN SMALL ENTITY RATE($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))							OR		
						TOTAL ADD'L FEE		OR	TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest found in the appropriate box in column 1.

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APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
13/479,148	05/23/2012	3723	1055	02074-24012.NP	27	5

CONFIRMATION NO. 7248

UPDATED FILING RECEIPT

20551
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

OC000000055933768

Date Mailed: 08/17/2012

Receipt is acknowledged of this non-provisional patent application. The application will be taken up for examination in due course. Applicant will be notified as to the results of the examination. Any correspondence concerning the application must include the following identification information: the U.S. APPLICATION NUMBER, FILING DATE, NAME OF APPLICANT, and TITLE OF INVENTION. Fees transmitted by check or draft are subject to collection. Please verify the accuracy of the data presented on this receipt. **If an error is noted on this Filing Receipt, please submit a written request for a Filing Receipt Correction. Please provide a copy of this Filing Receipt with the changes noted thereon. If you received a "Notice to File Missing Parts" for this application, please submit any corrections to this Filing Receipt with your reply to the Notice. When the USPTO processes the reply to the Notice, the USPTO will generate another Filing Receipt incorporating the requested corrections**

Applicant(s)

Chien-Min Sung, Tansui, TAIWAN;

Power of Attorney: The patent practitioners associated with Customer Number 20551

Domestic Priority data as claimed by applicant

This appln claims benefit of 61/489,074 05/23/2011

Foreign Applications (You may be eligible to benefit from the **Patent Prosecution Highway** program at the USPTO. Please see http://www.uspto.gov for more information.)

If Required, Foreign Filing License Granted: 06/04/2012

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 13/479,148**

Projected Publication Date: 11/29/2012

Non-Publication Request: No

Early Publication Request: No
**** SMALL ENTITY ****

Title

CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

Preliminary Class

451

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

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Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2001/0003884	06/2001	Wei et al.	
		2001/0009844	07/2001	Cho et al.	
		2002/0042200	04/11/2002	Fawcett	
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Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
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First Named Inventor	Chien-Min Sung
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Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
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Attorney Docket Number	02074-24012.NP

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Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

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PTO/SB/08A (08-03)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet | | of |

Complete if Known	
Application Number	13/479,148
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

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Examiner	Cite	Foreign Patent Document	Publication	Name of Patentee or	Pages, Columns, Lines, Where	

PTO/SB/08A (08-03)
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First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

Initials*	No.[1]	Country Code[3]- Number[4] – Kind Code[5] (if known)	Date MM-DD-YYYY	Applicant of Cited Document	Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1]Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/416,201
Filing Date	3/9/2012
First Named Inventor	Chien-Min Sung
Art Unit	1731
Examiner Name	
Attorney Docket Number	00802-T5100.CIP9

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Examiner Signature		Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:

DAVID W. OSBORNE

THORPE NORTH & WESTERN, LLP PO BOX 1219 SANDY UT 84091-1219 USA

RECEIVED
MAY 18 2012
THORPE NORTH & WESTERN

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing *(day/month/year)* 11 MAY 2012 (11.05.2012)	
Applicant's or agent's file reference 3356-32820.PCT2	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. **PCT/US2011/052627**	International filing date *(day/month/year)* **21 SEPTEMBER 2011 (21.09.2011)**
Applicant **SUNG CHIEN-MIN et al**	

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:

   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 - 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19months.

For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon, 189 Cheongsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer COMMISSIONER Telephone No. 82-42-481-8753

Form PCT/ISA/220 (July 2010)

OVER

* Attention

Copies of the documents cited in the international search report can be searched in the following Korean Intellectual Property Office English website for three months from the date of mailing of the international search report.

http://www.kipo.go.kr/en/ => PCT Services => PCT Services

ID : PCT international application number
PW : **PJGDHYKN**

Inquiries related to PCT International Search Report or Written Opinion prepared by KIPO as an International Searching Authority can be answered not only by KIPO but also through IPKC (Intellectual Property Korea Center), located in Vienna, VA, which functions as a PCT Help Desk for PCT applicants.

Homepage: http://www.ipkcenter.com
Email: ipkc@ipkcenter.com
Phone: +1 703 388 1066
Fax: +1 703 388 1084

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	FOR FURTHER ACTION	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
3356-32820.PCT2		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2011/052627	**21 SEPTEMBER 2011 (21.09.2011)**	21 SEPTEMBER 2010 (21.09.2010)

Applicant

SUNG CHIEN-MIN et al

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 4 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

I. **Basis of the report**

a. With regard to the **language**, the international search was carried out on the basis of:

☒ the international application in the language in which it was filed

☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).

c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.

2. ☐ **Certain claims were found unsearchable** (See Box No. II)

3. ☐ **Unity of invention is lacking** (See Box No. III)

4. With regard to the **title,**

☒ the text is approved as submitted by the applicant.

☐ the text has been established by this Authority to read as follows:

5. With regard to the **abstract,**

☒ the text is approved as submitted by the applicant.

☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. With regard to the drawings,

a. the figure of the **drawings** to be published with the abstract is Figure No. 4

☒ as suggested by the applicant.

☐ as selected by this Authority, because the applicant failed to suggest a figure.

☐ as selected by this Authority, because this figure better characterizes the invention.

b. ☐ none of the figure is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/052627

A. CLASSIFICATION OF SUBJECT MATTER

B24B 53/12(2006.01)i, H01L 21/304(2006.01)i, B24D 18/00(2006.01)i, B24B 37/04(2006.01)i, B24D 7/06(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B24B 53/12; C09K 3/14; B24D 3/06; B24B 1/00; B24B 21/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: CMP, abrasive, particle, layer

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	US 2008-0271384 A1 (THOMAS PUTHANANGADY et al.) 06 November 2008 See paragraphs 22-38 and figures 2-6.	1-13,18-23 14-17
Y	US 7198553 B2 (BRIAN D. GOERS) 03 April 2007 See column 3, line 13 - column 4, line 33 and figure 5.	14-17
A	US 7651386 B2 (CHIEN-MIN SUNG) 26 January 2010 See column 14, line 29 - column 18, line 14 and figures 1-6.	1,12,22
A	US 2006-0073774 A1 (CHIEN-MIN SUNG) 06 April 2006 See paragraphs 54-57 and figures 1-4.	1,12,22

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
10 MAY 2012 (10.05.2012)	**11 MAY 2012 (11.05.2012)**

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
Government Complex-Daejeon, 189 Cheongsa-ro,
Seo-gu, Daejeon 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

MYUNG Dae Keun

Telephone No. 82-42-481-8417

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2011/052627

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008-0271384 A1	06.11.2008	AT 515372 T	15.07.2011
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2011/052627

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PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
DAVID W. OSBORNE

THORPE NORTH & WESTERN, LLP PO BOX 1219
SANDY UT 84091-1219 USA

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing *(day/month/year)*	**11 MAY 2012 (11.05.2012)**
Applicant's or agent's file reference 3356-32820.PCT2	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2011/052627	**21 SEPTEMBER 2011 (21.09.2011)**	21 SEPTEMBER 2010 (21.09.2010)

International Patent Classification (IPC) or both national classification and IPC

B24B 53/12(2006.01)i, H01L 21/304(2006.01)i, B24D 18/00(2006.01)i, B24B 37/04(2006.01)i, B24D 7/06(2006.01)i

Applicant

SUNG CHIEN-MIN et al

DOCKETED
Description Due Date Initials
Response 8-11-12 dc
INITIAL

1. This opinion contains indications relating to the following items:

- [X] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [X] Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [ ] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.
For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/KR	Date of completion of this opinion	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, 189 Cheongsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	10 MAY 2012 (10.05.2012)	MYUNG Dae Keun Telephone No.82-42-481-8417

Form PCT/ISA/237 (cover sheet) (July 2011)

DOCKETED MAY 23 2012 TNW

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2011/052627

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

   a. a sequence listing filed or furnished
      ☐ on paper
      ☐ in electronic form

   b. time of filing or furnishing
      ☐ contained in the international application as filed.
      ☐ filed together with the international application in electronic form.
      ☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additioanl copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2011/052627

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-23	YES
	Claims	NONE	NO
Inventive step (IS)	Claims	NONE	YES
	Claims	1-23	NO
Industrial applicability (IA)	Claims	1-23	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: US 2008-0271384 A1 (THOMAS PUTHANANGADY et al.) 06 November 2008
D2: US 7198553 B2 (BRIAN D. GOERS) 03 April 2007
D3: US 7651386 B2 (CHIEN-MIN SUNG) 26 January 2010
D4: US 2006-0073774 A1 (CHIEN-MIN SUNG) 06 April 2006

1. Novelty and Inventive Step

1.1 Independent Claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses a CMP pad dresser comprising a first monolayer of superabrasive particles disposed on and coupled to one side of a substrate, and a second monolayer of superabrasive particles disposed on and coupled to the substrate on an opposite side from the first monolayer. Claim 1 differs from D1 in that a CMP pad dresser of claim 1 comprises superabrasive particles of a first monolayer having substantially the same distribution as superabrasive particles of a second monolayer. However, it would be easily predicted by the feature that the dresser of D1 comprises superabrasive particles equally applicable on both sides of the substrate. Therefore, claim 1 lacks an inventive step under PCT Article 33(3).

1.2 Dependent Claims 2-11

1.2.1 Concerning Claim 2-7

The additional features of claims 2-7 to be related with the material of superabrasive particles would be easily predicted by the feature that the CMP pad dresser of D1 comprises diamond and cubic boron nitride as the material of superabrasive particles. Therefore, claims 2-7 lack an inventive step under PCT Article 33(3).

1.2.2 Concerning Claim 8

The additional feature of claim 8 would be easily predicted by the feature that the CMP pad dresser of D1 comprises a zirconia support coupled to the second monolayer. Therefore, claim 8 lacks an inventive step under PCT Article 33(3).

(Continued on Supplemental Box)

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Box V

1.2.3 Concerning Claim 9 and 10

The additional features of claims 9 and 10 to be related with a braze alloy would be easily predicted by the feature that the CMP pad dresser of D1 comprises brazing alloy to couple the first and second monolayers to the substrate. Therefore, claims 9 and 10 lack an inventive step under PCT Article 33(3).

1.2.4 Concerning Claim 11

The additional feature of claim 11 would be easily predicted by the feature that the dresser of D1 comprises superabrasive particles equally applicable on both sides of the substrate. Therefore, claim 11 lacks an inventive step under PCT Article 33(3).

1.3 Independent Claim 12

D1, which is considered to be the closest prior art to the subject matter of claim 12, discloses a method of making a CMP pad dresser comprising the steps of disposing a first monolayer of superabrasive particles on a substrate; disposing a second monolayer of superabrasive particles on the substrate on a side opposite the first monolayer, wherein the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer; and bonding the first monolayer and the second monolayer to the substrate. Claim 12 differs from D1 in that a method of claim 12 comprises bonding monolayers to a metal suppport layer such that symmetrical forces precludes substantial warping of the metal support layer. However, it would be easily predicted by the feature that the method of D1 comprises superabrasive particles equally applicable on both sides of the substrate. Therefore, claim 12 lacks an inventive step under PCT Article 33(3).

1.4 Dependent Claims 13-21

1.4.1 Concerning Claim 13

The additional feature of claim 13 would be easily predicted by the feature that the method of D1 comprises brazing alloy to couple the first and second monolayers to the substrate. Therefore, claim 13 lacks an inventive step under PCT Article 33(3).

1.4.2 Concerning Claims 14 and 17

The additional features of claims 14 and 17 would be easily predicted by the feature that a method of D2 comprises the step of bonding abrasive particles (6) to a substrate (4) under heat and pressure. Accordingly, claims 14 and 17 would have been obvious over D1 in view of D2. Therefore, claims 14 and 17 lack an inventive step under PCT Article 33(3).

(Continued on Next Page)

Supplemental Box

In case the space in any of the preceding boxes is not sufficient.
Continuation of:

Previous Page

1.4.3 Concerning Claims 15 and 16

The additional features of claims 15 and 16 dependent on claim 14 would be easily predicted by the feature that the method of D1 comprises the steps sintering and brazing during bonding. Therefore, claims 15 and 16 lack an inventive step under PCT Article 33(3).

1.4.4 Concerning Claim 18

The additional feature of claim 18 would be easily predicted by the feature that the method of D1 comprises superabrasive particles equally applicable on both sides of the substrate. Therefore, claim 18 lacks an inventive step under PCT Article 33(3).

1.4.5 Concerning Claims 19 and 21

The additional features of claims 19 and 21 would be easily predicted by the feature that the method of D1 comprises a zirconia support coupled to the second monolayer. Therefore, claims 19 and 21 lack an inventive step under PCT Article 33(3).

1.4.6 Concerning Claim 20

The additional feature of claim 20 would be easily predicted by the feature that the method of D1 comprises the steps sintering and brazing during bonding. Therefore, claim 20 lacks an inventive step under PCT Article 33(3).

1.5 Independent Claim 22

D1, which is considered to be the closest prior art to the subject matter of claim 22, discloses a method of minimizing warpage of a CMP pad dresser comprising bonding a plurality of superabrasive particles to a substrate. Claim 22 differs from D1 in that a method of claim 22 comprises the step of substantially equalizing warping forces on opposing sides of a metal support layer. However, it would be easily predicted by the feature that the method of D1 comprises superabrasive particles equally applicable on both sides of the substrate. Therefore, claim 22 lacks an inventive step under PCT Article 33(3).

1.6 Dependent Claim 23

The additional feature of claim 23 would be easily predicted by the feature that the method of D1 comprises superabrasive particles equally applicable on both sides of the substrate. Therefore, claim 23 lacks an inventive step under PCT Article 33(3).

2. Industrial Applicability

Claims 1-23 are industrially applicable under PCT Article 33(4).

Electronic Acknowledgement Receipt

EFS ID:	14157995
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Eileen Fuessel
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	06-NOV-2012
Filing Date:	23-MAY-2012
Time Stamp:	12:08:03
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1		24012.pdf	770892 0406d73162a61695a0fc8a900c1076d4d74a043f	yes	14

	Multipart Description/PDF files in .zip description				
	Document Description		Start	End	
	Transmittal Letter		1	4	
	Information Disclosure Statement (IDS) Form (SB08)		5	14	
Warnings:					
Information:					
2	Non Patent Literature	sr52627.pdf	589518 4f02e9c6260a383c35fb1dfc8093269b098e382d	no	11
Warnings:					
Information:					
3	Non Patent Literature	oa917.pdf	406160 c228cd2f2bac8a31dcf65564398158141880e004	no	13
Warnings:					
Information:					
4	Non Patent Literature	oa110.pdf	1554633 bb9806fe1fd118d1d035594e6b8b79e7ab58f794	no	30
Warnings:					
Information:					
5	Non Patent Literature	oa422.pdf	858660 23255b1322830088e5b0f01082e66ad3de79f486	no	16
Warnings:					
Information:					
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Warnings:					
Information:					
7	Non Patent Literature	ntc110.pdf	517025 fafd31c2a13097e6ec1ba6088513d075812b730b	no	10
Warnings:					
Information:					
		Total Files Size (in bytes):	5383622		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: 11-6-2012 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /DavidWOsborne/ David W. Osborne

INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement

in accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☒ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any

over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 6th day of November, 2012.

Respectfully submitted,

/DavidWOsborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
Customer No. 20,551
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Sandy, Utah 84091-1219
Telephone: (801) 566-6633

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP

CONFIRMATION NO. 7248

20551
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

PUBLICATION NOTICE



Title:CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

Publication No.US-2012-0302146-A1
Publication Date:11/29/2012

NOTICE OF PUBLICATION OF APPLICATION

The above-identified application will be electronically published as a patent application publication pursuant to 37 CFR 1.211, et seq. The patent application publication number and publication date are set forth above.

The publication may be accessed through the USPTO's publically available Searchable Databases via the Internet at www.uspto.gov. The direct link to access the publication is currently http://www.uspto.gov/patft/.

The publication process established by the Office does not provide for mailing a copy of the publication to applicant. A copy of the publication may be obtained from the Office upon payment of the appropriate fee set forth in 37 CFR 1.19(a)(1). Orders for copies of patent application publications are handled by the USPTO's Office of Public Records. The Office of Public Records can be reached by telephone at (703) 308-9726 or (800) 972-6382, by facsimile at (703) 305-8759, by mail addressed to the United States Patent and Trademark Office, Office of Public Records, Alexandria, VA 22313-1450 or via the Internet.

In addition, information on the status of the application, including the mailing date of Office actions and the dates of receipt of correspondence filed in the Office, may also be accessed via the Internet through the Patent Electronic Business Center at www.uspto.gov using the public side of the Patent Application Information and Retrieval (PAIR) system. The direct link to access this status information is currently http://pair.uspto.gov/. Prior to publication, such status information is confidential and may only be obtained by applicant using the private side of PAIR.

Further assistance in electronically accessing the publication, or about PAIR, is available by calling the Patent Electronic Business Center at 1-866-217-9197.

Office of Data Managment, Application Assistance Unit (571) 272-4000, or (571) 272-4200, or 1-888-786-0101

PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		U.S. Application 12/255,823; filed 10/22/2008; Chien-Min Sung; notice of allowance dated 12/26/2012	

Examiner Signature		Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		6722952	04/20/2004	Goers et al.	
		6458018	10/01/2002	Goers et al.	
		6354929	03/12/2002	Adefris et al.	
		5725421	03/10/1998	Goers et al.	
		6125612	10/03/2000	Main	
		6629884	10/07/2003	Goers	
		7247577	07/24/2007	Palmgren et al.	
		6123612	09/26/2000	Goers	
		7641538	01/05/2010	Goers	
		7840305	11/23/2010	Behr et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

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This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	14606937
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Eileen Fuessel
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	03-JAN-2013
Filing Date:	23-MAY-2012
Time Stamp:	14:25:29
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	trans.PDF	79706 40a3c6aac78d53e9af9493b3eaf34a5ae4b96c23	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	77096 42e2dd40bdd889452fc478a29104e9ba145fdd1a	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	107036 e6eafd85cdf739b61f2067b8b494e59557b309cf	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	Non Patent Literature	ntc823.pdf	752049 ead17c18296f1673918baf1b4a1170f29af36176	no	15
Warnings:					
Information:					
		Total Files Size (in bytes):	1015887		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: January 3, 2013 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /DavidWOsborne/ David W. Osborne

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☐ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 3rd day of January, 2013.

Respectfully submitted,

/DavidWOsborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
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Sandy, Utah 84091-1219
Telephone: (801) 566-6633

PTO/SB/08A (08-03)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2010/0261419	10/14/2010	Chien-Min Sung	
		2007-0266639	11/22/2007	Chein-Min Sung	
		2010/0248595	09/30/2010	Dinh-Ngoc	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		JP 2007-044823	02/22/2007	Soken		

Examiner Signature		Date Considered	

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Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		PCT/US2012/039199; filed 05/23/2012; Chien-Min Sung; International Search Report dated 12/18/2012	
		U.S. Application 13/362,917; filed 01/13/2012; Chien-Min Sung; office action dated 12/31/2012	
		U.S. Application 12/168,110; filed 07/05/2008; Chien-Min Sung; notice of allowance dated 01/18/2013	

Examiner Signature		Date Considered	

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If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

No documents available for this priority number.

Europäisches Patentamt
European Patent Office
Office européen des brevets

Espacenet

Bibliographic data: JP2007044823 (A) — 2007-02-22

CMP PAD CONDITIONER IN SEMICONDUCTOR PLANARIZATION CMP PROCESS (CHEMICAL-MECHANICAL POLISHING)

Inventor(s): TANI KAZUNORI; IWASAKI HIDEKAZU ± (TANI KAZUNORI, ; IWASAKI HIDEKAZU)

Applicant(s): SOKEN KK ± (SOKEN:KK)

Classification: **- international:** ***B24B37/00; B24B53/12; B24D3/00; H01L21/304***
- cooperative:

Application number: JP20050232524 20050810

Priority number (s): JP20050232524 20050810

Abstract of JP2007044823 (A)

PROBLEM TO BE SOLVED: To reduce the time and trouble for replacing a CMP pad conditioner, and the down time and loss time of a CMP device by preventing abrasion, wearing and alteration of abrasive grains and fallout and defective of the abrasive grains to achieve long-time conditioning of the polishing pad. ; SOLUTION: This pad conditioner includes abrasive grains for pad polishing and grinding used in a semiconductor planarization CMP process, a bond layer holding the abrasive grains; and a bed to which the bond layer is fixed, wherein the abrasive grains or coating material coating the abrasive grains is a material having durability against CMP slurry. The material having durability is silicon carbide (SiC), diamond-like carbon, sapphire, alumina, TiO<SB>2</SB>, stabilized zirconia, ZrN, ZrC, WC, WC-Co, TiC, TiAlN, Tin-Ni, LiNbO<SB>3</SB>, NbC, LiTaO<SB>3</SB>, TaC or HfC. ; COPYRIGHT: (C) 2007,JPO&INPIT

Last updated: 19.12.2012 Worldwide Database 5.8.4; 93p

(19)日本国特許庁(JP)　(12)公開特許公報(A)　(11)特許出願公開番号
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(P2007-44823A)
(43)公開日　平成19年2月22日(2007.2.22)

(51)Int.Cl.		F I			テーマコード（参考）
B24B 53/12	(2006.01)	B24B	53/12	Z	3C047
H01L 21/304	(2006.01)	H01L	21/304	622M	3C058
B24B 37/00	(2006.01)	B24B	37/00	A	3C063
B24D 3/00	(2006.01)	B24D	3/00	320A	
		B24D	3/00	330D	

審査請求 未請求　請求項の数 8　OL　（全 9 頁）　最終頁に続く

(21)出願番号　特願2005-232524 (P2005-232524)
(22)出願日　平成17年8月10日 (2005.8.10)

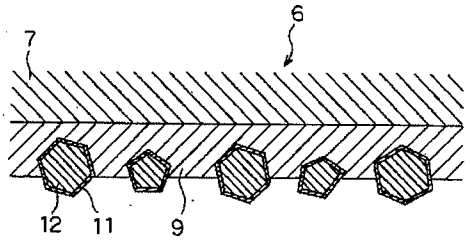
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Ｆターム(参考)　3C047 AA12　AA34　EE18　EE19　FF08

最終頁に続く

(54)【発明の名称】半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー

(57)【要約】　（修正有）
【課題】砥粒の磨耗、磨滅、変質や砥粒の脱落、欠損を防止できるので、長時間研磨パッドのコンディショニングを行うことができ、ＣＭＰパッドコンディショナーの交換の手間やＣＭＰ装置のダウンタイムならびにロス時間を減らすこと。
【解決手段】パッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、砥粒あるいは砥粒を被覆する被膜物質がＣＭＰスラリーに対して耐久性を持つ物質である。耐久性を持つ物質は、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣである。
【選択図】　図２



【特許請求の範囲】
【請求項1】
半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒はダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質であることを特徴とする半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項2】
半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒の表面にＣＭＰスラリーに対して耐久性を持つ物質が被覆されていることを特徴とする半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項3】
半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、ＣＭＰスラリーに対して耐久性を持つ物質を上記砥粒表面及び上記ボンド層表面に被覆せしめたことを特徴とする半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項4】
上記被覆した物質の膜厚が１０ｎｍ～９００μｍであることを特徴とする請求項２又は３記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項5】
上記各砥粒は夫々離間しており、上記砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする請求項１、２、３又は４記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項6】
上記各砥粒は夫々離間しており、上記被覆した砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする請求項２、３又は４記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項7】
上記ダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質が、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアであることを特徴とする請求項１又は５記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項8】
上記ＣＭＰスラリーに対して耐久性を持つ物質が、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣであることを特徴とする請求項２、３、４、５又は６記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。

【発明の詳細な説明】
【技術分野】
【0001】
本発明は半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー、特に、化学機械的研磨（ＣＭＰ）装置に用いるＣＭＰパッドのコンディショナーに関するものである。
【背景技術】
【0002】

コンピュータのＣＰＵ能力向上の為には回路の集積度を上げる必要があり、これを実現する為に配線の多層化が行なわれているが、この時、シリコン基板上の各層間絶縁膜を平坦化するＣＭＰ（Chemical Mechanical Polishing）加工技術がキーテクノロジーとなる。半導体デバイスの多層配線化プロセスにおいては、半導体ウェハ表面の凹凸を極力平坦化することが重要であり、この半導体ウェハ表面の平坦化装置として化学的エッチングと研磨剤による機械的研磨とを組み合わせた研磨加工を行うＣＭＰ装置がある。

【0003】

図４は従来のＣＭＰ装置のコンセプトの一例を示す。１は回転自在な直径３００ｍｍの円板状の定盤、２は上記定盤１の略全面に設けたＣＭＰ研磨パッド、３は上記定盤１の回転中心軸に対して偏心した位置に設けた円板状の半導体ウェハ、４は上記半導体ウェハ３を保持し、上記半導体ウェハ３を上記研磨パッド２に押圧せしめる回転自在の半導体ウェハ押圧具、５は上記研磨パッド２上にコロイダルシリカ系、ヒュームドシリカ系、セリア系またはアルミナ系などのＣＭＰスラリーを供給するＣＭＰスラリー供給部、６は上記研磨パッド２の表面を再研磨または再研削（コンディショニング）するため上記半導体ウェハ３とは異なる位置で上記研磨パッド２上に載置した回転自在のＣＭＰパッドコンディショナーを示す。

【0004】

上記研磨パッド２は一般に大別して発泡ウレタンを基材としたパッドと無発泡のウレタンを基材としたパッドが使用されている。前者の発泡ウレタンを基材とする研磨パッドは弾力性があり後者の無発泡のウレタンを基材とするものに比べ平坦性が劣るという報告もある。発泡性ウレタン研磨パッドのＣＭＰパッドコンディショナーにはブラシ状の繊維を埋めこんだもの、あるいはダイヤモンド砥粒をメタルボンドした砥石状のＣＭＰパッドコンディショナーが使用される。一方、無発泡のウレタンの基材を用いたＣＭＰパッドコンディショナーにはダイヤモンド砥粒をメタルボンドした砥石状のＣＭＰパッドコンディショナーが用いられる。

【0005】

上記砥石状のＣＭＰパッドコンディショナー６は図４及び図５に示すように、円板状の金属製台金７と、この台金７の下面に設けた粒径５０μｍ～２００μｍのダイヤモンド砥粒８と、上記ダイヤモンド砥粒８を保持するための上記金属製台金７の下面あるいは台金表面全体を被覆するＮｉメッキボンド層等のボンド層９とよりなる。

【0006】

上記のような従来のＣＭＰ装置においては、上記ＣＭＰ研磨パッド２上にＣＭＰスラリーを供給し、上記定盤１と上記半導体ウェハ押圧具４とを相対的に回転せしめて、上記半導体ウェハ押圧具４により上記半導体ウェハ３を上記ＣＭＰ研磨パッド２上に押圧せしめれば、上記半導体ウェハ３の表面が研磨される。また、上記ＣＭＰパッドコンディショナー６を常時又は定期的に回転せしめれば、上記研磨パッド２の平坦度を維持、修復し、また目詰まりを防止せしめ、また、ＣＭＰ研磨パッド表面の面粗さを維持することによりＣＭＰスラリーの研磨特性を維持、回復せしめることができる。

【0007】

また、上記ＣＭＰパッドコンディショナー６におけるボンド層９により上記台金７を被覆しているので、上記ＣＭＰスラリーにより台金が溶出することがなく、ダイヤモンド砥粒８の脱落を防止できる。このようなＣＭＰ装置は特許文献１に記載されている。

【特許文献1】特開２００１－２３９４４９号

【発明の開示】

【発明が解決しようとする課題】

【0008】

しかしながら、上記従来のＣＭＰ装置においては、ある程度ＣＭＰ研磨パッド２のコンディショニングを続ければ、ＣＭＰパッドコンディショナー上の砥粒の切刃が研磨、磨滅、平坦化され、切れ味が鈍ることにより上記ＣＭＰ研磨パッド２の平坦度の修復が遅くなる。またダイヤモンド砥粒８等がＣＭＰパッドコンディショナー６のボンド層９から脱落

、欠損し、脱落したダイヤモンド砥粒８等がＣＭＰ研磨パッド２の表面に落下、固定され、あるいは転動してウェハ表面に傷をつけてしまうという欠点があった。

【0009】

本発明者は種々実験研究の結果、ダイヤモンド砥粒はコロイダルシリカ系、ヒュームドシリカ系、セリア系またはアルミナ系などのＣＭＰスラリーにより磨耗、磨滅、変質すること、また、この磨耗等により砥粒にかかる力が増大しダイヤモンド砥粒が脱落、欠損することを見出した。また、ＣＭＰスラリーに対して耐久性のある物質、例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣで砥粒あるいはＣＭＰコンディショナーの加工部表面を被覆すれば砥粒の磨耗等を少なくでき、研磨パッドの平坦度ならびに面粗さを維持し、砥粒の脱落等を防止できることを見出した。また、安価な砥粒にＣＭＰスラリーに対して耐久性のある物質を被覆すれば、安価で高品質のＣＭＰコンディショナーを提供できることを見出した。本発明はかかる知見をもとになされたものである。

【課題を解決するための手段】

【0010】

本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒はダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質であることを特徴とする。

【0011】

本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒の表面にＣＭＰスラリーに対して耐久性を持つ物質が被覆されていることを特徴とする。

【0012】

本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、ＣＭＰスラリーに対して耐久性を持つ物質を上記砥粒表面及び上記ボンド層表面に被覆せしめたことを特徴とする。

【0013】

上記被覆した物質の膜厚は１０ｎｍ～９００μｍであることを特徴とする。

【0014】

上記各砥粒は夫々離間しており、上記砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする。

【0015】

上記各砥粒は夫々離間しており、上記被覆した砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする。

【0016】

上記ダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質は、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアであることを特徴とする。

【0017】

上記ＣＭＰスラリーに対して耐久性を持つ物質は、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣであることを特徴とする。

【発明の効果】
【0018】
本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーによれば、砥粒の磨耗、磨滅、変質や砥粒の脱落、欠損を防止できるので、長時間研磨パッドのコンディショニングを行うことができ、ＣＭＰパッドコンディショナーの交換の手間やＣＭＰ装置のダウンタイムならびにロス時間を減らすことができ、また、半導体ウェハ表面に傷が付くのを防止することができるという大きな利益がある。また、安価で高品質のＣＭＰコンディショナーを提供できる。
【発明を実施するための最良の形態】
【0019】
以下図面によって本発明の実施例を説明する。
【実施例】
【0020】
本発明のＣＭＰ装置用のＣＭＰパッドコンディショナー６においては、図１に示すように、ＣＭＰ研磨パッドのＣＭＰコンディショニング用砥粒としてダイヤモンド砥粒８を用いる代わりに、例えば粒径１００μｍ±４０μｍの、ダイヤモンドよりＣＭＰスラリーに対して耐磨耗性、耐磨滅性、耐変質性等の耐久性を持つ化学的に安定した結晶構造を持った例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアなどの物質からなる砥粒などの物質からなる砥粒１０を用いる。パッドコンディショナー用の台金７に形成せしめたＮｉメッキボンド層等のボンド層９の厚さは、上記砥粒１０の粒径のおよそ三分の一を突出せしめて固着せしめることができる程度が好適である。なお、各砥粒間隔は例えば約１０μｍ～１０ｍｍとし、ＣＭＰコンディショナーにかかる加圧力と相関してひとつの砥粒にかかる加圧力でＣＭＰコンディショナー全体の砥粒の数を決定することが望ましい。
【0021】
本発明によれば、上記砥粒１０はＣＭＰスラリー対して耐久性がダイヤモンドより大きいので、磨耗、磨滅、変質しづらく、砥粒の脱落、欠損を防ぐ事ができ、長期間ＣＭＰ研磨パッドのコンディショニングを続けることができるという大きな利益がある。
【0022】
なお、ＣＭＰスラリーをポリシャーとしての被研磨特性を試行したところ、ダイヤモンドは１時間程度で磨滅したが、サファイアを同じ量削るには２～３時間かかり、また、ＳｉＣを同量研磨するには１０～２０時間かかった。従って、ＣＭＰスラリーに対して耐久性のある物質としては特にＳｉＣが好ましい。
【0023】
また、上記各砥粒を夫々離間せしめ、また、上記砥粒のうち、台金からの先端高さが一番低い砥石の先端高さと、台金からの先端高さが一番高い砥粒の先端高さとの差を１００μｍ以内、例えば３μｍ以内としたＣＭＰコンディショナーを用いた場合、ＣＭＰパッドの面粗さを均一化することができ、ＣＭＰ加工品質を向上させ、半導体ウェハの品質を高めることができる。
【0024】
また、上記台金７は金属系の他に樹脂系、粉末冶金系であってもよい。
【実施例】
【0025】
本発明の第２の実施例においては、図２に示すように研磨パッドのコンディショニング用の砥粒として、その表面にスパッタリング、イオンプレーティング、真空蒸着法又は化学蒸着（ＣＶＤ）法等により、ＣＭＰスラリーに対して耐久性のある、例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣなどの物質１１を例えば約１０ｎｍ～９００μｍ被覆したダイヤモンド砥粒、ＳｉＣ砥粒、アルミナ砥粒あるいは立方晶窒

化ホウ素（ＣＢＮ）砥粒などの砥粒１２を用い、パッドコンディショナー用の台金７に形成せしめたＮｉメッキボンド層等のボンド層９に、上記砥粒１２の全部あるいは一部を上記ボンド層９で固着せしめる。

【0026】

この第２の実施例においては、上記物質１１はＣＭＰスラリーに対して耐久性があるので、磨耗等しづらく、砥粒の脱落等を防ぐ事ができ、長期間ＣＭＰ研磨パッドのコンディショニングを続けることができる。また、安価な砥粒にＣＭＰスラリーに対して耐久性のある物質を被覆すれば、安価で高品質のＣＭＰコンディショナーを提供できる。

【0027】

なお、上記物質１１を被覆する部分は、上記砥粒１２の切刃となる部分の表面だけであってもよい。

【0028】

また、各砥粒を夫々離間せしめ、また、上記被覆した砥粒のうち、台金からの先端高さが一番低い砥石の先端高さと、台金からの先端高さが一番高い砥粒の先端高さとの差を１００μｍ以内、例えば３μｍ以内としたＣＭＰコンディショナーを用いた場合、ＣＭＰパッドの面粗さを均一化することができ、ＣＭＰ加工品質を向上させ、半導体ウェハの品質を高めることができる。

【0029】

また、上記台金は金属系の他に樹脂系、粉末冶金系であってもよい。

【0030】

また、上記ＣＭＰスラリーに対して耐久性のある物質は炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアなどのダイヤモンドよりＣＭＰスラリーに対して耐久性のある物質であることが好ましい。

【実施例】

【0031】

本発明の第３の実施例においては、図３に示すようにＣＭＰ研磨パッドのコンディショニング用の砥粒としてダイヤモンド砥粒、ＳｉＣ砥粒、アルミナ砥粒あるいは立方晶窒化ホウ素（ＣＢＮ）砥粒などの砥粒１２を用い、パッドコンディショナー用の台金７に形成せしめたＮｉメッキボンド層等のボンド層９に、上記砥粒１２の全部あるいは一部を上記ボンド層９の表面から突出せしめて固着せしめる。また加えて上記ボンド層９の表面から突出した砥粒１２の表面及び上記ボンド層９の表面にスパッタリング又はＣＶＤ法等により、ＣＭＰスラリーに対する耐久性のある、例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣなどの物質１１を例えば厚さ約１０ｎｍ～９００μｍで被覆せしめる。

【0032】

この第３の実施例においても、上記物質１１はＣＭＰスラリーに対して耐久性があるので、磨耗等しづらく、砥粒の脱落等を防ぐ事ができ、長期間ＣＭＰ研磨パッドのコンディショニングを続けることができる。また、安価な砥粒にＣＭＰスラリーに対して耐久性のある物質を被覆すれば、安価で高品質のＣＭＰコンディショナーを提供できる。

【0033】

なお、上記砥粒１２を被覆する部分は、上記砥粒１２の切刃となる部分の表面だけであってもよい。

【0034】

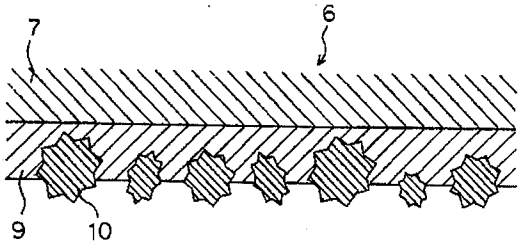
また、上記ＣＭＰスラリーに対して耐久性のある物質は炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアなどのダイヤモンドよりＣＭＰスラリーに対して耐久性のある物質であることが好ましい。

【図面の簡単な説明】

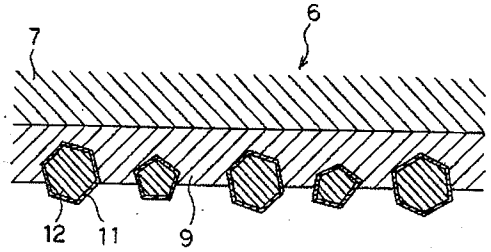
【0035】

【図1】本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの第１の実施例の要部を拡大した縦断側面図である。
【図2】本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの第２の実施例の要部を拡大した縦断側面図である。
【図3】本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの第３の実施例の要部を拡大した縦断側面図である。
【図4】従来の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰ装置の斜視図である。
【図5】従来の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの要部を拡大した縦断側面図である。
【符号の説明】
【0036】
１　定盤
２　ＣＭＰ研磨パッド
３　半導体ウェハ
４　半導体ウェハ押圧具
５　ＣＭＰスラリー供給部
６　ＣＭＰパッドコンディショナー
７　金属製台金
８　砥粒
９　ボンド層
１０　砥粒
１１　被覆物質
１２　砥粒

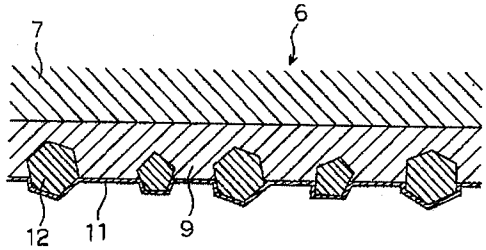
【図1】



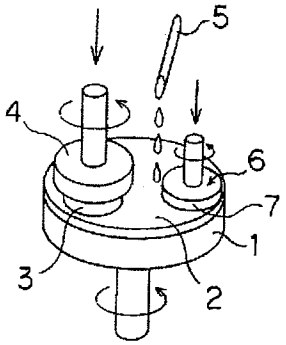
【図2】



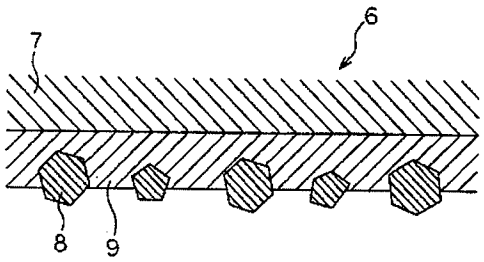
【図3】



【図4】



【図5】



(51)Int.Cl.	F I	テーマコード（参考）
	Ｂ２４Ｄ　3/00　３１０Ｄ	

Ｆターム(参考)　3C058 AA07 AA19 CB04 CB05 DA12 DA17
3C063 AB05 BA37 BB02 BB03 BB04 BB15 BC02 EE26 FF08 FF22
FF23

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:

OSBORNE DAVID W.

P.O. BOX 1219 SANDY UT 84091-1219 USA

RECEIVED
DEC 26 2012
THORPE NORTH & WESTERN

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Applicant's or agent's file reference 02074-24012PCT	Date of mailing *(day/month/year)* 18 DECEMBER 2012 (18.12.2012) **FOR FURTHER ACTION** See paragraphs 1 and 4 below
International application No. **PCT/US2012/039199**	International filing date *(day/month/year)* **23 MAY 2012 (23.05.2012)**

Applicant

SUNG CHIEN-MIN

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

Filing of amendments and statement under Article 19:

The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 . 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19months.

For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea	Authorized officer COMMISSIONER
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-8754

Form PCT/ISA/220 (July 2010)

DOCKETED
DEC 30 2012
TNW

(over)

* Attention

Copies of the documents cited in the international search report can be searched in the following Korean Intellectual Property Office English website for three months from the date of mailing of the international search report.

http://www.kipo.go.kr/en/ => PCT Services => PCT Services

ID : PCT international application number
PW : **XW34DDSW**

Inquiries related to PCT International Search Report or Written Opinion prepared by KIPO as an International Searching Authority can be answered not only by KIPO but also through IPKC (Intellectual Property Korea Center), located in Vienna, VA, which functions as a PCT Help Desk for PCT applicants.

Homepage: http://www.ipkcenter.com
Email: ipkc@ipkcenter.com
Phone: +1 703 388 1066
Fax: +1 703 388 1084

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
02074-24012P		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2012/039199	**23 MAY 2012 (23.05.2012)**	23 MAY 2011 (23.05.2011)

Applicant

SUNG CHIEN-MIN

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 3 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 1
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figure is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/039199

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/304(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 21/304; B05D 3/02; B24B 53/02; B24B 53/00; C09K 3/14; B24B 53/12

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: "CMP, pad, grain, abrasive particle, protruding"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010-0261419 A1 (CHIEN-MIN SUNG) 14 October 2010 See paragraphs [0033] - [0054]; and claims 1 - 2; and figure 2.	1-27
A	US 2007-0266639 A1 (CHIEN-MIN SUNG) 22 November 2007 See paragraphs [0053] - [0055]; and claims 22 - 35; and figures 1 - 3.	1-27
X A	US 2010-0248595 A1 (DINH-NGOC CHARLES et al.) 30 September 2010 See paragraphs [0071] - [0096]; and claim 1; and figures 1 - 2.	10 1-9,11-27
A	JP 2007-044823 A (SOKEN:KK) 22 February 2007 See paragraphs [0001] - [0034]; and claims 1 - 6; and figures 1 - 3.	1-27

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
17 DECEMBER 2012 (17.12.2012)	**18 DECEMBER 2012 (18.12.2012)**

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

Lee, Myoung Jin

Telephone No. 82-42-481-8364

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2012/039199

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0261419 A1	14.10.2010	CN 101856806 A	13.10.2010
		TW 201036762 A	16.10.2010
US 2007-0266639 A1	22.11.2007	TW 200806432 A	01.02.2008
		TW I331066B	01.10.2010
		US 7771498 B2	10.08.2010
		WO 2007-136864 A2	29.11.2007
US 2010-0248595 A1	30.09.2010	CA 2764358 A1	09.12.2010
		CN 102341215 A	01.02.2012
		CN 102484054 A	30.05.2012
		EP 2411181 A1	01.02.2012
		EP 2438609 A2	11.04.2012
		IL 215146D0	29.12.2011
		JP 2012-521309 A	13.09.2012
		KR 10-2011-0124370 A	16.11.2011
		KR 10-2012-0027449 A	21.03.2012
		SG 174351A1	28.10.2011
		US 2010-0330886 A1	30.12.2010
		WO 2010-110834 A1	30.09.2010
		WO 2010-141464 A2	09.12.2010
JP 2007-044823 A	22.02.2007	None	

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
OSBORNE DAVID W.

P.O. BOX 1219 SANDY UT 84091-1219 USA

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing *(day/month/year)*	**18 DECEMBER 2012 (18.12.2012)**
Applicant's or agent's file reference 02074-24012P	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2012/039199	**23 MAY 2012 (23.05.2012)**	23 MAY 2011 (23.05.2011)

International Patent Classification (IPC) or both national classification and IPC

H01L 21/304(2006.01)i

DOCKETED
Description Due Date Initials
Response 3-23-13 KL
INITIAL

Applicant

SUNG CHIEN-MIN

1. This opinion contains indications relating to the following items:

- [X] Box No. I Basis of the opinion
- [ ] Box No. II Priority
- [ ] Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- [ ] Box No. IV Lack of unity of invention
- [X] Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- [ ] Box No. VI Certain documents cited
- [ ] Box No. VII Certain defects in the international application
- [X] Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.
For further options, see Form PCT/ISA/220.

Name and mailing address of the ISA/KR	Date of completion of this opinion	Authorized officer
Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. 82-42-472-7140	17 DECEMBER 2012 (17.12.2012)	Lee, Myoung Jin Telephone No.82-42-481-8364

Form PCT/ISA/237 (cover sheet) (July 2011)

DOCKETED DEC 30 2012 TNW

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/039199

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of:

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

   a. a sequence listing filed or furnished
      ☐ on paper
      ☐ in electronic form

   b. time of filing or furnishing
      ☐ contained in the international application as filed.
      ☐ filed together with the international application in electronic form.
      ☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing has been filed or furnished, the required statements that the information in the subsequent or additioanl copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/039199

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	1-9,11-27	YES
	Claims	10	NO
Inventive step (IS)	Claims	1-9,11-27	YES
	Claims	10	NO
Industrial applicability (IA)	Claims	1-27	YES
	Claims	NONE	NO

2. Citations and explanations :
Reference is made to the following documents:

D1: US 2010-0261419 A1 (CHIEN-MIN SUNG) 14 October 2010
D2: US 2007-0266639 A1 (CHIEN-MIN SUNG) 22 November 2007
D3: US 2010-0248595 A1 (DINH-NGOC CHARLES et al.) 30 September 2010
D4: JP 2007-044823 A (SOKEN:KK) 22 February 2007

1. Novelty and Inventive Step

1.1. Claims [1-9]

1.1.1. Independent Claim [1]

The subject matter of claim [1] differs from these prior art documents in that a CMP pad dresser comprises the superabrasive particles, wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 50 microns and the difference in protrusion distance between the highest 1% of the protruding tips of the monolayer of superabrasive particles are within about 80 microns or less. Therefore, claim [1] meets the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

1.1.2. Dependent Claims [2-9]

Claims [2-9] are dependent on claim [1]. Therefore, claims [2-9] meet the requirements of PCT Article 33(2) and (3).

Continued on Supplemental Box

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/US2012/039199

Box No. VIII Certain observations on the international application

The following observations on the clarity of the claims, description, and drawings or on the question whether the claims are fully supported by the description, are made:

Box VIII

The term "The dresser claim 1" used in claim 8 is unclear since "the dresser claim 1" is typo of "the dresser of claim 1" shown in claim 8, thereby resulting in lack of clarity (PCT Article 6).

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of :
Box V

1.2. Claims [10-13]
1.2.1. Independent Claim [10]

D3, which is considered to be the closest prior art to the subject matter of claim [10], discloses the abrasive tool comprising (a) a first layer of abrasive grains attached to the first major surface, wherein a substrate having a first major surface and a second major surface opposite the first major surface, and (b) a second layer of abrasive grains attached to the second major surface, wherein the second layer of abrasive grains are arranged in a same distribution as the first layer of abrasive grains, and (c) a protective layer(261) providing a layer of material overlying the abrasive grains to safeguard the grains from damage. Thus, claim [10] lacks novelty under PCT Article 33(2).

1.2.2. Dependent Claims [11-13]

The subject matter of claims [11-13] differ from these prior art documents in that a CMP pad dresser comprises the superabrasive particles, wherein the differences in protrusion distance (a) between the highest protruding tip and the second highest protruding tip, / (b) between the highest protruding tip and the 10th highest protruding tip, / (c) between the highest protruding tip and the 100th highest protruding tip, are definitely specified. Therefore, claims [11-13] meet the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

Continued on Supplemental Box

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of :

Supplemental Box

1.3. Claims [14-24]
1.3.1. Independent Claim [14]

The subject matter of claim [14] differs from these prior art documents in that a method of making a CMP pad dresser comprises bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the metal support layer such that symmetrical forces due to the substantially similar distribution between the first monolayer and the second monolayer preclude substantial warping of the metal support layer. Therefore, claim [14] meets the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

1.3.2. Dependent Claims [15-24]
Claims [15-24] are dependent on claim [14]. Therefore, claims [15-24] meet the requirements of PCT Article 33(2) and (3).

1.4. Claims [25-26]
1.4.1. Independent Claim [25]

The subject matter of claim [25] differs from these prior art documents in that a method of minimizing warpage of a CMP pad dresser comprises substantially eaualizing warping forces on opposing sides of a metal support layer, wherein warpage of the support layer is minimized. Therefore, claim [25] meets the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

1.4.2. Dependent Claim [26]
Claim [26] is dependent on claim [25]. Therefore, claim [26] meets the requirements of PCT Article 33(2) and (3).

Continued on Supplemental Box

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of:

Supplemental Box

1.5. Claim [27]

1.5.1. Independent Claim [27]

The subject matter of claim [27] differs from these prior art documents in that a CMP pad dresser comprises the superabrasive particles, wherein the differences in protrusion distance (a) between the highest protruding tip and the second highest protruding tip, / (b) between the highest protruding tip and the 10th highest protruding tip, / (c) between the highest protruding tip and the 100th highest protruding tip, and the protrusion distance of the highest protruding tip are definitely specified. Therefore, claim [27] meets the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

2. Industrial Applicability

Claims [1-27] are industrially applicable under PCT Article 33(4), because they are closely related to semiconductor technology.

Electronic Acknowledgement Receipt

EFS ID:	14853237
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Eileen Fuessel
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	01-FEB-2013
Filing Date:	23-MAY-2012
Time Stamp:	13:57:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	trans.PDF	79557 29eb7a7e9015996da82266f29b891d2993b21fb9	no	4

Warnings:	
Information:	

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	105595 e2895cf6c3a565fae4f1a4565be95aec8bd40643	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	76882 8c055bf1ac57648d80d181e3a4f6c6abefecc93b	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	Foreign Reference	jp823.pdf	518746 de65af588f5929ef3be2ee011746241a1e1e9f6e	no	10
Warnings:					
Information:					
5	Non Patent Literature	sr199.pdf	526584 d13f2976501d936223dc82cab760d042b29b5d14	no	12
Warnings:					
Information:					
6	Non Patent Literature	oa917.pdf	307976 37ded579caa47b7d74b4ba739c7ec1c12a0a68c2	no	10
Warnings:					
Information:					
7	Non Patent Literature	ntc110.pdf	773838 276261801ae3553d61ad180e618a757b48a5b757	no	14
Warnings:					
Information:					
		Total Files Size (in bytes):	2389178		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: February 1, 2013 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /DavidWOsborne/ David W. Osborne

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☒ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 1st day of February, 2013.

Respectfully submitted,

/DavidWOsborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
Customer No. 20,551
P.O. Box 1219
Sandy, Utah 84091-1219
Telephone: (801) 566-6633

PTO/SB/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2004/0203325	10/14/2004	Donohue	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**.

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Electronic Acknowledgement Receipt

EFS ID:	15330541
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Eileen Fuessel
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	22-MAR-2013
Filing Date:	23-MAY-2012
Time Stamp:	12:53:07
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	trans.PDF	79469 e9a65d55f19f21073e41b777d3229529ecf1035b	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	103769 948b2dd0c9f4df1ea3c7301fd03654cb2b996df3	no	1

Warnings:	
Information:	
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Total Files Size (in bytes):	183238

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New International Application Filed with the USPTO as a Receiving Office

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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: March 22, 2013 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /DavidWOsborne/ David W. Osborne

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

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☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

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Dated this 22nd day of March, 2013.

Respectfully submitted,

/DavidWOsborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
Customer No. 20,551
P.O. Box 1219
Sandy, Utah 84091-1219
Telephone: (801) 566-6633

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet [ ] of [ ]

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		U.S. Application 12/726,786; filed 03/18/2010; Chien-Min Sung; office action dated 03/19/2013	
		U.S. Application 13/362,917; filed 01/31/2012; Chien-Min Sung; office action dated 04/10/2013	

Examiner Signature		Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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PTO/SB/08A (08-03)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Sheet | | of | |

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Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		6196911	03/2001	Preston et al.	
		2010/0203811	08/2010	Phillipossian et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

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Electronic Acknowledgement Receipt

EFS ID:	16104782
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
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Attorney Docket Number:	02074-24012.NP
Receipt Date:	20-JUN-2013
Filing Date:	23-MAY-2012
Time Stamp:	16:30:47
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	trans.PDF	79650 ddff80410825f35f4cdb7f471e4df9f0c49b021e	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	77506 71ff5c0cd9e6b3ffd8cee95042368275e6673688	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	104108 63a480be80e3282659e42cb1e473de505f260716	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	Non Patent Literature	oa786.pdf	1863560 2189c92b2e06a51e1e1c15f7ddfae861c30a8a11	no	38
Warnings:					
Information:					
5	Non Patent Literature	oa917.pdf	1011364 11eb305b41b331359bbb3db79eb10baddb6d22dc	no	24
Warnings:					
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		Total Files Size (in bytes):	3136188		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: June 20, 2013 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /David W. Osborne/ David W. Osborne

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☐ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 20th day of June, 2013.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
Customer No. 20,551
P.O. Box 1219
Sandy, Utah 84091-1219
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PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet [ ] of [ ]

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		U.S. Application 13/239,198; filed 09/21/2011; Chien-Min Sung; office action dated 07/23/2013	
		PCT/US2013/042538; filed 05/23/2013; Chien-Min Sung; international search report dated 08/27/2013	
		U.S. Application 12/726,786; filed 03/18/2010; Chien-Min Sung; notice of allowance dated 09/04/2013	

Examiner Signature		Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:
OSBORNE DAVID W.

P.O. BOX 1219 SANDY UT 84091-1219 USA

RECEIVED
SEP - 3 2013
THORPE NORTH & WESTERN

PCT

NOTIFICATION OF TRANSMITTAL OF THE INTERNATIONAL SEARCH REPORT AND THE WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY, OR THE DECLARATION

(PCT Rule 44.1)

Date of mailing *(day/month/year)*	27 August 2013 (27.08.2013)
Applicant's or agent's file reference	**FOR FURTHER ACTION** See paragraphs 1 and 4 below
02074 - 24012NPCIPPC T	
International application No.	International filing date *(day/month/year)*
PCT/US2013/042538	**23 May 2013 (23.05.2013)**

Applicant

SUNG CHIEN-MIN

1. ☒ The applicant is hereby notified that the international search report and the written opinion of the International Searching Authority have been established and are transmitted herewith.

   Filing of amendments and statement under Article 19:

   The applicant is entitled, if he so wishes, to amend the claims of the international application (see Rule 46):

   When? The time limit for filing such amendments is normally two months from the date of transmittal of the international search report.

   Where? Directly to the International Bureau of WIPO, 34 chemin des Colombettes 1211 Geneva 20, Switzerland, Facsimile No.: +41 22 338 82 70

   For more detailed instructions, see *PCT Applicant's Guide*, International Phase, paragraphs 9.004 . 9.011.

2. ☐ The applicant is hereby notified that no international search report will be established and that the declaration under Article 17(2)(a) to that effect and the written opinion of the International Searching Authority are transmitted herewith.

3. ☐ **With regard to any protest** against payment of (an) additional fee(s) under Rule 40.2, the applicant is notified that:

   ☐ the protest together with the decision thereon has been transmitted to the International Bureau together with any request to forward the texts of both the protest and the decision thereon to the designated Offices.

   ☐ no decision has been made yet on the protest; the applicant will be notified as soon as a decision is made.

4. **Reminders**

The applicant may submit comments on an informal basis on the written opinion of the International Searching Authority to the International Bureau. The International Bureau will send a copy of such comments to all designated Offices unless an international preliminary examination report has been or is to be established. Following the expiration of 30 months from the priority date, these comments will also be made available to the public.

Shortly after the expiration of **18 months** from the priority date, the international application will be published by the International Bureau. If the applicant wishes to avoid or postpone publication, a notice of withdrawal of the international application, or of the priority claim, must reach the International Bureau before the completion of the technical preparations for international publication (Rules 90bis.1 and 90bis.3).

Within **19 months** from the priority date, but only in respect of some designated Offices, a demand for international preliminary examination must be filed if the applicant wishes to postpone the entry into the national phase **until 30 months** from the priority date (in some Offices even later); otherwise, the applicant must, **within 20 months** from the priority date, perform the prescribed acts for entry into the national phase before those designated Offices.

In respect of other designated Offices, the time limit of **30 months** (or later) will apply even if no demand is filed within 19months.

For details about the applicable time limits, Office by Office, see www.wipo.int/pct/en/texts/time_limits.html and the PCT Applicant's Guide, National Chapters.

Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea	Authorized officer COMMISSIONER
Facsimile No. 82-42-472-7140	Telephone No. 82-42-481-8755

Form PCT/ISA/220 (July 2010)

DOCKETED

	Description	Due Date	Initials
00802-T5100.CIP11	IDS	11-27-13	
" " .CIP3.CON.ACN2	IDS	11-27-13	
" T5100.CIP6	IDS	11-27-13	
" " " 7	IDS	11-27-13	
" " " 8	IDS	11-27-13	
" " " 9			

INITIAL

DOCKETED

	Description	Due Date	Initials
	Modify Abstract	9-27-13	
	Article 19	10-27-13	
	Chpt II Demand	3-23-14	
24012-NP	IDS	11-27-13	
" .CIP	IDS	11-27-13	

INITIAL

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	Description	Due Date	Initials
32979.NP.CIP.CON	IDS	11-27-13	
" " CIP2	IDS	11-27-13	
" " .CON	IDS	11-27-13	
3356-32820.NP2	IDS	11-27-13	
00802-T5110.CIP10	IDS	11-27-13	

INITIAL

* Attention

Copies of the documents cited in the international search report can be searched in the following Korean Intellectual Property Office English website for three months from the date of mailing of the international search report.

http://www.kipo.go.kr/en/ => PCT Services => PCT Services

ID : PCT international application number
PW : **6GGTL9PA**

Inquiries related to PCT International Search Report or Written Opinion prepared by KIPO as an International Searching Authority can be answered not only by KIPO but also through IPKC (Intellectual Property Korea Center), located in Vienna, VA, which functions as a PCT Help Desk for PCT applicants.

Homepage: http://www.ipkcenter.com

Email: ipkc@ipkcenter.com

DOCKETED SEP - 6

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 24012NPCIPPC	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
International application No. **PCT/US2013/042538**	International filing date *(day/month/year)* **23 May 2013 (23.05.2013)**	(Earliest) Priority Date *(day/month/year)* 23 May 2012 (23.05.2012)
Applicant **SUNG CHIEN-MIN**		

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of 5 sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of:
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____, which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. 1
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figure is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/042538

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/304(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L 21/304; B24B 53/02; B24B 53/017; B05D 3/02; C09K 3/14; B24B 53/12; B24B 1/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: CMP, dresser, pad, protrusion, distance

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010-0248595 A1 (CHARLES DINH-NGOC et al.) 30 September 2010 See abstract; paragraphs [0065], [0075]-[0076], [0167] and figures 2A, 24B, 24D.	1-20
A	KR 10-2007-0063569 A (CHIEN-MIN SUNG) 19 June 2007 See abstract; pages 2-4, 6-8 and figures 5-6, 10.	1-20
A	WO 2012-040374 A2 (RITEDIA CORPORATION et al.) 29 March 2012 See abstract; page 9, line 31 - page 17, line 2 and figures 1-4.	1-20
A	KR 10-2002-0036138 A (KINIK COMPANY) 16 May 2002 See abstract; pages 3-5 and figures 1-6.	1-20
A	US 2007-0266639 A1 (CHIEN-MIN SUNG) 22 November 2007 See abstract; paragraphs [0054]-[0061] and figures 1-7.	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 August 2013 (27.08.2013)	**27 August 2013 (27.08.2013)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea Facsimile No. +82-42-472-7140	Authorized officer CHOI Sang Won Telephone No. +82-42-481-8291

Form PCT/ISA/210 (second sheet) (July 2009)

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/042538

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0248595 A1	30/09/2010	CA 2764358 A1	09/12/2010
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		EP 2411181 A1	01/02/2012
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		IL 215146 D0	29/12/2011
		JP 2012-521309 A	13/09/2012
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		JP 2006-501073 A	12/01/2006
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		JP 3801215 B2	26/07/2006
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2013/042538

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		KR 10-0366466 B1	31/12/2002
		KR 10-2005-0046802 A	18/05/2005
		KR 10-2006-0132973 A	22/12/2006
		TW 200916262 A	16/04/2009
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		CN 102893419 A	23/01/2013

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2012-0241943 A1	27/09/2012
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		US 2012-0280253 A1	08/11/2012
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		US 7771498 B2	10/08/2010
		WO 2007-136864 A2	29/11/2007
		WO 2007-136864 A3	31/01/2008

Electronic Acknowledgement Receipt

EFS ID:	17204278
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/eileen fuessel
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	23-OCT-2013
Filing Date:	23-MAY-2012
Time Stamp:	12:53:35
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	trans.PDF	79503 65a7c802d85b62e83f8308d847901a4e8a0d4315	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	107215 798f15d87e369c145de6a7fa68c1ae130e115615	no	1
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This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

<u>New Applications Under 35 U.S.C. 111</u>
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

<u>National Stage of an International Application under 35 U.S.C. 371</u>
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

<u>New International Application Filed with the USPTO as a Receiving Office</u>
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: October 23, 2013 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /David W. Osborne/ David W. Osborne

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☐ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 23rd day of October, 2013.

Respectfully submitted,

/David W. Osborne/

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Office européen des brevets

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Bibliographic data: KR20020036138 (A) — 2002-05-16

DIAMOND GRID-CHEMICAL MECHANICAL POLISH PAD DRESSER

No documents available for this priority number.

Inventor(s): LIN FRANK S; SUNG CHIEN-MIN ± (LIN FRANK S, ; SUNG CHIEN-MIN)

Applicant(s): KINIK CO ± (KINIK COMPANY)

Classification: **- international:** ***B24B1/00;*** (IPC1-7): B24B1/00
- cooperative:

Application number: KR20000066159 20001108

Priority number(s): KR20000066159 20001108

Abstract of KR20020036138 (A)

PURPOSE: A diamond grid-chemical mechanical polish pad dresser is provided to improve polishing efficiency of a CMP(Chemical Mechanical Polish) pad and prolong the service life. CONSTITUTION: A diamond grid-chemical mechanical polish pad dresser (30) constitutes plural abrasive grains(180) of desirable size attached to a plate member. The abrasive grains are extended on the plate member in predetermined height, at regular intervals. The abrasive grains are crystal grains of diamond or cubic boron nitride of a single crystal or poly-crystal type. The crystal grains are placed on a plate(40) coated with an anticorrosion layer(130). The anticorrosion layer is diamond or diamond carbon coated on the surface of a disk to prevent corrosion of brazing alloy(90) by chemical slurry used relatively to the CMP pad.

Last updated: 23.09.2013 Worldwide Database 5.8.11.4; 93p

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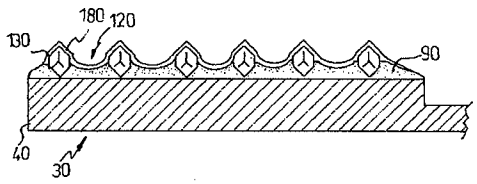
전체 청구항 수 : 총 48 항

(54)다이아몬드 그리드 화학 기계적 연마 패드 드레서

(57)요 약

본 발명은 돌출하는 균일하게 일정한 간격을 이룬 다수의 연마 입자들(180)을 가진 CMP 패드 드레서를 나타낸다. 상기 연마 입자들(180)은 우수한 경질 재료로, 일반적으로 다이아몬드, 다결정 다이아몬드(PCD), 입방 보론 질화물(cBN), 또는 다결정 입방 보론 질화물(PcBN)이다. 연마 입자들(180)은 부가 내식 층(130)으로 코팅된 기판(40)에 착지된다. 상기 내식층(130)은 보통 CMP 패드와 연관되어 사용된 화학 슬러리에 의해 경납 합금(90)의 부식을 방지하기 위해 디스크의 표면위로 코팅되는 다이아몬드 또는 다이아몬드형 카본이다. 화학 부식에 대한 상기 면역은 작업편을 연마하는 동안 패드를 드레싱하기 위한 CMP 패드 드레서를 허용한다. 기판(40)상의 평탄한 일정한 간격에 더하여, 연마 입자들(180)은 수직과 수평방향으로 CMP 패드의 손질 또는 드레싱을 위해 허용하는 기판(40)으로부터 떨어진 균일한 거리로 연장한다. 또한 그러한 CMP 패드 드레서를 제조하는 방법이 나타내어졌다.

대 표 도 - 도 3



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청구의 범위

청구항 1

기판 부재에 부착된 바람직한 크기 범위내에 크기를 가진 다수의 연마 입자를 구성하고,

상기 연마 입자들은 균일하게 일정한 간격을 이루고 및 기판 부재위에서 미리 결정된 높이로 연장되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 2

제 1 항에 있어서,

상기 연마 입자들은 단결정 또는 다결정 형태로써 다이아몬드 또는 입방 보론 질화물의 결정 입자들인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 3

제 1 항에 있어서,

상기 크기 범위는 50 내지 250 마이크로미터인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 4

제 1 항에 있어서,

상기 연마 입자들은 크기에 있어서 실질적으로 균일하고, 모든 연마 입자들은 서로 10%내 크기를 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드
레서.

청구항 5

제 1 항에 있어서,

상기 다수의 균일하게 일정한 간격을 이룬 연마 입자들은 미리 결정된 형태에 따라서 분포되고, 미리 결정된 거리는 두 개의 입자들사이에 유지되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 6

제 5 항에 있어서,

각 입자 사이의 미리 결정된 거리는 입자들의 평균 크기의 1.5 내지 10 배인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 7

제 5 항에 있어서,

상기 미리 결정된 형태는 그리드(grid)인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 8

제 1 항에 있어서,

기판위의 미리 결정된 높이는 모든 연마 입자들이 50 마이크로미터내로 연장하는 균일한 높이인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 9

제 1 항에 있어서,

상기 기판위의 미리 결정된 높이는 평균 70μm 이상인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 10

제 1 항에 있어서,

상기 연마 입자들은 자형(euhedral) 결정 형상을 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 11

제 1 항에 있어서,

상기 연마 입자들은 미리 결정된 형상을 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 12

제 1 항에 있어서,

상기 연마 입자들은 기판으부터 떨어져 방향지어진 가장자리 또는 예리한 지점을 구비하는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 13

제 1 항에 있어서,

상기 기판은 금속 재료로 만들어진 것을 특징으로 하는 화학 기계적 연마 (CMP) 패드 드레서.

청구항 14

제 12 항에 있어서,

상기 금속 재료는 스테인레스강인 것을 특징으로 하는 화학 기계적 연마 (CMP) 패드 드레서.

청구항 15

제 1 항에 있어서,

상기 연마 입자들은 경납 합금에 의해 기판에 부착되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 16

제 14 항에 있어서,

추가로 상기 경납 합금은 1 wt% 이상의 크롬 량을 가진 니켈 합금을 구성하는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 17

제 14 항에 있어서,

상기 경납 합금은 기판의 표면위에 미리 결정된 두께이고, 각 연마 입자의 10 내지 90%가 노출되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 18

내식층으로 코팅되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 19

제 18 항에 있어서,

연마 입자들의 층은 전기 도금 니켈에 의해 기판에 결합되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 20

제 18 항에 있어서,

상기 내식층은 다이아몬드형 카본으로 구성되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 21

제 18 항에 있어서,

상기 다이아몬드형 카본은 다이아몬드 결합에 있어서 70% 이상을 함유한 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 22

제 18 항에 있어서,

상기 내식층은 3 마이크로미터 이하의 두께를 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 23

제 18 항에 있어서,

상기 다이아몬드형 카본은 95% 이상의 원자 탄소 함량을 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서.

청구항 24

a) 기판 부재를 제공하는 단계,

b) 상기 기판의 표면위에 다수의 연마 입자들을 균일하게 일정한 간격으로
유지하는 단계, 및

c) 각 연마 입자들이 기판 부재위에 미리 결정된 높이로 연장하도록 기판에 상기 연마 입자들을 부착하는 단계를 구성하는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 25

제 24 항에 있어서,

상기 연마 입자들은 단결정 또는 다결정 형태로써 다이아몬드 또는 입방 보론 질화물의 결정 입자들인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 26

제 24 항에 있어서,

단계 b) 및 c)는 추가로,

a) 연마 입자의 배치가 구멍들의 위치에 의해 제어되도록 경납 합금의 시트상에 그 안에 형성된 구멍들의 미리 결정된 형태를 가지는 형판을 놓는 단계,

b) 연마 입자들로 상기 형판의 구멍을 채우는 단계,

c) 형판 구멍내에 있지않은 연마 입자들을 제거하는 단계,

d) 상기 연마 입자들이 경납 합금으로 부분적으로 애워싸여지게 되도록 경납 합금의 시트내부 구멍에 함유된 연마 입자들을 가압하는 단계,

e) 연마 입자들이 경납 합금의 시트상에 놓인 상태로 유지하도록 형판을 제거하는 단계,

f) 기판에 연마 입자들을 함유하는 경납 합금의 시트를 부착하는 단계, 및

g) 진공로에서 제품을 경납하는 단계를 구성하는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 27

제 26 항에 있어서,

상기 구멍들은 단지 하나의 연마 입자를 수용하기에 충분한 크기를 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 28

제 27 항에 있어서,

상기 구멍들은 미리 결정된 범위의 연마 입자들을 수용하기 위해 선택된 미리 결정된 크기를 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 29

제 24 항에 있어서,

상기 연마 입자들은 50 내지 250 마이크로미터의 범위인 평균 크기를 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 30

제 24 항에 있어서,

상기 연마 입자들은 모든 연마 입자들이 서로의 10%내 크기를 가지도록 크기에 있어서 실질적으로 균일한 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드
레서 제조 방법.

청구항 31

제 26 항에 있어서,

미리 결정된 형태의 상기 구멍들은 두 개의 입자들 사이에 미리 결정된 거리를 만들기 위해 충분한 방법내에서 일정한 간격으로 유지되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 32

제 31 항에 있어서,

상기 각 입자사이의 미리 결정된 거리는 입자들 크기의 1.5 내지 10배인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 33

제 26 항에 있어서,

상기 미리 결정된 입자의 형태는 그리드인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 34

제 24 항에 있어서,

기판으로부터 미리 결정된 높이는 모든 연마 입자들이 50 마이크로미터내로 연장하는 균일한 높이인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 35

제 24 항에 있어서,

상기 연마 입자들은 자형 형상을 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 36

제 24 항에 있어서,

상기 연마 입자들은 미리 결정된 형상인 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 37

제 24 항에 있어서,

상기 연마 입자들은 상기 기판으로부터 떨어져 방향지어진 가장자리 또는 예리한 지점을 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 38

제 24 항에 있어서,

상기 기판 부재는 금속 재료로 만들어진 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 39

제 38 항에 있어서,

상기 금속 재료는 스테인레스강인 것을 특징으로 하는 화학 기계적 연마 (CMP) 패드 드레서 제조 방법.

청구항 40

제 26 항에 있어서,

상기 경납 합금의 시트는 유기 결합제로 서로 경납 합금 입자들을 결합하는 단계, 및

바람직한 두께의 시트로 상기 결합된 입자들을 형성하는 단계에 의해 제조되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 41

제 40 항에 있어서,

상기 시트로 경납 합금 입자들을 형성하는 단계는 압연, 압출 또는 테이프 케스팅에 의해 이루어지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 42

제 26 항에 있어서,

상기 경납 합금은 1wt% 이상의 크롬 양을 가지는 니켈 합금을 구성하는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 43

제 26 항에 있어서,

상기 경납 합금의 시트는 경납 합금위의 각 연마 입자의 10 내지 90% 사이의 노출을 허용하기 위해 충분한 경납 두께를 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 44

제 24 항에 있어서,

추가로 내식층을 가진 상기 경납 합금과 상기 연마 입자들을 코팅하는 단계를 구성하는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 45

제 44 항에 있어서,

상기 내식층은 다이아몬드, 또는 다이아몬드형 카본으로 구성되는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 46

제 44 항에 있어서,

상기 내식층은 3 마이크로미터 이하의 두께를 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 47

제 44 항에 있어서,

상기 다이아몬드형 카본은 90% 이상의 원자 탄소 함량을 가지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

청구항 48

제 47 항에 있어서,

상기 코팅 단계는 음극 아크 방법을 사용하여 이루어지는 것을 특징으로 하는 화학 기계적 연마(CMP) 패드 드레서 제조 방법.

명세서

발명의 명칭

다이아몬드 그리드 화학 기계적 연마 패드 드레서{A DIAMOND GRID CMP PAD DRESSER}

도면의 간단한 설명

[0001] 도 1은 디스크 기판에 다이아몬드를 고정하기 위해 전기 도금 방법을 사용한 종래 기술의 CMP 패드 드레서의 측면도이고,

[0002] 도 2는 디스크 기판에 다이아몬드 입자들을 고정하기 위한 종래 경납 방법을 사용하여 만들어진 종래 기술의 CMP 패드 드레서의 측면도이고,

[0003] 도 3은 본 발명의 원리에 따라 만들어진 CMP 패드 드레서의 측면도이고,

[0004] 도 4는 본 발명의 원리에 따라 만들어진 그의 표면위에 연마 입자들을 놓기 위한 형판을 가진 경납 합금의 시트에 대한 측면도이고,

[0005] 도 5는 그의 표면위에 형판과 상기 형판의 구멍들을 채우는 연마 입자들을 가진 경납 합금 시트의 측면도로, 평평한 표면은 본 발명의 원리에 따라서 경납 합금의 시트내부로 연마 입자들을 가압하여 사용하기 위한 것을 나타내었고,

[0006] 도 6은 본 발명의 원리에 따라서 상기 내부로 가압된 연마 입자들을 가진 경납 합금 시트의 측면도이다.

발명의 상세한 설명

[0007] 본 발명은 일반적으로 CMP(화학기계적 연마) 패드(pad)를 조절하고 또는 드레싱(dressing)하기 위한 장치 및 그의 제조 방법에 관한 것이다. 특히, 본 발명은 CMP 패드를 조절하고 또는 드레싱하기 위해 다이아몬드 또는 입방 보론 질화물과 같은 우수한 경질재료를 함유한 드레싱 디스크에 관한 것이다. 더욱 특이하게, 본 발명은 화학적 침식으로부터 보호하기 위해 탄소와 같은 다이아몬드의 얇은 피막으로 코팅될 수 있는, 평탄하게 일정한 간격을 이룬 연마 입자들을 가진 드레싱 디스크에 관한 것이다.

[0008] 많은 산업체에서는 현재 어떠한 작업편을 연마하기 위해 화학기계적 평탄화 (CMP) 방법을 사용하고 있다. 특히, 제조 산업은 세라믹, 실리콘, 유리, 석영 및 금속의 웨이퍼들을 연마하기 위해 대부분이 CMP 방법에 의존하고 있다. 일반적으로 그러한 연마공정은 폴리우레탄과 같은 내구성 유기물로 만들어진 회전 패드에 대항하여 웨이퍼 부착을 수반한다. 패드에 대하여, 웨이퍼 기판을 파괴시킬 수 있는 화학물질을 함유한 화학 슬러리 및 웨이퍼 표면을 물리적으로 침식시키기 위해 작용하는 많은 양의 연마 입자들이 첨가된다. 슬러리는 회전 CMP 패드에 연속적으로 첨가되고, 및 웨이퍼상에 발휘된 이중의 화학적 및 기계적 작용들은 바람직한 방법을 통해 연마되도록 한다.

[0009] 제조된 연마 품질에 대해 특별한 중요성의 하나는, 전체 패드를 통한 연마 입자들의 분포에 있다. 패드의 최상부는 보통 폴리우레탄내에 공공과 같은 수단에 의해 입자들을 지지하고 및 패드의 최상부상에 거친 조직을 유지한다. 추가로 유연한 패드 최상부는 웨이퍼상에서 연마를 허용하기 위해 필요한 지지물을 제공한다.

[0010] 패드의 최상부의 조직을 유지하는 것에 대한 문제는 작업편, 연마 슬러리 및 드레싱 디스크로부터 나오는 연마 부스러기(debris)의 축적때문이다. 상기 축적은 패드가 슬러리의 연마 입자들을 유지할 수 없게 만드는 패드의 최상부의 "글레이징 (glazing)" 또는 경화를 일으킨다.

[0011] 따라서, 시도들이 다양한 장치들로 상기를 "빗질"하므로써 패드 최상부의 재생을 만든다. 상기 공정이 CMP 패드를 "드레싱" 또는 "조절"하는 것으로써 공지되어 왔다. 많은 형태의 장치들 및 공정들은 상기 목적을 위해 사용되었다. 그러한 장치중 하나는 그의 기판 또는 표면에 부착된 다이아몬드 입자들과 같은 매우 단단한 결정질 입자들을 가진 디스크(disk)이다.

[0012] 불행이도, 종래 방법에 의해 만들어진 그러한 다이아몬드 디스크들은 몇 가지 문제점들을 나타내었다. 첫 번째, 다이아몬드들은 디스크의 기판으로부터 박리되어졌고 및 CMP 패드 표면에 포착되었다. 상기는 연마되는 작업편에 대하여 스크래치(scratch)를 유발한다. 두 번째, 종래 디스크들은 그룹으로 덩어리지고, 또는 기판의 표면위에 평탄하지 않게 일정한 간격을 이룬 다이아몬드를 가지기 쉬워진다. 상기 평탄하지 않은 그룹은 마모 영역을 발생하는 과다하게 드레싱될 CMP 패드의 약간의 부분들을 일으키고, 한편 다른 것들은 글레이징 층을 유발하는 드레이싱 결핍이 유발된다. 어느 경우에나, 패드 연마 효율은 감소되고, 및 평탄하지 않은 연마를 일으킨다. 마지막으로, 상기 디스크들의 다이아몬드들은 디스크의 기판 표면위의 균일한 높이로 연장하지 못한다. 상기 불균일함은 또한 단지 드레서로부터 충분한 높이로 돌출하는 상기 입자들이 패드에 접촉하기 때문에 CMP 패드의 평탄하
지 않은 드레싱을 일으킨다. 패드 최상부의 평탄하지 않은 드레싱은 웨이퍼의 불균일함을 초래할 수 있다.

[0013] 디스크 기판으부터 다이아몬드의 박리는 그들이 부착되어지는 열등한 방법 때문이다. 다이아몬드들이 기판에 전기도금된 니켈에 의해 유지될 때, 강력한 결합이 아닌 다이아몬드의 기계적 체결이 있게 된다. 따라서, 상기 입자들은 그들이 요동하여 느슨하게되자마자 박리되어질 것이다. 상기 박리 공정은 전기 도금재료상에 화학 슬러리의 화학적 침식에 의해 실행된다.

[0014] 한편, 다이아몬드들이 기판위로 경납(brazing)될 때, 화학 작용력은 더욱 확고하게 다이아몬드를 지탱한다. 그러나, 화학 슬러리내 산은 입혀진 물질을 빠르게 용해시키고 및 다이아몬드를 박리시킨다. 따라서, 화학작용으로 경납의 노출을 최소화하기 위해, 연마 공정은 드레이싱이 발생하는 동안 중지되고, 및 그 후에 다시 시작되어야 한다. 상기는 다른 연마가 뒤따르고 및 그 후 드레싱은 시간을 소비하게 때문에 비효율적이다.

[0015] 전술된 관점에서, CMP 패드의 평탄한 손질(grooming)을 제공하는 CMP 패드 드레서가 바람직할 수 있다. 또한, 평탄한 깊이로 CMP 패드를 손질하는 CMP 패드 드레서가 매우 바람직할 수 있다. 추가로, 다이아몬드 입자 박리에 덜 민감한 CMP 패드 드레서가 매우 바람직할 수 있다. 마지막으로, 화학 슬러리의 산 침식에 저항하고, 및 연속적으로 CMP 패드를 드레싱할 수 있고, 심지어 산 슬러리에서 연마가 수행되어지는 CMP 패드 드레서가 극히 바람직할 수 있다.

[0016] 본 발명의 목적은 평탄하게 드레스 또는 조절을 위한 연마 입자들을 사용할 수 있는 CMP 패드 드레서, CMP 패드를 제공하는 것이 본 발명의 목적이다.

[0017] 본 발명의 다른 목적은 연마 입자 박리에 덜 민감한 CMP 패드 드레서를 제공하기 위한 것이다.

[0018] 본 발명의 또 다른 목적은 CMP 패드를 일정하게 드레싱할 수 있고, 심지어는 패드가 산 슬러리내에서 연마 작용으로 체결되도록 내식성이 있는 CMP 패드 드레서를 제공하기 위한 것이다.

[0019] 또한 본 발명의 목적은 연마되어진 웨이퍼를 오염시키는 디스크로부터 성분들의 용해를 방지하는 화학 베리어를 제공하기 위한 것이다.

[0020] 추가로 본 발명의 목적은 평탄하게 CMP 패드를 드레싱하고 또는 조절하는 방법을 제공하기 위한 것이다.

[0021] 또한 본 발명의 목적은 패드가 산 슬러지에 담궈질 때 연마 입자 박리에 대하여 CMP 패드 드레서의 민감성을 감소시키는 방법을 제공하기 위한 것이다.

[0022] 상기 목적들 및 특별하게 인용되지 않은 다른 것들은 많은 평평하게 일정한 간격을 이룬 기판에 부착된 연마 입자들을 가지는 CMP 패드 드레서의 특별하게 설명된 실시예를 통해 이루어졌다. 일반적으로, 상기 입자들은 단결정 또는 다결정 형태에서, 다이아몬드, 또는 입방형 보론 질화물(cBN)과 같은 매우 단단한 기판중의 하나이다.

[0023] 본 발명의 CMP 패드 드레서를 형성하는 하나의 방법에서, 브레이징 파우다 와 유기 결합제가 첫 번째 반죽(dough)을 형성하기 위해 완전히 혼합된다. 그 후
상기 반죽은 경납 합금의 유연한 시트를 형성하기 위해 두 개의 롤러 사이를 통해 압연된다. 그 후 연마 입자들은 다수의 평평하게 일정한 간격을 이룬 구멍들을 포함하는 형판의 사용에 의해 경납 합금의 시트상에 평평하게 놓여진다. 상기 형판의 구멍들은 하나의 연마 입자 또는 "그리트(grit)"의 크기보다 크지만, 두 개의 크기보다 작다. 모든 구멍들이 연마 입자들로 채워질 때, 어느 과도한 연마 입자들은 제거되고, 및 연마 입자들은 강판과 같은 일반적으로 평평한 표면을 사용하므로써 그 안에 그들이 묻히도록 경납 합금 시트내부로 가압된다. 그 후 상기 형판은 제거되고, 및 연마 입자를 함유한 경납 합금은 아크릴 아교를 가진 기판에 부착된다. 마지막으로, 전체 조립체는 경납 공정을 완성하고 및 확고하게 기판에 연마 입자들을 고정시키기 위해 진공로에서 경납된다.

[0024] 다른 방편으로, 연마 입자들은 상기에 기술된 것 처럼 형판을 사용하여 아크릴 아교를 가진 기판에 부착될 수 있다. 다음, 경납 합금 입자들은 연마 입자들과 기판위로 나타내어진다. 마지막으로, 전체 조립체는 경납 공정을 완성하고 및 확고하게 기판에 연마 입자들을 부착하기 위해 진공 경납로에서 가열된다.

[0025] 제어된 방법에서 연마 입자들을 위치시키기 위해 형판을 사용하므로써, 어떠한 바람직한 형태의 배치는 이루어질 수 있다. 상기 패턴은 거의 어떠한 상상할 수 있는 패턴일 수 있지만, 그러나 대부분이 상당히 기판위에 연마 입자들을 평평하게 일정한 간격을 유지시킬 수 있는 능력을 제공한다. 또한, 균일한 크기인 구멍들을 가진 형판을 사용하므로써, 각 연마 입자의 균일한 크기가 확보된다. 마지막으로, 기판 내부로 연마 입자들을 가압하기 위한 평평한 표면의 사용은 기판 표면위로 돌
출하는 연마 입자들의 균일한 높이를 만든다. 상기 균일한 높이의 연마 입자들은 균일한 깊이로 CMP 패드의 드레싱 또는 홈파기(plowing)를 확보한다. 추가로, 기판을 가로지른 연마 입자들의 균일한 분포는 그의 표면을 가로지른 패드의 균일한 드레싱을 위해 허용한다.

[0026] 기판에 연마 입자들을 부착한 후, 부가적인 내식 재료의 얇은 코팅이 CMP 패드 드레이서에 적용될 수 있다. 그러한 코팅은 효과적으로 CMP 패드 드레서의 표면을 밀봉한다. 그러한 밀봉제는 연마 입자 및 경납을 보호하고, 또는 다른 정착제는 연마 슬러리, 특히 산을 함유한 상기 슬러리들의 화학물질로부터 화학 침식에 대한 그들의 민감성을 감소시킨다. CMP 패드 드레서의 표면이 화학 분해로 덜 민감하게 되는 것 처럼, 또한 연마 입자 박리에 대한 그의 민감성은 줄어든다. 따라서, CMP 패드 드레서는 기판에 대하여 연마 입자들을 결합하는 작용제가 화학 박리로부터 보호되기 때문에 연마 작용동안에도 CMP 패드를 연속적으로 드레서할 수 있다.

[0027] 본 발명의 상기 및 다른 목적, 형태 및 장점들이 첨부된 도면들과 관련하여 나태내어진 다음의 상세한 설명으로부터 더욱 명백히 나타내어질 것이다.

[0028] 현재 CMP 패드 드레서 및 수반된 사용 방법 및 제조가 나타내어지고 및 기술되어지기전, 상기는 본 발명이 여기에서 나타내어진 특별한 공정 단계 및 재료에 제한을 두지 않았지만, 관계 기술에서 보통 기술된 것들에 의해 인식되어진 것 처럼 그의 대등한 연장으로 이해되어질 것이다. 또한 상기는 여기에서 사용된 용어는 단지 특별한 실시를 기술하기 위한 목적으로 사용되었고 및 제한되길 의도되지 않
은 것으로 이해되어져야 한다.

[0029] 상기 상기 명세서 및 첨부된 청구범위에서 사용된 것 처럼, 단일 형태들 "a", "and", "the"는 문맥이 분명하게 다른 것으로 규정되지 않는 한 복수의 지지 대상을 포함하는 것으로 주목되어야 한다. 따라서, 예를 들면, "연마 입자" 또는 "그리트"로 인용은 하나 이상의 그러한 연마 입자들 또는 그리트들에 대한 인용을 포함한다.

[0030] 본 발명을 기술하고 및 청구함에 있어서, 다음의 용어는 아래 설명된 정의에 따라서 사용될 것이다.

[0031] 여기에서 사용된 것으로, "연마 입자", 또는 "그리트", 또는 유사한 말들은 어떤 우수한 단단한 결정질, 또는 다결정 물질, 또는 물질의 혼합물을 의미하고 및 포함하지만 다이아몬드, 다결정 다이아몬드(PCD), 입방 보론 질화물, 및 다결정 입방 보론 질화물(PCBN)로 제한되지 않는다. 추가로, "연마 입자", "그리트", "다이아몬드", "다결정 다이아몬드(PCD)", "입방 보론 질화물" 및 "다결정 입방 보론 질화물(PCBN)"의 용어들은 서로 교환하여 사용될 수 있다.

[0032] 여기에서 사용된 것으로써, "기판"은 연마 입자들이 부착될 수 있는 표면을 가진 CMP 드레서의 기부(基部)를 의미한다. 상기 기부는 어떠한 형상, 두께 또는 재료일 수 있고 및 포함하지만, 그러나 금속, 합금, 세라믹 및 그의 혼합물로 제한되지 않는다.

[0033] 여기에서 사용된 것으로써, "자형(euhedral)"은 고유 형태를 가짐을 의미하고, 또는 성장된 결정학적면을 가진 변경되지 않은 자연 형상을 가짐을 의미한다.

[0034] 여기에서 사용된 것으로써, "끝이 뾰족한(sharp point)"은 결정으로 되는 어떠한 협소한 정점을 의미하고, 포함하지만 모서리들, 융기들, 오벨리스크(obelisk)들, 및 다른 돌출부들로 제한되지 않는다.

[0035] 여기에서 사용된 것으로써, "금속"은 어떠한 금속의 형태, 금속 합금 또는 그의 혼합물을 의미하고 및 특별하게 포함하지만 강, 철, 및 스테인레스강으로 제한되지 않는다.

[0036] 발명자는 CMP 패드를 조절 또는 드레싱의 효율성 및 품질을 개선하기 위한 장치를 발견하였다. 장치를 사용하고 및 제조하기 위한 방법이 여기에 포함되었다. CMP 패드를 조절하고 드레싱하기 위한 장치를 사용하므로써, 디스크 수명 및 패드 수명이 연장될 뿐만 아니라 패드가 사용될 수 있는 동일성이 연장되었고, 따라서 작업이 완성되는 처리량이 향상되었다. 또한, 연마된 웨이퍼의 균일성 및 결함율이 개선되었다.

[0037] 도 1을 참고로, 거기에는 다수의 다이아몬드 입자들(50), 전기 도금된 기판 (40)을 구비한 CMP 패드 드레서가 나타내어져있다. 전기 도금 재료(60)는 일반적으로 산 용액으로부터 석출된 니켈이다. 그러한 전기 도금 방법은 고가이고 및 시간이 소모될 뿐만 아니라, 공정에 의해 발생된 폐기물 때문에 환경적으로 위험하다.

[0038] 전기 도금된 CMP 패드 드레서(10)는 도 1에 나타낸 것 처럼 나타내어진 많은 단점을 가지고 있다. 첫 번째, 전기 도금 재료(60)는 다이아몬드 입자(50)로 어떠한 화학 결합을 형성할 수 없다. 따라서, 단지 약한 가공력은 기판(60)위로 다이아몬드 입자들(50)을 유지한다. 그러한 가공력은 패드 드레서가 CMP 패드에 대항하여
문질러질 때 공간(70)과 같은 전기 도금 재료(60)내에 공공들을 남겨 전기 도금 재료(60)로부터 쉽게 느슨해지는 다이아몬드 입자들(50)에 작용하는 큰 마찰력에 의해 빠르게 극복된다. 그러한 공공들은 슬러리로부터 화학 제품 및 연마 입자들 뿐만 아니라 작업편의 연마된 잔유물로 빠르게 채워지게된다. 그러나, 그러한 증착된 잔유물은 경화되고 및 떨어질 때, 종종 미세 스크래치를 발생시키고, 연마된 웨이퍼의 생산량을 감소시킨다.

[0039] 전기 도금 재료(60)에 의해 생산된 가공력이 기판(40)상에서 다이아몬드 입자들(50)을 지지하고, 다이아몬드 입자(50)를 노출하는 유일한 수단이고, 상기 전기도금 재료가 최소로 유지되어야 한다. 따라서, 전기 도금 재료(60)와 CMP 패드사이의 접촉은 피할 수 없다. 그러한 접촉은 전기 도금 재료를 마모시키고 및 다이아몬드 입자(50)들의 방출을 촉진시킨다.

[0040] 또한, 전기 도금 재료(60)는 볼록한 부분(80)과 같은 장소에서 다이아몬드 (50)위로 성장하는 경향이 있다. 상기 과도한 성장은 이미 낮은 노출 및 다이아몬드 입자(50)들의 빽빽한 간격에 더하여, 만약 불가능하지 않다면, 어려운 CMP 패드 내부로 다이아몬드 입자(50)의 상당한 관통을 만든다. 그러한 관통없이, 드레싱 공정은 심하게 방해를 받는다.

[0041] 도 2를 참고로, 거기에는 경납 재료(90) 및 종래 경납 기술을 사용하여 기판(40)에 경납된 다이아몬드 입자(50)들을 가지고, 기판(40)을 가진 종래 기술의 CMP 드레서 패드를 나타내었다. 경납 재료들은 일반적으로 탄화물 형성자와 혼합된 금속 합금을 구성한다. 그러한 탄화물 형성자들은 차례로 기판과 결합하여, 재료
(90)를 경납하기 위해 화학적 결합으로 다이아몬드 입자(50)들을 허용한다. 상기 결합 장치는 그리트 부착 강도를 상당히 증가시키지만, 약간의 바람직하지 않은 부작용에 의해 수반되어진다.

[0042] 경납 재료(90)는 다이아몬드 입자(50)들을 완전히 덮는 것으로부터 유지하기 위해서 최소로 유지되어야 한다. 따라서, 다이아몬드 입자(50)들은 단지 경납 재료 (90)의 얇은 코팅으로 감싸진다. 상기 문제는 일반적인 경납 재료들이 기계적으로 약하다는 사실에 의해 혼합된다. 상기 기계적 약함은 경납 재료 그 자체가 분리된 다이아몬드 입자로 잘리워질 수 있기 때문에 다이아몬드 입자(50)들과 경납 재료 (90)사이의 화학 결합의 강도를 상쇄시킨다.

[0043] 경납 재료(90)를 가진 부가적인 문제는, 상기에 언급된 전기 도금 니켈과 같이 연마 슬러리에 의해 화학 침식에 매우 민감하다는 것이다. 그러한 화학 침식은 경납 재료(90)를 약하게 하는 것과 같이 다이아몬드 입자(50)들의 분리에 기여한다. 따라서, 화학 슬러리에 CMP 패드 드레서(20)의 노출을 감소시키기 위해서, 작업편의 연마가 중지되어야 하고, 및 화학 슬러리는 패드 드레서(20)가 적용되기전 패드를 떠나는 것을 허용한다. 그러한 연마 공정에서 중지는 마무리 제품을 제조하기 위해 요구된 시간을 증가시키고, 및 따라서 비효율적이다.

[0044] 종래 경납에 대한 다른 결점은 용융 금속 합금의 표면 장력이 기판(40)에 적용될 때 "덩어리"로 연마 입자(50)들을 발생시키는 경향이 있다는 것이다. 그러한 덩어리는 100으로 설명되었고, 틈(110)을 남긴다. 전체 효과는 비효율적이 손질을 만드는 다이아몬드 입자(20)들의 고르지 않은 분포를 남긴다. 상기 비효율성은 틈
(110) 때문이고, 조절되지 않고 남아 있는 CMP 패드의 영역을 발생시킨다.

[0045] 상기 고르지 않은 조절은 작업편의 마모 영역이 적당하게 조절된 영역보다 덜 효과적으로 연마되기 때문에 고르지 않은 연마를 받는 전체 결과로 다른 것 보다 빠르게 마모되는 CMP 패드의 영역을 발생시킨다.

[0046] 연마 입자들의 덩어리를 만드는 다른 효과는 경납 재료(90)내에 작은 무더기 (mound)의 형성이다. 작은 무더기 형성은 약간의 다이아몬드 입자들을 다른 연마 입자들의 것보다 큰 기판(40)위로 높게 상승시킨다. 따라서, 높아진 돌출 입자들은 CMP 패드 내부로 깊게 관통하고, 그들은 어떠한 손질 효과에 의해 연마 입자들이 돌출하는 것을 더 적게 방지할 것이다. 상기는 또한 비효율성 및 부적합한 조절을 발생시킨다.

[0047] 종래 기술의 CMP 패드 드레서와 대조적으로, 본 발명은 CMP 패드의 고른 드레싱을 허용한다. 도 3을 참고로, 거기에는 본 발명의 원리에 따라서 만들어진 CMP 패드 드레서를 나타낸다. 상기 CMP 패드 드레서는 경납 재료(90)로 기판(40)에 부착된 다수의 연마 입자(180)를 가진다. 연마 입자(180)들은 어떠한 우수한 경질 재료일 수 있다. 바람직한 재료들은 다이아몬드로 제한되지 않은 다결정질 다이아몬드(PCD), 입방 보론 질화물(CBN) 및 다결정 입방 보론 질화물(PCBN)을 포함한다.

[0048] 또한 도 3에 나타내어진 것 처럼, 내식 층(130)이다. 상기 내식 층은 연마 입자(180)들이 아래에 기술된 방법을 통해 기판(40)에 부착되어진 후 CMP 패드 드레서의 표면위에 형성된다. 내식 층(130)은 다이아몬드, 또는 다이아몬드형 카본과 같은 다른 우수한 경질 재료이다. 바람직한 실시예에서, 내식 층(130)은 비다이아
몬드 카본의 메트릭스내에 약 70% 이상의 다이아몬드로 구성되었다. 내식 층(130)은 임의의 두께일 수 있으나, 일반적으로 0.5 내지 3μm의 범위이다. 바람직한 실시예에서, 내식 층(130)은 약 1의 두께를 가진다. 그러한 얇은 내식 층(130)은 물리 증기 증착(PVD)방법에 의해 제조될 수 있다. 흑연 음극을 가진 음극 아크의 사용과 같은 PVD 방법은 기술내에서 공지되었고 및 내식 층(130)을 제조하기 위해 사용될 수 있다.

[0049] 내식 층(130)에 의해 제공된 장점은 효과적으로 가공 표면을 "밀봉"하는 것이고, 및 또한 화학 침식에 취약할 수 있는 CMP 패드 드레서의 다른 바람직한 표면들을 밀봉할 수 있다. 밀봉제로써, 내식 층(130)은 CMP 패드내에 유지된 연마 화학 슬러리에 의해 화학 침식으로부터 경납 재료(90)를 보호한다. 상기 보호는 패드가 작업편을 연마할 때에도 CMP 패드 드레서(30)가 연속적으로 CMP 패드를 드레싱하는 것을 허용하고, 및 종래 기술의 CMP 패드 드레서의 수명을 연장하기 위해 사용된 제조 중지를 제거한다. CMP 패드의 연속적이고 및 고른 드레싱은 더 많은 제품 생산을 허용하고, 및 CMP 패드의 수명 및 효과를 연장한다.

[0050] 기판(40)에 연마 입자(180)들을 부착하는 하나의 방법이 도 4-6에 나타내어졌다. 첫 번째, 구멍(150)을 가진 형판(140)은 경납 합금(90)의 시트위에 놓인다. 형판의 사용은 바람직한 형태로 구멍들을 가진 형판을 디자인하므로써 제어될 연마 입자(180)들의 배치를 허용한다. 연마 입자 배치를 위한 형태들은 CMP 패드 드레서가 사용될 특별하게 필요한 조건들을 맞추기 위한 기술에서 보통 기술된 하나에 의해 선택될 수 있다.

[0051] 본 발명의 하나의 양상에서, 구멍들의 분포는 경납 합금(90)에 의해 결합된 연마 그리트(180)들 사이에 바람직한 양의 공간을 만들기 위해 미리 결정된 구멍들 사이에 공간을 가진 그리드(grid) 형태이다. 바람직한 실시예에서, 상기 그리트는 각 그리트 크기의 약 1.5 내지 약 10배의 거리로 고르게 일정한 간격을 이룬다.

[0052] 형판(140)이 경납 합금 시트(90)에 놓인 후, 구멍(150)들은 연마 입자 (180)들로 채워진다. 구멍(150)들은 단지 하나의 연마 입자가 각 구멍에 채워지도록 바람직한 크기를 가진다.

어떠한 크기의 연마 입자, 또는 그리트는 수용할 수 있지만, 그러나 본 발명의 양상에서, 입자들 크기는 직경으로 약 100 내지 350 마이크로미터이다.

[0053] 본 발명의 다른 양상에서, 형판내에 구멍들의 크기는 크기에서 변하거나 또는 실질적으로 균일한 크기인 연마 입자들의 형태를 얻기 위해서 요구되어질 수 있다. 바람직한 실시예에서, 형판의 구멍들은 서로의 크기에서 50 마이크로미터내에 있는 그리트를 단지 선택하기 위해 충분하다. 상기 그리트 크기의 균일성은 각 연마 입자의 가공 하중이 고르게 분포되는 것 처럼, CMP 패드 손질의 균일성에 기인한다. 차례로, 고른 가공 하중 분포는 개개의 연마 입자들상에 응력을 감소시키고, 및 CMP 패드 드레서(30)의 효과적인 수명을 연장한다.

[0054] 형판(150)의 구멍들이 그리트(180)로 채워진 후, 어떤 과도한 연마 입자들은 제거되고, 및 평평한 표면(160)이 연마 입자(180)에 적용된다. 평평한 표면(160)은 경납 합금 시트(90)내부로 내려오는 연마 입자(180)들을 밀어낼 수 있는 것과 같은 강하고 단단한 재료로 이루어져야 한다. 그러한 재료들은 일반적으로 포함되지만,
강, 철, 그의 합금등에 제한되지 않는다.

[0055] 연마 입자(180)들은 도 6에서 경납 합금 시트(90)내에 포함되는 것으로 나타내어졌다. 표면(160)이 평평하기 때문에, 연마 입자(180)들은 기판(40)으로부터 균일한 거리로 떨어져 연장할 것이다. 상기 거리는 형판(140)의 두께에 의해 결정될 것이고, 및 바람직한 실시예에서, 각 연마 입자는 상기 거리의 50 마이크로미터내로 연장할 것이다.

[0056] 도 4-6에서 나타내어진 것과 같이 연마 입자(180)들은 둥글다. 그러나, 도 3에서 그들은 뾰족하였다. 본 발명의 범위는 자형을 포함한 어떠한 형상, 또는 자연적으로 형상을 이룬 입자들의 연마 입자들을 포함한다. 그러나, 바람직한 실시예에서, 연마 입자(180)들은 기판(40)으로부터 떨어진 방향으로 연장하는 뾰족한 포인트 또는 가장자리를 가진다.

[0057] 연마 입자(180)들이 경납 합금 시트(90)내에 포함되어진 후, 상기 시트는 도 3에 나타내어진 것 처럼, 기판(40)에 부착된다. 사용된 경납 합금은 기술내에서 공지된 어떠한 경납 재료일 수 있지만, 그러나 바람직하게 중량 %로 2% 이상의 크롬을 함유한 니켈 합금이다.

[0058] 연마 입자(180)들이 경납 합금 시트(90)내에 포함되었기 때문에, 액체 경납 합금의 표면 장력은 입자 덩어리를 발생시키기에는 불충분하다. 또한, 경납의 두께는 훨씬 낮은 수준으로 발생하고 및 "무더기"가 형성되지 않는다. 반대로, 경납은 상당한 지지물과 슬러리 틈을 제공하는 각 연마 입자사이의 오목한 표면을 형성한다. 마지막으로, 바람직한 실시예에서, 경납 합금 시트(90)의 두께는 경납 재료
(90)의 외부 표면위로 돌출하기 위한 각 연마 입자의 약 10 내지 약 90%를 허용하기 위해 선택되어진다.

[0059] 경납 합금 시트(90)내에 연마 입자(180)를 포함하기 위한 방법의 결과로써, 고른 공간(120)이 만들어진다. 또한, 연마 그리트(180)들은 CMP 패드에 적용될 때를 의미하는 기판(40)위의 거리 또는 균일한 높이로 연장하고, 그들은 패드 섬유내부 균일한 깊이로 돌출할 것이다. 상기 고른 공간 및 균일한 돌출은 CMP가 고르게 드레싱되고 손질되는 것을 발생시키는 것으로, CMP 패드의 연마 효율성을 증가시키고 및 그의 사용 수명을 연장시킨다.

[0060] 본 발명의 더 많은 이해를 위해서, 실시예들이 아래에 제공되어졌다. 이러한 실시예들은 본 발명의 범위의 제한내에서 사용됨을 의미하지는 않는다.

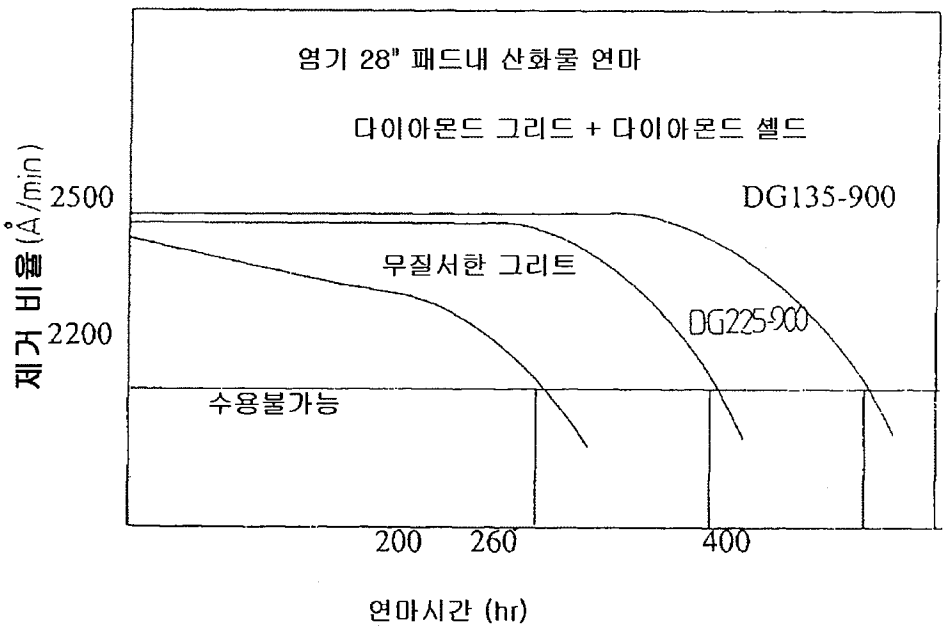
[0061] 실시예 1

[0062] 두 개의 CMP 패드 드레서 디스크들이 다음과 같이 제조되었다. 경납 합금 시트는 두개의 롤러사이에서 금속 파우다와 유기 결합체의 혼합물로 만들어진다. 135 및 225 마이크로미터의 평균 크기를 가진 제네럴 일렉트릭사에 의해 제조된 MBS970의 다이아몬드 그리트들은 경납 합금 시트내부로 형판의 도움에 의해 포함된다. 사용된 형판은 각 다이아몬드 그리트사이의 900 마이크로미터의 거리로 그리드 패턴 내부로 다이아몬드 그리트를 형성하였다.

[0063] 경납 합금 시트내부에 다이아몬드 그리트 입자들의 배치 후, 상기 시트는 아크릴 아교를 사용하여 금속 기판에 부착된다. 그 후 상기 조립체는 1000°C의 온도
로 진공로에서 경납된다. 얻어진 제품들은 약 100 밀리미터의 직경 및 약 6.5 밀리미터의 두께를 가진 두 개의 평평한 디스크이다.

[0064] 그 후 상기 디스크들은 무질서한 형상으로 배치된 다이아몬드 입자들의 양을 5배 이상 가진 디스크에 대항하여 시험되어졌다. 상기 디스크들은 스트라우스바우 (STRAUSBOUGH) 기계상에 장착된 28 인치 CMP 패드를 드레싱하기 위해 사용되었다. 상기 패드는 알칼리성 슬러리내에 8 인치 실리콘 웨이퍼를 연마하기 위해 사용되었다. 시험 결과가 아래 표 1에 나타내어졌다. DG 135-900은 900μm의 거리로 분리된 135 마이크로미터 입자들을 가진 디스크이고, 및 DG 225는 900μm의 거리로 분리된 225 마이크로미터 입자들을 가진 디스크이다.

[0065]



[0066] 나타내어진 것 처럼, 균일한 입자 배치를 가진 두 개의 디스크들은 무질서하게 배치된 다이아몬드를 가진 디스크를 상당히 능가하였다. 또한, 135 마이크로미
터 입자들을 가진 디스크는 거의 무질서한 입자 디스크의 수행력의 두배였다.

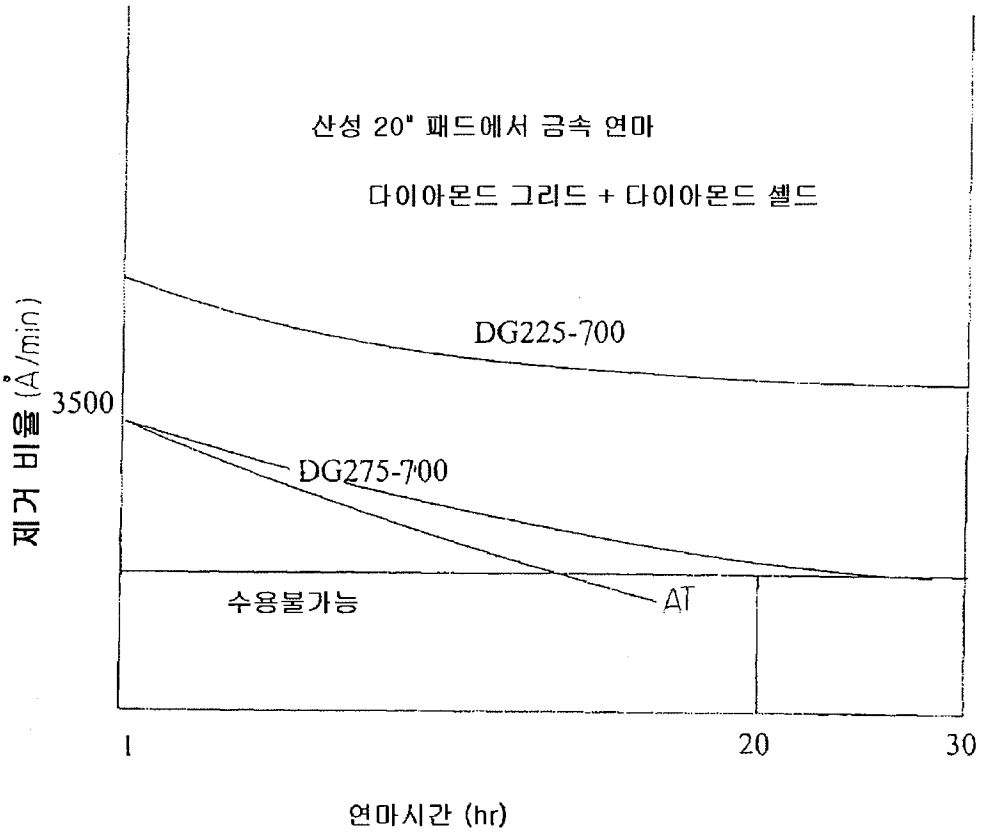
[0067] 실시예 2

[0068] 두 개의 부가 다이아몬드 디스크들은 실시예 1의 방법에 의해 제조되었다. 그러나, 225 마이크로미터 및 275 마이크로미터 크기의 다이아몬드가 사용되었다. 또한, 각 디스크는 경납 합금을 보화하기 위해 1 마이크로미터 두께 다이아몬드형 탄소 코팅으로 코팅되었다. 상기 다이아몬드형 탄소 피막은 음극 아크 방법에 의해 증착되었다.

[0069] 그 후 상기 디스크들은 8 인치 실리콘 웨이퍼를 연마하기 위한 적용된 재료 기계(Mirra)상에 장착된 CMP 패드를 드레싱하므로써 종래 다이아몬드 디스크와 비교되었다. 상기 패드는 3.0 pH의 산성 슬러리에 담궈졌다. 상기 드레싱은 연마가 발생되는 동안 동시에 수행되었다.

결과가 아래 표 2에 나타내어졌다. DG 275-700은 고르게 간격을 유지한 크기에 있어서 275 마이크로미터의 700μm 그리트를 함유한 디스크이다. DG 225-700은 고르게 간격을 유지한 크기에 있어서 225 마이크로미터의 700μm 그리트를 함유한 디스크이고, 및 AT는 보호 코팅없이 무질서하게 분포된 그리트를 함유하는 종래 다이아몬드 디스크이다.

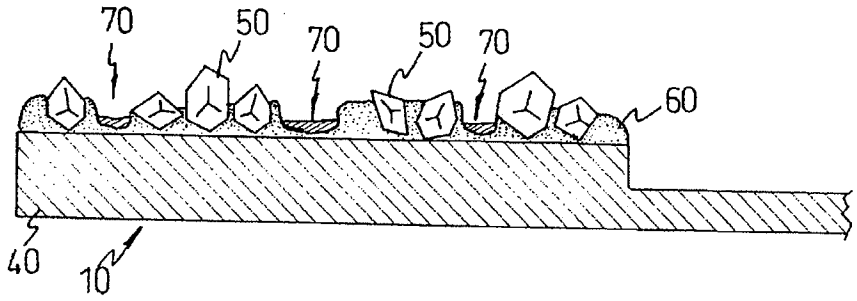
[0070]

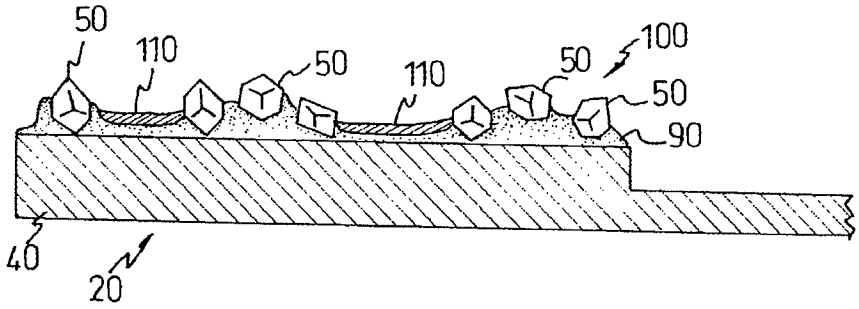


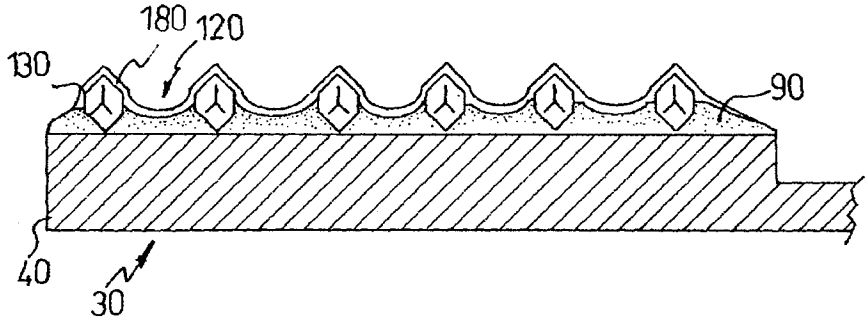
[0071] 표 2로부터 볼 수 있는 것 처럼, 종래 제조된 다이아몬드 디스크는 연마된 웨이퍼의 제거 비율을 유지할 수 없다. 또한, 금속 결합은 단지 1.5 시간동안 연마 슬러리의 산성 분위기에서 유지된다. 그 후, 다이아몬드는 떨어지기 시작하고 및 고가의 웨이퍼상에 많은 스크래치를 발생시킨다. 그러나, 본 발명의 디스크들은 산성 분위기에서 30 시간이상동안 유지되었다. 그러한 수명의 범위는 더 나은 CMP 패드 드레싱 결과를 얻을 수 있고, 및 종래 기술보다 상당히 개선된 웨이퍼 제조의 전체 비용 및 생산량을 구성한다. 물론, 상기는 상기 기술된 실시예가 본 발명의 원리의 적용으로 단지 설명되는 것으로 이해되어졌다.

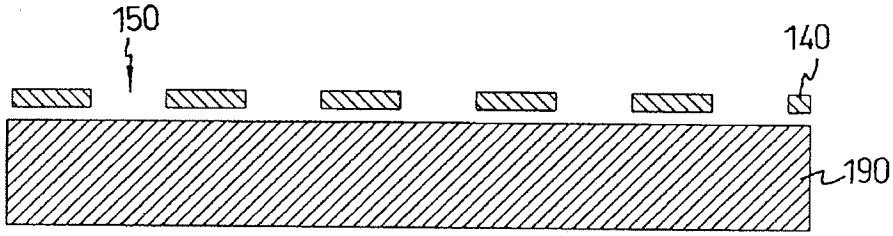
[0072] 많은 변경 및 다른 장치들이 본 발명의 범위 및 범주로부터 벗어남 없이 본 기술내에서 기술된 것들에 의해 발명되어졌고 및 첨부된 청구범위는 그러한 변경 및 장치들을 보호하기 위해 의도되어졌다. 따라서, 본 발명이 본 발명의 가장 실질적이고 및 바람직한 실시예로 간주되는 것과 관련하여 특별하고 및 상세하게 상기에 기술되어졌지만, 상기는 크기의 다양함, 재료, 형상, 형태, 기능, 작동 방법, 조립체, 및 용도에 제한을 두지 않고 포함된 많은 변경이 여기에서 설명된 개념 및 원리로부터 벗어남 없이 만들어질 수 있는 기술내에서 보통 기술의 것들로 명백해질 것이다.

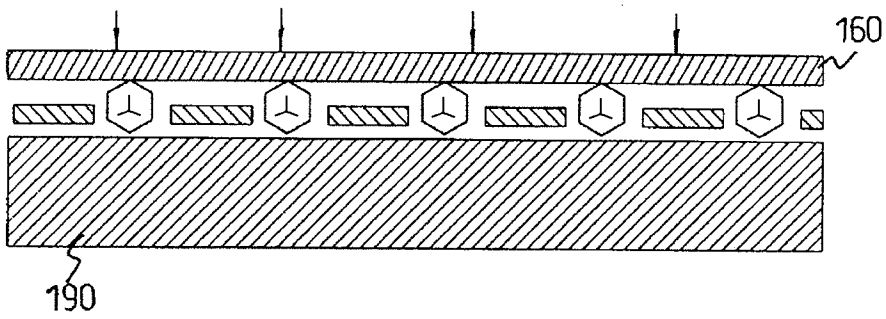
[0073] 상기한 바와 같이, 본 발명은 경납 합금 시트내에 연마 입자를 포함하기 위한 방법의 결과로써, 고른 공간이 만들어지고, 연마 그리트들은 CMP 패드에 적용될 때를 의미하는 기판 위의 거리 또는 균일한 높이로 연장하고, 그들은 패드 섬유내부 균일한 깊이로 돌출함에 따라, 상기 고른 공간 및 균일한 돌출로 CMP가 고르게 드레싱되고 손질되어 CMP 패드의 연마 효율성을 증가키고 및 그의 사용 수명을 연장시킨다.

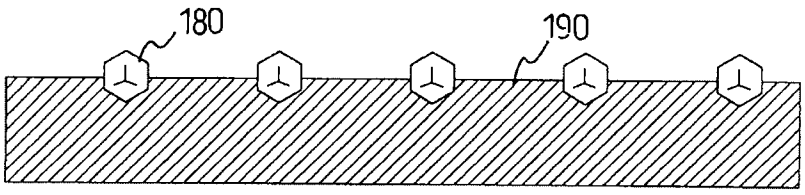

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CONTOURED CMP PAD DRESSER AND ASSOCIATED METHODS

No documents available for this priority number.

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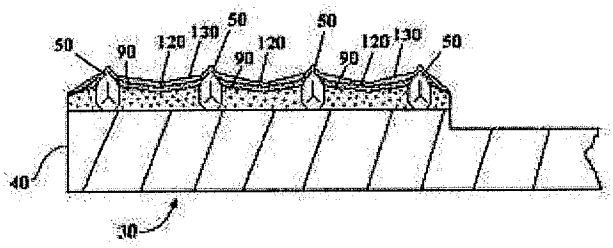
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Abstract of KR20070063569 (A)

CMP pad dressers with increased pad dressing work loads on centrally located abrasive particles (310) during dressing of a CMP pad, and methods associated therewith are disclosed and described. The increase in work loads on centrally located particles (310) improves pad dressing performance and also extends the service life of the pad dresser.



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(54) 윤곽지어진 CMP 패드 드레서 및 관련 방법들

(57) 요약

CMP 패드의 드레싱 동안 중심에 위치한 연마 입자들(310)에 패드 드레싱 작업 부하를 증가시킨 CMP 패드 드레서, 및 이와 관계된 방법이 개시되고 설명된다. 중심에 위치한 입자들(310)에 대한 작업 부하의 증가는 패드 드레싱 성능을 개선시키고 또한 패드 드레서의 사용 수명을 연장시킨다.

대표도

도 10

특허청구의 범위

청구항 1.

둘레에 위치한 입자들의 CMP 패드 내부로의 침투를 감소시키고 중심에 위치한 입자들의 CMP 패드 내부로의 침투를 증가시키는 패턴으로 초연마 입자들을 배열하는 것을 포함하는,

CMP 패드를 드레서로 드레싱하는 동안 CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 2.

제 1항에 있어서, 상기 초연마 입자들의 패턴은 둘레에 위치한 입자들의 작업 말단으로부터 중심에 위치한 입자들의 작업 말단까지 상향의 기울기를 제공함을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 3.

제 2항에 있어서, 상기 기울기는 둘레에 위치한 입자들에서 중심에 위치한 입자들까지 드레서의 작업 표면 위의 입자 높이를 증가시킴으로써 제공됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 4.

제 2항에 있어서, 상기 기울기는 패드 속도(velocity) 및 가요성을 측정하여 결정됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 5.

제 2항에 있어서, 상기 기울기는 0.1% 내지 0.5% 임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 6.

제 5항에 있어서, 상기 기울기는 0.2%임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 7.

제 1항에 있어서, 상기 초연마 입자들의 패턴은 중심에 위치한 입자들의 밀도 보다 더 높은, 둘레에 위치한 입자들의 밀도를 제공함을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 8.

제 7항에 있어서, 상기 둘레에 위치한 입자들의 밀도는 중심에 위치한 입자들의 밀도보다 5배 이상 더 큼을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

Ex. 1003, Page 178

청구항 9.

제 7항에 있어서, 상기 둘레에 위치한 입자들의 밀도는 중심에 위치한 입자들의 밀도보다 2배 이상 더 큼을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 10.

제 7항에 있어서, 상기 둘레에 위치한 입자들의 밀도는 중심에 위치한 입자들의 밀도보다 1.25배 이상 더 큼을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 11.

제 7항에 있어서, 중심에 그리고 둘레에 위치한 입자들 사이의 초연마 입자들은 중심에 위치한 입자들 및 둘레에 위치한 입자들의 밀도 사이의 밀도로 배치됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 12.

제 7항에 있어서, 상기 초연마 입자들의 패턴은 둘레에 위치한 입자들에서는 높고 중심에 위치한 입자들에서는 낮은, 실질적으로 연속적인 밀도 구배를 제공함을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 13.

제 1항에 있어서, 상기 초연마 입자들의 패턴은 둘레에 위치한 입자들의 애티튜드에 의하여 제공되는 침투보다 CMP 패드 내부로 더 큰 입자 침투를 유발하는 애티튜드를 가지는 중심에 위치한 입자들을 제공함을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 14.

제 13항에 있어서, 상기 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 꼭지점(apex)이며, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 에지 또는 면임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 15.

제 13항에 있어서, 상기 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 에지이며, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 면임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 16.

제 13항에 있어서, 상기 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 꼭지점(apex)이며, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 면이고, 사이에 위치한 입자들은 이들의 작업 말단에서 에지의 애티튜드를 가짐을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

Ex. 1003, Page 179

청구항 17.

제 1항, 2항, 7항 또는 13항 중 어느 한 항에 있어서, 상기 중심에 위치한 입자들의 작업 부하는 상기 둘레에 위치한 입자들의 작업 부하의 적어도 30% 까지 이내까지 증가됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 18.

제 17항에 있어서, 상기 중심에 위치한 입자들의 작업 부하는 둘레에 위치한 입자들의 작업 부하의 적어도 10% 이내까지 증가됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 19.

제 17항에 있어서, 상기 중심에 위치한 입자들의 작업 부하는 둘레에 위치한 입자들의 작업 부하와 실질적으로 동일하게 증가됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 20.

제 17항에 있어서, 모든 입자들의 작업 부하는 실질적으로 동일함을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 21.

제 2항 또는 13항에 있어서, 상기 초연마 입자들은 각각 개별적으로 예정된 패턴에 따라 기판 상의 특정 위치에 배치됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 22.

제 21항에 있어서, 상기 패턴은 실질적으로 균일한 격자임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 23.

제 1항, 2항, 7항 또는 13항 중 어느 한 항에 있어서, 상기 초연마 입자들은 다이아몬드, 다결정질 다이아몬드 (PCD), 입방정 질화 붕소 (cBN), 및 다결정질 입방정 질화 붕소 (PCBN)로 구성된 그룹에서 선택됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 24.

제 23항에 있어서, 상기 초연마 입자들은 다이아몬드임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 25.

제 1항, 2항, 7항 또는 13항 주 어느 한 항에 있어서, 초연마 입자들이 결합되는 기판을 제공하는 단계를 더욱 포함함을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 26.

제 25항에 있어서, 상기 초연마 입자들은 브레이징, 소결, 또는 전기도금에 의하여 기판에 결합됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 27.

제 1항, 2항, 7항 또는 13항 중 어느 한 항에 있어서, 상기 초연마 입자들은 실질적으로 균일한 형상을 가짐을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 28.

제 27항에 있어서, 상기 균일한 형상은 자형임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 29.

제 27항에 있어서, 상기 균일한 형상은 팔면체임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 30.

제 25항에 있어서, 상기 기판은 가요성의 금속 또는 세라믹 물질로 제조됨을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 31.

제 30항에 있어서, 상기 금속 물질은 스테인레스 강임을 특징으로 하는, CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 작업 부하를 증가시키는 방법.

청구항 32.

다음을 포함하는 CMP 패드 드레서:

기판; 및

상기 기판에 부착된 복수의 초연마 입자들, 여기서 상기 초연마 입자들은 둘레에 위치한 입자들의 작업 말단으로부터 중심에 위치한 입자들의 작업 말단까지 상향의 기울기를 제공하는 예정된 패턴으로 배열됨.

청구항 33.

다음을 포함하는 CMP 패드 드레서:

기판; 및

상기 기판에 부착된 복수의 초연마 입자들, 여기서 상기 초연마 입자들은 중심에 위치한 입자들의 밀도 보다 더 높은, 둘레에 위치한 입자들의 밀도를 제공하는 예정된 패턴으로 배열됨.

청구항 34.

다음을 포함하는 CMP 패드 드레서:

기판; 및

상기 기판에 부착된 복수의 초연마 입자들, 여기서 상기 초연마 입자들은 중심에 위치한 입자들에, 둘레에 위치한 입자들의 애티튜드에 의하여 제공되는 침투보다, CMP 패드 내부로 더 큰 입자 침투를 유발하는 애티튜드를 제공하는 예정된 패턴으로 배열됨.

청구항 35.

제 32항에 있어서, 상기 기울기는 둘레에 위치한 입자들로부터 중심에 위치한 입자들까지 드레서의 작업 표면 위의 입자 높이를 증가시킴으로써 제공됨을 특징으로 하는, CMP 패드 드레서.

청구항 36.

제 32항에 있어서, 상기 기울기는 패드 속도(velocity) 및 가요성의 측정치로서 결정됨을 특징으로 하는, CMP 패드 드레서.

청구항 37.

제 32항에 있어서, 상기 기울기는 0.1% 내지 0.5%임을 특징으로 하는, CMP 패드 드레서.

청구항 38.

제 32항에 있어서, 상기 기울기는 0.2%임을 특징으로 하는, CMP 패드 드레서.

청구항 39.

제 33항에 있어서, 상기 둘레에 위치한 입자들의 밀도는 중심에 위치한 입자들의 밀도 보다 5배 이상임을 특징으로 하는, CMP 패드 드레서.

청구항 40.

제 33항에 있어서, 둘레에 위치한 입자들의 밀도는 중심에 위치한 입자들의 밀도 보다 2배 이상 더 큼을 특징으로 하는, CMP 패드 드레서.

청구항 41.

제 33항에 있어서, 둘레에 위치한 입자들의 밀도는 중심에 위치한 입자들의 밀도 보다 1.25배 이상 더 큼을 특징으로 하는, CMP 패드 드레서.

청구항 42.

제 33항에 있어서, 중심에 위치한 입자들과 둘레에 위치한 입자들 사이의 초연마 입자들은 중심에 위치한 입자들의 밀도와 둘레에 위치한 입자들의 밀도 사이의 밀도로 배치됨을 특징으로 하는, CMP 패드 드레서.

청구항 43.

제 33항에 있어서, 상기 초연마 입자들의 패턴은 둘레에 위치한 입자들에서는 높고 중심에 위치한 입자들에서는 낮은, 연속적 밀도 구배를 제공함을 특징으로 하는, CMP 패드 드레서.

청구항 44.

제 34항에 있어서, 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 꼭지점(apex)이고, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 에지 또는 면임을 특징으로 하는, CMP 패드 드레서.

청구항 45.

제 34항에 있어서, 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 에지이고, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 면임을 특징으로 하는, CMP 패드 드레서.

청구항 46.

제 34항에 있어서, 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 꼭지점(apex)이고, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 면이며, 이들 사이에 위치한 입자들은 이들의 작업 말단에서 에지의 애티튜드를 가짐을 특징으로 하는, CMP 패드 드레서.

청구항 47.

제 32항, 33항, 또는 34항 중 어느 한 항에 있어서, 상기 중심에 위치한 입자들의 작업 부하는 둘레에 위치한 입자들의 작업 부하의 적어도 30% 이내까지 증가됨을 특징으로 하는, CMP 패드 드레서.

청구항 48.

제 47항에 있어서, 상기 중심에 위치한 입자들의 작업 부하는 둘레에 위치한 입자들의 작업 부하의 적어도 10% 이내까지 증가됨을 특징으로 하는, CMP 패드 드레서.

청구항 49.

제 47항에 있어서, 상기 중심에 위치한 입자들의 작업 부하는 둘레에 위치한 입자들의 작업 부하와 실질적으로 같아지도록 증가됨을 특징으로 하는, CMP 패드 드레서.

청구항 50.

제 47항에 있어서, 모든 입자들의 작업 부하는 실질적으로 동일함을 특징으로 하는, CMP 패드 드레서.

청구항 51.

제 32항 또는 34항에 있어서, 초연마 입자들은 각각 개별적으로 예정된 패턴에 따라 특정 위치에 배치됨을 특징으로 하는, CMP 패드 드레서.

청구항 52.

제 51항에 있어서, 상기 패턴은 실질적으로 균일한 격자임을 특징으로 하는, CMP 패드 드레서.

청구항 53.

제 32항, 33항, 또는 34항 중 어느 한 항에 있어서, 상기 초연마 입자들은 다이아몬드, 다결정질 다이아몬드 (PCD), 입방정 질화 붕소 (cBN), 및 다결정질 입방정 질화 붕소 (PCBN)로 구성되는 그룹에서 선택됨을 특징으로 하는, CMP 패드 드레서.

청구항 54.

제 53항에 있어서, 상기 초연마 입자들은 다이아몬드임을 특징으로 하는, CMP 패드 드레서.

청구항 55.

제32항, 33항, 또는 34항 중 어느 한 항에 있어서, 상기 초연마 입자들은 브레이징, 소결, 또는 전기도금에 의해 기판에 부착됨을 특징으로 하는, CMP 패드 드레서.

청구항 56.

제 32항, 33항, 또는 34항 중 어느 한 항에 있어서, 상기 초연마 입자들은 실질적으로 균일한 형상을 가짐을 특징으로 하는, CMP 패드 드레서.

청구항 57.

제 56항에 있어서, 상기 균일한 형상은 자형임을 특징으로 하는, CMP 패드 드레서.

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청구항 58.

제 56항에 있어서, 상기 균일한 형상은 팔면체임을 특징으로 하는, CMP 패드 드레서.

청구항 59.

제 56항에 있어서, 상기 균일한 형상은 입방정 팔각임을 특징으로 하는, CMP 패드 드레서.

청구항 60.

제 32항, 33항 또는 34항 중 어느 한 항에 있어서, 상기 기판은 가요성의 금속 또는 세라믹 물질로 제조됨을 특징으로 하는, CMP 패드 드레서.

청구항 61.

제 60항에 있어서, 상기 금속 물질은 스테인레스 강임을 특징으로 하는, CMP 패드 드레서.

청구항 62.

다음 단계들을 포함하는, 제 32항 내지 34항 중 어느 한 항의 CMP 패드 드레서를 제조하는 방법:

기판을 제공하는 단계; 및

둘레에 위치한 입자들의 CMP 패드 내부로의 침투는 감소시키고 중심에 위치한 입자들의 CMP 패드 내부로의 침투는 증가시키는 패턴으로 기판에 복수의 초연마 입자들을 부착하는 단계.

명세서

기술분야

발명의 분야

본원 발명은 일반적으로 화학적 기계적 연마 (CMP) 패드를 드레싱 또는 컨디셔닝 하기 위한 장치 및 방법에 관계한다. 따라서, 본원 발명은 화학 및 물질 과학 분야에 관계된다.

배경기술

발명의 배경

많은 산업들은 특정 피가공물을 연마하기 위해 화학적 기계적 가공(CMP)을 사용하고 있다. 특히, 컴퓨터 제조 산업은 세라믹, 실리콘, 유리, 석영 및 이들의 금속들의 웨이퍼들을 연마하기 위하여 CMP 공정에 크게 의존하기 시작했다. 이러한 연마 공정들은 일반적으로 폴리우레탄과 같은 내구성 유기 물질로 제조된 회전식 패드에 대면하는 웨이퍼 사용을 수반한다. 패드에, 웨이퍼 물질을 손상시킬 수 있는 화학물질을 함유하는 화학물질 슬러리 및 웨이퍼 표면을 물리적으로 부식시키기 위하여 작용하는 양의 연마 입자들이 첨가된다. 슬러리는 회전하는 CMP 패드에 연속적으로 첨가되며, 웨이퍼에 가해지는 이원 화학물질 및 기계적 힘은 웨이퍼가 원하는 방식으로 연마되게 한다.

구현되는 연마의 품질에 특히 중요한 것은 패드 전체에 두루 퍼져있는 연마 입자들의 분포이다. 패드의 상부는 통상적으로 섬유, 또는 소형 공극과 같은 메커니즘으로 입자들을 지지하는데, 섬유 또는 소형 공극과 같은 메커니즘들은 패드의 회전 운동에 의해 발생되는 원심력으로 인해 패드가 이탈하는 것을 방지하기에 충분한 마찰력을 제공한다. 그러므로, 패드 상부를 가능한 한 가요성인 상태로유지하는 것, 그리고 섬유들을 가능한 한 직립으로 유지하는 것, 또는 새로운 연마 입자들을 수용할 수 있는 여분의 개구 및 공극들이 존재하도록 확보하는 것이 중요하다.

패드의 상부를 유지하는 것에 관한 문제는 피가공물, 연마 슬러리, 및 드레싱 디스크에서 생긴 연마 부스러기의 축적에 의해 야기된다. 이러한 축적은 패드 상부의 "글레이징" 또는 경화를 야기하며, 섬유질들을 헝클어 버리므로, 패드가 슬러리의 연마 입자들을 덜 지지할 수 있도록 만들고, 패드의 전체적인 연마 성능을 현저히 감소시킨다. 또한, 많은 패드들에 있어서, 슬러리를 지지하기 위하여 사용되는 공극들은 막히게 되고, 패드의 연마 표면의 전체적인 조도는 저하되어 편평해진다. 그러므로, 다양한 장치를 사용하여 패드 상부를 "코밍(combing)" 또는 "컷팅(cutting)"하여 재생시키기 위한 시도들이 이루어졌다. 이러한 공정은 CMP 패드를 "드레싱" 또는 "컨디셔닝"하는 것으로 공지되었다. 이러한 목적을 위하여 많은 유형의 장치들 및 공정들이 사용되었다. 이러한 하나의 장치는 표면에 부착된 다이아몬드 입자들과 같은 복수의 초경질 결정질 입자들을 구비한 디스크 또는 이들의 기판이다.

불행하게도, 전통적인 방법에 의하여 제조된 이러한 연마 디스크들은 여러 가지 문제점들을 보인다. 첫째, 연마 입자들은 디스크의 기판으로부터 제거되어 CMP 패드 섬유질에 붙잡힐 수 있다. 이는 연마되는 피가공물의 긁힘 및 파손을 초래한다. 둘째, 선행 기술의 제조 방법들은 기판의 표면위에 고르지 않은 간격의 그룹으로 밀집되는 연마 입자들을 가지는 디스크들을 생산하기 쉽다. 입자들 사이에 생성된 균일하지 않은 간격은 CMP 패드의 일부분을 과다하게 드레싱되게 하여 마모흔들을 생성하고, 그밖의 다른 부분들을 덜 드레싱하여, 광택있는 층들을 생성한다. 셋째, 이러한 디스크들의 연마 입자들은 패드를 균일한 깊이로 침투하도록 배열되지 않는다. 이러한 비-균일성은 CMP 패드의 고르지 않은 드레싱을 추가적으로 생성한다. 마지막으로, CMP 패드가 유연한 정도에 따라, 드레서의 처음 리딩 에지 앞부분에서는 드레서에 의하여 생성되는 하향력으로 인하여 볼록해지거나 둥글어지는 경향이 있다. 이러한 볼록함은 패드가 드레서의 잔여 부분아래서 지나갈 때, 패드의 함몰이 일어나게 할 수 있으며, 순차적으로 남아있는 연마 입자들, 특히 패드 드레서의 중심에 위치한 입자들이 패드 전체에 걸쳐 덜 깊게 침투하게 또는 심지어는 침투하지 않게 할 수 있다. 드레서 입자들에 대한 이러한 고르지 않은 작업 부하는 패드를 고르지않게 드레싱 되도록 할 수 있으며, 또한 드레서를 고르지 않게 마모되게 하거나 조기에 마모되어 닳도록 할 수 있다.

또한 현재의 CMP 패드 드레서가 가지는 또다른 결점은 패드 컨디셔너의 사용 수명 감소이다. CMP 패드 컨디셔너의 사용 효과 및 효율성은 작업하는 연마 입자들의 수 및 각 입자가 수행하는 작업의 양에 의해 결정된다. 상기 지적한 바와 같이, 패드 컨디셔너의 사용 수명은 초연마 입자들에 대한 작업 부하의 고르지 않은 분포에 의해 감소될 수 있다. 가요성 CMP 패드가 드레서의 압력하에서 함몰할 때, 패드 컨디셔너의 리딩 에지 결정들에 과다한 마모가 발생할 수 있는데, 이는 이러한 결정들이 대부분의 작업 부하를 견디게 되기 때문이다. 또한, 중심에 위치한 연마 입자들은 동일한 작업 부하를 수용하지 못하게 된다. 이러한 작업 부하의 불일치는 리딩 에지 입자들에 대한 마모 속도를 증가시키고, 중심에 위치한 입자들의 소모 이전에 드레서를 쓸모없게 만들 수 있다.

입자 보유와 관련하여, 두가지 요인들이 연마 입자들로 하여금 선행 기술의 패드 드레서 디스크로부터 제거되기 쉽게 한다. 첫째, 제거는 종종 연마 입자들이 부착되었던 열등한 방법으로 인하여 발생한다. 전기도금된 니켈 또는 그밖의 다른 기저에 놓인 물질들에 의해서만 기판에 지지된 연마 입자들은 약한 기계적 힘에 의하여만 확보되며, 어떤 형태의 화학적 결합에 의하여도 확보되지 않는다. 그러므로, 이러한 입자들은 마찰력과 같은 강한 기계적 힘에 노출될 때 용이하게 제거되게 된다. 더욱이, 입자 제거는 화학물질 슬러리에 의하여 제공되는 전기도금 물질에 대한 화학적 공격에 의해 촉진된다.

대조적으로, 연마 입자들이 기판 위에 브레이징 될 때, 화학적 결합은 입자들을 더욱 견고하게 지지한다. 그러나, 화학물질 슬러리의 산은 브레이즈-입자 결합들을 급속하게 약하게 하며, 패드 드레싱의 마찰력 하에서 연마 입자들을 제거하게 할 수 있다. 그러므로, 화학물질들에 대한 브레이즈의 노출을 최소화하고 패드 드레서의 가용 수명을 연장하기 위하여, 연마 공정들은 드레싱이 발생하는 동안 정지되어야 한다. 결과적으로 연마 및 그 이후 드레싱을 교대시키는 연쇄는 시간을 낭비시키며, 비효율적이다.

브레이징 공정 동안 패드 드레서 작업 표면의 뒤틀림 또한 종종 연마 입자들을 제거되게 한다. 브레이징 공정 동안 패드 드레서는 상당한 고온에 노출되어야 한다. 이러한 극도의 열에 대한 노출은 패드 드레서의 작업 표면을 뒤틀리게 할 수 있으므로, 패드 드레서 작업 표면의 매끄러움 및 평면성을 손상시킨다. 결과적으로, 작업 표면의 브레이즈 부분은 거칠게 되며,

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높고 낮은 지점들을 가지게 될 것이다. 이러한 지점들은 바람직하지 않은데, 왜냐하면 이들은 브레이즈를 조각조각 떨어지기 시작하도록 만들 수 있으며, 피가공물의 연마된 표면에 미세-긁힘을 만들 수 있다. 또한, 이러한 울퉁불퉁함은 드레서의 또다른 가공, 및 연마 입자 보유력과 관련하여 문제점을 유발할 수 있다.

전술한 관점에서, 최대의 효율성 및 수명을 가지며 최적의 드레싱 결과를 구현하기 위하여 제작되고 구성된 CMP 패드 드레서가 계속하여 요구되고 있다.

발명의 요약

따라서, 한 양태에서, 본원 발명은 CMP 패드를 드레싱 하는 동안 CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 대한 작업 부하를 증가시키기 위한 방법 및 CMP 패드 드레서 구조물을 제공한다. 이러한 한 방법에서, 각각이 기판 부재에 연결되고 예정된 패턴에 따라 특정 위치에 지지된 복수의 초연마 입자들을 가지는 CMP 패드 드레서가 제공된다. 초연마 입자들은 둘레에 위치한 입자들의 CMP 패드 내부로의 침투는 감소시키고 중심에 위치한 입자들의 CMP 패드 내부로의 침투는 증가시키는 패턴으로 배열될 수 있으므로, 중심에 위치한 초연마 입자들에 대하여 가해지는 작업 부하를 최적화 시킬 수 있다. 일반적으로, 입자들은 단일 결정 또는 다결정질 형태의 다이아몬드, 또는 입방정 질화 붕소 (cBN)와 같은 초경질 물질들이다.

본원 발명의 한 구체예에서, 중심에 위치한 초연마 입자들에 대한 작업 부하를 증가시키는 방법은 둘레에 위치한 입자들의 작업 말단으로부터 중심에 위치한 입자들의 작업 말단까지 상향인 기울기를 제공하는 패턴으로 배열된 초연마 입자들을 보유하는 기판을 가지는 CMP 패드 드레서의 이용을 포함한다. 또한, 이용되는 기울기의 정확한 각도는 중심에 위치한 입자들이 부담하는 작업 부하를 제어하도록 형성될 수 있다. 이러한 기울기는 다양한 방식으로 생성될 수 있다. 예를 들면, 한 양태에서, 기울기는 실질적으로 편평한 기판 위에 또는 내부에 초연마 입자들을 배치함으로써 생성될 수 있는데, 여기서 기판의 작업 표면위의 초연마 입자들의 높이는 둘레에 위치한 입자들로부터 중심에 위치한 입자들을 향하여 증가한다. 몇몇 경우에, 바람직한 기울기 각도는 패드 속도(velocity) 및 패드 가요성의 측정으로서 결정될 수 있다.

본원 발명의 또다른 바람직한 구체예에서, 중심에 위치한 입자들에 대한 작업 부하를 증가시키는 방법은 중심에 위치한 입자들보다 더 높은 밀도로 둘레에 위치한 초연마 입자들을 배치하는 패턴으로 기판에 결합된 복수의 초연마 입자들을 가지는 CMP 패드 드레서를 제공하는 것을 포함할 수 있다. 더 높은 밀도로 밀집된 입자들은 서로 더 먼 간격으로 밀집된 입자들만큼 깊게 패드 내부로 침투할 수 없음이 발견되었다. 그러므로, 기판 상의 입자들의 밀도를 변화시킴으로써 작업 부하는 한 부위에서 다른 부위로 이전될 수 있다.

또한 본원 발명의 또다른 구체예에서, 중심에 위치한 입자들에 대한 작업 부하를 증가시키는 방법은 중심에 위치한 입자들을 둘레에 위치한 입자들의 애티튜드(attitude)에 의해 제공되는 침투보다 CMP 패드 내부로 더 높은 입자 침투를 유발시키는 애티튜드로 배향시킴으로써 구현될 수 있다. 한 양태에서, 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에 꼭지점(apex)을 제공할 수 있으며, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에 면 또는 에지를 제공할 수 있다. 또다른 양태에서, 중심에 위치한 입자들의 애티튜드는 이들의 작업 말단에 에지를 제공할 수 있으며, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에 면을 제공할 수 있다. 또한 또다른 양태에서, 중심에 위치한 입자들의 애티튜드가 이들의 작업 말단에 꼭지점(apex)을 제공할 때, 둘레에 위치한 입자들의 애티튜드는 이들의 작업 말단에서 면을 제공할 수 있으며, 둘레에 위치한 입자들과 중심에 위치한 입자들 사이에 위치한 입자들의 애티튜드는 이들의 작업 말단에 에지를 제공할 수 있다. 상기 언급된 사용 방법 이외에도, 본원 발명은 또한 중심에 위치한 초연마 입자들에서 증가된 작업 부하를 보여주는 CMP 패드 드레서를 제공하는 방법을 포함한다. 일반적으로 말하면, 이러한 방법은 다음 단계들을 포함한다: 1) 기판을 제공하는 단계; 및 2) 둘레에 위치한 입자들의 CMP 패드 내부로의 침투는 감소시키고 중심에 위치한 입자들의 CMP 패드 내부로의 침투는 증가시키는 패턴으로 복수의 초연마 입자들을 기판 위에 부착하는 단계.

상기 설명된 방법을 사용하여, 상당한 이점들을 보이는 CMP 패드 드레서를 제조할 수 있다. 예를 들면, CMP 패드 드레서의 작업 표면은 외부 또는 이들의 "리딩 에지"를 지나치게 접촉하기 보다는 드레서의 중심 이하의 부분에서 CMP 패드의 접촉을 증가시키기 위하여 배열될 수 있다. 이러한 중심 접촉의 증가는 드레서의 둘레부로부터 드레서의 중심부로 작업 부하의 일부를 이전시키므로, 드레서의 사용 수명을 길게하고 드레서로 하여금 패드를 더욱 효과적으로 절삭 및 그루밍(grooming)할 수 있게 한다. 상기 배열을 결합시킨 CMP 패드 드레서는 본원 발명에 포함되며, 상기 언급된 방법들을 뒷받침하기 위하여 이루어진 특정 구조를 가지는 CMP 패드 드레서들도 포함한다.

본원 발명의 상기 언급된 특징들 및 이점들은 첨부된 도면 및 다음의 상세한 설명을 참고하면 더욱 자명해질 것이다.

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발명의 상세한 설명

발명의 상세한 설명

본원의 CMP 패드 드레서 및 수반되는 사용 및 제조 방법을 개시하고 설명하기에 앞서, 본원 발명은 본원에 개시된 특정 공정 단계들 및 물질들에 제한되는 것이 아니라, 관련 분야의 통상의 당업자가 인식하게 되는 이들의 균등물에까지 확장됨을 이해하여야 한다. 또한 본원에서 사용되는 용어는 단지 특정 구체예들을 설명하기 위하여 사용되는 것이며 제한하기 위하여 사용되되는 것이 아님을 이해하여야 한다.

본원 명세서 및 첨부된 청구항에서 사용되는, 단수형들 "하나" 및, "그것"은 명확하게 다른 언급이 없으면 복수형을 포함함을 알아두어야 한다. 그러므로, 예를 들면, 하나의 "연마 입자" 또는 "그릿"이라는 언급은 하나 또는 그 이상의 연마 입자들 또는 그릿들에 대한 언급을 포함한다.

정의

본원 발명을 설명하고 청구함에 있어서, 아래 설명된 정의에 따라 다음의 용어가 사용될 것이다.

본원에서 사용되는, "연마 입자" 또는 "그릿" 또는 유사한 용어들은 초경질의 결정질 또는 다결정질 물질, 또는 이들 물질들의 혼합물을 의미하며, 다이아몬드, 다결정질 다이아몬드 (PCD), 입방정 질화 붕소, 및 다결정질 입방정 질화 붕소 (PCBN)를 포함하나, 이에 제한되는 것은 아니다. 또한, "연마 입자", "그릿", "다이아몬드", "다결정질 다이아몬드 (PCD)", "입방정 질화 붕소" 및 "다결정질 입방정 질화 붕소(PCBN)" 의 용어들은 호환적으로 사용될 수 있다.

본원에서 사용되는, "기판"은 연마 입자들을 지지하는, 그리고 연마 입자들이 고정될 수 있는, CMP 드레서의 일부를 의미한다. 본원 발명에서 유용한 기판들은 의도한 목적에 유용한 공구를 제공하기에 충분한 방식으로 연마 입자들을 지지할 수 있는, 임의의 형상, 두께 또는 물질일 수 있다. 기판들은 고체 물질, 가공시 고체가 되는 분말 물질, 또는 가요성 물질일 수 있다. 전형적인 기판 물질들의 예에는 금속, 금속 합금, 세라믹, 및 이들의 혼합물을 포함하나, 이에 제한되는 것은 아니다. 또한 기판은 브레이징 합금 물질을 포함할 수 있다.

본원에서 사용되는, "착업 표면"은 작업하는 동안 위를 향하는, 또는 CMP 패드와 접촉하게 되는 CMP 패드 드레서의 표면을 의미한다.

본원에서 사용되는, "리딩 에지"는 CMP 패드가 움직이는 방향에 기초하여, 또는 패드가 움직이는 방향에 기초하여, 또는 이들 모두에 기초하여 전두 에지인 CMP 패드 드레서의 에지를 의미한다. 특히, 몇몇 양태에서, 리딩 에지는 특정하게 드레서의 에지 부위를 포함할 뿐만 아니라, 또한 실제 에지로부터 약간 안쪽으로 연장하는 드레서의 일부들을 포함할 수 있는 것으로 생각된다. 한 양태에서, 리딩 에지는 CMP 패드 드레서의 외부 에지를 따라 위치될 수 있다. 또다른 양태에서, CMP 패드 드레서는 CMP 패드 드레서 작업 표면의 중심 또는 내부 부분 위에 적어도 하나의 효과적인 리딩 에지를 제공하는 연마 입자들의 패턴으로 형성될 수 있다. 다시 말하면, 드레서의 중심 또는 내부 부분은 드레서의 외부 에지 위에 리딩 에지의 효과와 유사한 기능적 효과를 제공하도록 형성될 수 있다.

본원에서 사용되는, "날카로운 부분"은 결정이 올 수 있는 협소한 부분을 의미하며, 코너, 융기, 에지, 오벨리스크, 및 그밖의 다른 돌출부들을 포함하나, 이에 제한되는 것은 아니다.

본원에서 사용되는, "중심에 위치한 입자"는 통상의 드레싱 환경하에서 둘레에 위치한 입자에 비하여 감소된 작업 부하를 수용하는 드레서의 입자를 의미한다. 몇몇 양태에서, "중심" 또는 "중심에 위치한"이란 드레서의 중심 지점에서 시작하여 드레서 에지를 향해 바깥쪽으로 드레서 직경의 최대 약 90%까지 연장하는 영역을 의미한다. 몇몇 양태에서, 상기 영역은 반경의 약 20% 내지 약 90%까지 바깥쪽으로 연장할 수 있다. 그밖의 다른 양태에서, 상기 영역은 반경의 약 50%까지 연장할 수 있다. 또한 또다른 양태에서, 상기 영역은 드레서 반경의 약 33%까지 연장할 수 있다.

본원에서 사용되는, "둘레에 위치한"이란 통상적인 드레싱 환경하에서 중심에 위치한 입자들에 비하여 과다한 작업 부하를 수용하는 드레서의 입자를 의미한다. 몇몇 양태에서, "둘레의" 또는 "주변의" 또는 "둘레에 위치한"이란 드레서의 리딩 에지 또는 외부 가장자리에서 시작하여 드레서 직경의 최대 약 90%까지 중심을 향하여 안쪽으로 연장하는 영역을 의미할 수

있다. 몇몇 양태에서, 상기 영역은 반경의 약 20% 내지 90%까지 안쪽으로 연장할 수 있다. 그밖의 다른 양태에서, 상기 영역은 반경의 약 50%까지 연장할 수 있다. 또한 또다른 양태에서, 상기 영역은 드레서 직경의 약 33%까지 연장할 수 있다 (즉, 중심으로부터 66% 떨어짐).

본원에서 사용되는, "작업 부하"란 드레서를 사용하는 동안 드레서에 있는 입자들에 가해지는 작업량 또는 힘의 양을 의미한다.

본원에서 사용되는, "작업 말단"이란 CMP 패드를 향하여 배향되고 드레싱 작업을 하는 동안 패드와 접촉하는 입자의 말단을 의미한다. 거의 대부분 입자의 작업 말단은 입자가 부착되는 기판으로부터 말단이 될 것이다.

본원에서 사용되는, "비정질 브레이즈"란 비-결정질 구조를 가지는 균질의 브레이즈 조성물을 의미한다. 이러한 합금은 가열시 부조화 용융하는 공융상을 실질적으로 전혀 함유하지 않는다. 비록 간결한 합금 조성물을 확보하기 어렵지만, 본원에서 사용되는 비정질 브레이징 합금은 좁은 온도 범위에 걸쳐 실질적으로 조화용융 거동을 보여야 한다.

본원에서 사용되는, "합금"이란 제 2 물질과 금속의 고체 또는 액체 혼합물을 의미하며, 상기 제 2 물질은 탄소와 같은 비-금속, 금속, 또는 금속의 성질을 향상 또는 개선시키는 합금이 될 수 있다.

본원에서 사용되는, "금속 브레이징 합금," "브레이징 합금," "브레이즈 합금", "브레이즈 재료" 및 "브레이즈"는 호환적으로 사용될 수 있으며, 초연마 입자들, 및 매트릭스 지지 재료 또는 기판을 서로 실질적으로 결합시키기 위하여 화학적으로 결합할 수 있는 금속 합금을 의미한다. 본원에 개시된 특정 브레이즈 합금 성분들 및 조성물은 이와 관계되어 개시된 특정 구체예에 제한되는 것이 아니며, 본원에 개시된 본원 발명의 어떠한 구체예에서도 사용될 수 있다.

본원에서 사용되는, "브레이징" 공정은 초연마 입자들의 탄소 원자들과 브레이즈 재료 사이의 화학적 결합 생성을 의미하는 것으로 간주된다. 또한, "화학적 결합"이란 기계적 인력 또는 그보다 약한 원자 내부의 인력이라기 보다는, 탄화물 또는 보라이드 결합과 같은 공유 결합을 의미한다. 그러므로, "브레이징"이 초연마 입자들과 관련하여 사용되는 경우, 진정한 화학적 결합이 형성되는 것이다. 그러나, "브레이징"이 금속 대 금속 결합과 관련하여 사용되는 경우, 이 용어는 더욱 전형적인 야금학적 결합의 의미로 사용된다. 그러므로, 공구 몸체에 대한 초연마 세그먼트의 브레이징은 탄화물 형성제의 존재를 요하지 않는다.

본원에서 사용되는, "초연마 입자들" 및 "초연마 그릿들"은 호환적으로 사용될 수 있으며, 천연 또는 인공 다이아몬드, 초경질 결정질, 또는 다결정질 물질, 또는 물질들의 혼합물의 입자들을 의미하며, 다이아몬드, 다결정질 다이아몬드 (PCD), 입방정 질화 붕소 (CBN), 및 다결정질 입방정 질화 붕소 (PCBN)를 포함하나, 이에 제한되는 것은 아니다. 또한, "연마 입자", "그릿", "다이아몬드", "PCD", "CBN" 및 "PCBN"이란 용어들은 호환적으로 사용될 수 있다.

브레이징 공정과 관련하여 본원에서 사용되는, "직접적으로"란 결합 매질로서 단일 브레이징 금속 또는 합금을 사용하여 초연마 입자들 및 동일한 재료 사이에 화학적 결합의 형성을 의미하는 것으로 간주된다.

본원에서 사용되는, "돌기"란 다양한 표면 분석의 특성들에 의하여 평가된 표면의 거칠음을 의미한다. 다양한 측정들은 피크 높이 또는 그 위의 돌출, 및 밸리의 깊이 또는 그 내부에 함몰하는 함몰부와 같은 표면 돌기의 지표로서 사용될 수 있다. 더욱이, 돌기의 측정치에는 주어진 표면 영역 내부의 피크 또는 밸리의 수 (즉, 피크 또는 밸리 밀도), 및 피크들 또는 밸리들 사이의 거리가 포함될 수 있다.

본원에서 사용되는, "세라믹"이란 비-금속 물질, 때때로 금속 물질과 함께 연소함에 의해 제조될 수 있는, 상당히 내열성이며 내식성인, 경질의, 때때로 결정질의 재료를 의미한다. 세라믹으로 고려되는 수많은 산화물, 질화물, 및 탄화물 재료들이 당해 분야에 잘 알려져 있으며, 산화 알루미늄, 산화 알루미늄, 산화 규소, 질화 붕소, 질화 규소, 및 탄화 규소, 탄화 텅스텐, 등이 포함되나, 이에 제한되는 것은 아니다.

본원에서 사용되는, "금속성"이란 임의의 타입의 금속, 금속 합금, 또는 이들의 혼합물을 의미하며, 구체적으로는 강(스틸), 철, 및 스테인레스 강이 포함되나, 이에 제한되는 것은 아니다.

본원에서 사용되는, "격자"는 복수의 사각형을 형성하는 선들의 패턴을 의미한다.

거리 및 크기와 관련하여 본원에서 사용되는, "균일한"이란 전체 약 75 마이크로미터 미만으로 상이한 크기를 의미한다.

본원에서 사용되는, "Ra"란 피크 및 이웃하는 밸리 사이의 높이차로 결정되는 표면 조도의 측정치를 의미한다. 또한, "Rmax"는 표면 위에서 가장 높은 피크와 표면에서 가장 낮은 밸리 간의 높이차로 결정되는 표면 조도의 측정치이다.

콘센트레이션, 양, 및 그밖의 다른 수치 데이타는 본원에서 범위 형식으로 표현되거나 나타내어질 수 있다. 이러한 범위 형식은 단순히 편의 및 간결함을 위해 사용되는 것이므로, 범위의 한계로 명확히 언급되는 수치 값들 뿐만 아니라, 그 범위 내에 포함되는 모든 개개의 수치 값들 또는 하위-범위들도 마치 각각의 수치 값 및 하위-범위가 명확히 언급된 것처럼 포함되는 것으로 해석되어야 함을 이해하여야 한다.

설명하자면, "약 1 마이크로미터 내지 약 5 마이크로미터"의 수치 범위는 약 1 마이크로미터 내지 약 5 마이크로미터 중 명확히 언급된 수치들 뿐만 아니라, 지시된 범위에 속하는 개별적인 수치들 및 하위-범위들도 포함되는 것으로 해석되어야 한다. 그러므로, 상기 수치 범위에는 2, 3, 및 4와 같은 개개의 수치들 및 1-3, 2-4, 및 3-5, 등과 같은 하위-범위까지도 포함된다. 이와 동일한 원리가 단 하나의 수치 값을 언급하는 범위들에도 적용된다. 더욱이, 이러한 해석은 설명되는 범위의 폭 및 특성들에 관계없이 적용되어야 한다.

발명

출원인은 CMP 패드 컨디셔닝 또는 드레싱의 효율성과 품질을 개선하기 위한 장치 및 방법들을 발견하였다. CMP 패드를 컨디셔닝 또는 드레싱 하기 위한 장치를 사용함으로써, 패드 수명이 연장될 뿐만 아니라, 또한 패드가 사용될 수 있는 항구성, 및 그리하여 장치가 구현하는 장치의 작업 속도가 개선된다.

이제 도 1을 참고하면, 선행 기술의 CMP 패드 드레서(10)이 도시되는데, 이것은 기판 (40)에 전기도금된 복수의 연마 입자들(50)을 가진다. 전기도금 재료(60)는 일반적으로 산 용액으로부터 침전된 니켈이다.

기판에 연마 입자들 (50)을 부착하기 위하여 전기도금 재료(60)만을 사용하는 CMP 패드 드레서는 도 1에 도시된 바와 같이 자명한 많은 결점들을 가진다. 첫째, 전기도금 재료는 연마 입자들과 화학적 결합을 형성할 수 없다. 그러므로, 단지 약한 기계적 힘들이 기판(40) 상에서 연마 입자들을 지지한다. 패드 드레서가 CMP 패드를 대면하여 회전되는 경우, 이러한 기계적 힘들은 연마 입자들에 작용하는 마찰력에 의해 신속하게 극복된다. 결과적으로 연마 입자들은 전기도금 재료로부터 쉽게 헐거워져서, 전기도금 재료에 공간(70)과 같은 공극들을 남긴다. 이러한 공극들은 피가공물에서 연마되어 나온 잔여물 뿐만 아니라, 슬러리로부터 화학물질 및 연마 입자들로 신속히 채워진다. 이러한 물질들은 전기도금 재료를 화학적으로 공격하며 더욱 약화시킨다.

전기도금 재료(60)에 의해 생성된 기계적 힘은 기판(40) 위에 연마 입자들(50)을 지지시키는 단 하나의 수단이기 때문에, 연마 입자들 above the 전기도금 재료 위의 연마 입자들의 노출은 최소로 유지되어야 한다. 그럼에도 불구하고, 전기도금 재료와 CMP 패드 사이의 접촉은 필연적이다. 이러한 접촉은 전기도금 재료를 마모시키며, 연마 입자들의 방출을 더욱 촉진시킨다. 추가적으로, 제조하는 동안, 전기도금 재료는 볼록한 부분(80)과 같은 공간에서 연마 입자들 주위에 쌓이기 쉽다. 불가능한 것이 아니라면, 이미 낮은 노출 및 연마 입자들의 빽빽한 공간 이외에도 이러한 볼록한 부분들은 연마 입자들의 CMP 패드 섬유질 내부로의 상당한 침투를 어렵게 한다. 이러한 침투가 없다면, 드레싱 공정의 효과는 불리하다.

이제 도 2를 보면, 브레이징 재료(90) 및 전통적인 진공로 브레이징 기술을 사용하여 기판에 브레이즈된 연마 입자들(50)을 가지는 기판(40)을 구비한 선행 기술의 CMP 패드 드레서가 도시된다. 브레이징 재료(90)은 일반적으로 탄화물 형성제와 혼합된 금속 합금을 포함한다. 이러한 탄화물 형성제는 연마 입자들을 브레이징 재료에 화학적으로 결합할 수 있게 하여 순차적으로 기판과 결합할 수 있게 한다. 이러한 결합 배열은 CMP 드레서의 전체 강도를 현저히 증가시키지만, 몇가지 바람직하지 않은 부작용을 수반한다.

브레이징 재료(90)는 연마 입자들(50)을 완전히 커버하지 않도록 하기 위하여 최소로 유지되어야 한다. 그러므로, 연마 입자들은 브레이징 재료의 얇은 코팅만으로 감싸진다. 이러한 문제는 전형적인 브레이징 재료들이 기계적으로 너무 약하다는 사실에 의해 사화된다. 이러한 기계적 결함은 연마 입자들과 브레이징 재료 사이에 생성되는 화학 결합의 강도를 상쇄시킨다. 사실상, 연마 입자들과 브레이징 재료 사이의 화학 결합들은 떨어져 나간 연마 입자들과 함께 브레이징 재료 자체가 종종 전단되어 나가기에 충분히 강하다.

브레이징 재료(90)는 또한 연마 슬러리에 의한 화학적 공격에 매우 민감하다. 이는 연마 입자들(50)의 탈착에 기여하는데, 왜냐하면 연마 입자들의 탈착은 브레이징 재료를 더욱 약화시키기 때문이다. 화학물질 슬러리에 대한 CMP 패드 드레서

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(20)의 노출을 감소시키기 위하여, 피가공물의 연마는 중단되어야 하며, 화학물질 슬러리는 패드 드레서에 도포되기 전에 패드에서 제거되게 하여야 한다. 연마 공정에서 이러한 중단은 패드가 사용될수 있는 항구성을 현저히 감소시키고, 완제품을 제조하는데 필요한 시간을 증가시키므로, 비효율적이다.

연마 입자들(50)을 전통적인 브레이징만을 사용하여 기판(40)에 결합시키는 것에 대한 또다른 결점은 용융 금속 합금이 기판에 사용될 경우 연마 입자들의 "밀집"을 유발하기 쉽다는 것이다. 이러한 밀집은 (100)에 도시되는데, 의도하지 않은 공백(110)을 남긴다. 전체적인 효과는 연마 입자들의 비-균일한 분포이며, 이것은 그루밍(grooming)을 비효율적이게 한다. 또한, 공백들은 패드의 고르지않은 컨디셔닝을 유발하며, 이는 궁극적으로 CMP 패드의 특정 영역을 그밖의 다른 영역보다 더 빠르게 마모시키며, 전체적으로는, 마모된 영역들이 적절히 컨디셔닝된 영역 보다 덜 효과적으로 연마되기 때문에 피가공물이 고르지 않은 연마를 수용하게 되는 결과를 가져온다.

연마 입자들의 밀집은 브레이징 재료(90)에 둑을 형성함으로써 또다른 손실을 만든다. 둑 형성은 일부 연마 입자들을 기판(40) 위의 높이까지 상승하여 형성되며, 이것은 그밖의 다른 연마 입자들의 높이보다 더 높다. 그러므로, 가장 높이 돌출한 연마 입자들은 CMP 패드의 섬유질 내부로 매우 깊이 침투할 수 있으며, 그보다 덜 돌출한 연마 입자들이 CMP 패드를 접촉하지 못하게 하거나 유용한 그루밍 효과를 가지지 못하게 할 것이다.

선행 기술의 CMP 패드 드레서와 대조적으로, 본원 발명은 CMP 패드의 고른 드레싱을 가능하게 한다. 이제 도 3을 보면, 본원 발명의 원리에 따라 제조된 CMP 패드 드레서(30)이 도시되어 있다. CMP 패드 드레서는 브레이징 재료(90)을 가진 기판(40)에 결합된 복수의 연마 입자들(50)을 가진다.

연마 입자들(50)은 다양한 초경질 재료로 이루어질 수 있다. 이러한 재료의 예에는 다이아몬드, 다결정질 다이아몬드(PCD), 입방정 질화 붕소 (CBN) 및 다결정질 입방정 질화 붕소 (PCBN)가 포함되나, 이에 제한되는 것은 아니다.

추가적으로 도 3에는 최종 브레이징 공정 후에 처리되는 오버레이 재료층(120)이 도시된다. 상기 언급한 바와 같이, 오버레이는 브레이징 합금의 작업 표면보다 실질적으로 더 매끄러운 작업 표면을 제공한다. 이러한 매끄러움 및 평면성은 수많은 이점들을 제공하는데, 이 이점들에는 브레이즈를 조각조각 떨어뜨리는 것으로부터 미세-긁힘의 발생 감소 및 내식층이 포함되는 경우 내식층과 더 우수한 결합이 포함된다. 한 양태에서, 오버레이 재료의 작업 표면은 약 1 마이크로미터 미만의 Ra 값을 가질수 있다.

수많은 적절한 오버레이 재료가 사용될 수 있다. 그러나, 한 양태에서, 오버레이 재료들에는 주석, 니켈, 텅스텐, 코발트, 크롬, 및 지르코늄 니켈 합금과 같은 이들의 합금이 포함되나, 이에 제한되는 것은 아니다. 오버레이 재료는 다양한 방법들에 의해 처리될 수 있다. 오버레이 재료를 처리하는 방법들의 예에는 전기도금 및 물리적 증기 증착 (PVD)이 포함된다. 오버레이 재료층은 특수한 결과를 달성하기 위하여 필요한 두께일 수 있으나, 본원 발명의 한 양태에서, 오버레이 재료층은 약 0.1 내지 50 마이크로미터 두께의 두께를 가질 수 있다. 또다른 양태에서, 오버레이의 두께는 약 0.1 내지 약 5 마이크로미터일 수 있다.

또한 도 3에는 내식성 층(130)이 도시되어 있다. 선택적인 내식성 층은 연마 입자들(50)이 기판(40)에 고정된 후 CMP 패드 드레서의 표면 위에 형성된다. 한 양태에서, 내식성 층은 다이아몬드-형 탄소 (DLC), 또는 비정질 다이아몬드와 같은 초연마 재료일 수 있다. 한 구체예에서, 내식성 층은 약 80% 이상의 원자 탄소 함량을 가진다. 추가적으로, 내식성 층은 특수한 결과를 달성하기 위하여 필요한 다양한 두께를 가질 수 있으나, 일반적으로 그 두께는 0.5 내지 5 마이크로미터 범위이다. 한 양태에서, 내식성 층은 3 마이크로미터 미만의 두께를 가진다. 이러한 얇은 내식성 층은 CMP 패드 드레서의 작업 표면이 CMP 패드를 드레싱하는 연마 입자들의 능력을 감소시키지 않고 보호되는 것을 보장한다. 내식성 층은 일반적으로 물리적 증기 증착(PVD)법을 사용하여 제조된다. 흑연 양극과 함께 양극 아크를 사용하는 것과 같은 PVD 법은 일반적으로 당해 분야에 공지이다.

내식성 층(130)에 의해 제공되는 하나의 이점은 내식성 층이 작업 표면을 효과적으로 "밀폐"한다는 점이며, 또한 화학적 공격에 약할 수 있는, CMP 패드 드레서(30)의 그밖의 다른 표면들을 밀폐할 수 있다는 점이다. 밀폐제로서, 내식성 층은 CMP 패드 내부에 지지된 연마성 화학물질 슬러리에 의한 화학적 공격으로부터 브레이징 재료(90)를 보호한다. 이러한 보호는 CMP 패드 드레서로 하여금 즉석에서 CMP 패드를 드레싱할 수 있게 하며, 선행 기술의 CMP 패드 드레서의 가용 수명을 연장시키기 위하여 사용되는 제조 정지를 제거할 수 있게 한다. CMP 패드의 연속적이고 고른 드레싱은 더욱 많은 제조 작업 산출량을 가능하게 하며, CMP 패드의 수명 및 효율성을 연장시킨다.

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내식성 층(130)이 본원 발명의 몇몇 구체예에서 사용될 수 있으나, 오버레이 재료(120)는 그 자체로써 그리고 자연히 상당한 내식성을 가진다는 점이 두드러진다. 오버레이 재료만이 사용되고, 내식성 층이 사용되지 않는 경우, 이와 같은 많은 제조 이점들을 상당한 정도로 얻을 수 있다.

연마 입자들(180)을 기판에 고정시키는 한 가지 방법이 도 4-6에 도시된다. 먼저, 개구들(150)을 가지는 형판(140)이 브레이징 합금(190) 쉬트 위에 배치된다. 본원 발명의 한 양태에서, 브레이징 합금 쉬트는 연속적 비정질 브레이징 합금의 압연 쉬트일 수 있다. 또다른 양태에서, 브레이징 합금 쉬트는 결합제 재료와 함께 지지되는 브레이징 합금 분말일 수 있다. 또다른 양태에서, 브레이징 합금 분말에는 그밖의 다른 금속성 분말들이 포함될 수 있으며, 이러한 그밖의 다른 분말들은 브레이징 쉬트에서 재료의 대부분을 구성할 수 있다. 또한 또다른 양태에서, 쉬트는 기판으로서 기능하기에 충분할 수 있다. 형판의 사용은 개구들을 가지는 형판을 원하는 패턴으로 디자인함으로써 특정 위치에 각 연마 입자를 제어하여 배치할 수 있게 한다.

형판(140)이 브레이징 합금 쉬트(190) 위에 배치된 후, 개구들(150)은 연마 입자들(180)로 채워진다. 개구들은 오직 하나의 연마 입자 만이 각 개구에 채워지도록 예정된 크기를 가진다. 어떠한 크기의 연마 입자 또는 그릿이라도 사용할 수 있으나, 본원 발명의 한 양태에서, 입자 크기는 약 100 내지 약 350 마이크로미터 직경일 수 있다.

본원 발명의 또다른 양태에서, 형판에 있는 개구들의 크기는 균일한 크기 범위에 속하는 크기를 가지는 연마 입자들의 패턴을 얻기 위하여 주문제작될 수 있다. 한 구체예에서, 형판의 개구들은 50 마이크로미터 이하의 변화량을 가지는 크기 범위에 속하는 그릿들만을 선택하기에 충분하다. 이러한 그릿 크기의 균일성은 CMP 패드 그루밍의 균일성에 기여하는데, 이는 각각의 연마 입자의 작업 부하가 고르게 분포되기 때문이다. 순차적으로, 고른 작업 부하 분포는 개별적인 연마 입자들에 대한 응력(stress)을 감소시키고, CMP 패드 드레서의 유효 수명을 연장시킨다.

형판(150)의 개구들이 그릿들(180)로 모두 채워진 후, 과량의 연마 입자들이 제거되고, 편평한 표면(160)이 연마 입자들에 처리된다. 편평한 표면(160)은 브레이징 합금 쉬트(190) 내부로 연마 입자들을 내리누를 수 있도록 극히 강하고 단단한 재료여야 한다. 이러한 재료들에는 전형적으로 스틸, 철, 이들의 합금 등이 포함되나, 이에 제한되는 것은 아니다.

연마 입자들(180)은 도 6에서 브레이징 합금 쉬트(190)에 묻혀 있는 것으로 도시된다. 표면(160)이 편평하기 때문에, 연마 입자들은 기판으로부터, 예정된 균일한 높이까지 확장될 것이다. 이러한 균일한 높이는 T형판(140)의 두께에 의해 결정될 것이며, 바람직한 구체예에서, 각각의 연마 입자는 상기 거리의 50 마이크로미터 이내까지 확장할 것이다. 이와 같이, 각각의 연마 입자는 CMP 패드 상에서 실질적으로 동일한 깊이로 그루밍된다. 그러나, 어떠한 응용예에서는, 그릿 높이가 균일한 것이 바람직하지 않을 수도 있음을 알아두어야 한다. 이와 같이, 다양한 높이의 그릿 패턴들은 그러한 디자인을 제공하기 위해 형판(140) 및 표면(160)을 다양한 높이로 형성함으로써 제공될 수 있음을 당해 분야의 통상의 당업자들은 알고 있을 것이다. 예를 들면, 한 양태에서, 표면(160)은 둘레에 위치한 입자들을 중심에 위치한 입자들보다 더 아래로 가압하기 위하여 오목한 형상을 가질 수도 있다. 알 수 있는 바와 같이, 이러한 오목한 형상은, 둘레의 입자들의 작업 말단에서의 낮은 지점에서 시작하여 중심에 위치한 입자들의 작업 말단에서의 높은 지점까지 기울어지는, 연마 입자들을 위한 기울기를 제공할 것이다.

도 4-6에 도시된 연마 입자들(180)은 둥글다. 그러나, 도 3에서, 이들은 뾰족하다. 자형, 팔면체, 입방정 팔면체, 또는 천연적으로 형성된 입자들을 포함하여, 어떠한 형상의 연마 입자들이라도 본원 발명의 범위에 포함된다. 그러나, 한 구체예에서, 연마 입자들은 기판(40)으로부터 한 방향으로 뻗어나가는 뾰족한 지점 또는 꼭지점(apex)을 보유한 예정된 형상을 가진다.

다른 구체예에서, 연마 입자들(180)을 브레이징 합금 쉬트(190) 내부로 가압하기 보다는, 연마 입자들은 브레이징 합금 쉬트 표면 위에 접착제를 도포하여 형판에서와 같은 위치에 고정될 수 있다. 이러한 방식에서, 입자들은 형판이 제거되고 열처리되는 동안 제 위치에 고정된 채로 남는다. 또한 본원 발명의 또다른 구체예에서, 형판(140)은 그 위에 얇은 접착제를 보유한 전달 쉬트(도시되지 않음) 위에 놓일 수도 있다. 이러한 경우, 입자들은 상기 설명한 형판 절차를 사용하여 전달 쉬트에 부착되게 된다. 이후 형판은 제거되고, 전달 쉬트는 쉬트를 대면하는 연마 입자들과 함께 브레이징 쉬트(190) 위에 놓인다. 브레이징 쉬트위에 도포된 상기 접착제 층은 전달 쉬트 위의 접착제보다 훨씬 더 강한 접착제이다. 그러므로, 연마 입자들은 형판에 의해 지정된 패턴으로 브레이징 합금의 쉬트로 전달된다.

연마 입자들(180)이 브레이징 합금 쉬트(190) 내부에 적어도 부분적으로 묻히거나, 쉬트에 부착된 후, 쉬트는 도 3에 도시된 바와 같이 기판에 고정된다. 대안적으로 몇몇 구체예에서, 브레이징 합금 쉬트는 기판에 먼저 고정될 수 있으며, 연마 입자들은 본원에 설명된 형판 절차를 사용하여 후속적으로 브레이징 합금 쉬트에 추가된다. 사용되는 브레이징 합금은 당

해 분야에 공지된 어떠한 브레이징 재료일 수도 있으나, 한 양태에서, 2 중량% 이상의 크롬 함량을 가지는 니켈 합금일 수 있다. 이러한 조성의 브레이징 합금은 그 자체로 그리고 자연적으로 거의 초경질이 될 것이며, 연마제를 함유하는 슬러리로부터의 화학적 공격에 덜 민감할 것이다. 그러므로, 내식성 층(130), 및 오버레이 재료(120)는 선택적이다.

연마 입자들(50)이 브레이징 합금 쉬트(90) 안에 또는 위에 단단히 지지되기 때문에, 액체 브레이징 합금의 표면 장력은 도 2에서 도시된 바와 같은 입자 밀집을 유발하기에 불충분하다. 게다가, 브레이즈 농축은 훨씬 적은 정도로 발생하며, "둑(mound)"이 거의 또는 전혀 형성되지 않는다. 그보다, 브레이즈는 각 연마 입자 사이에 약간 오목한 표면을 형성하는데, 이는 추가적인 구조적 지지를 제공한다. 한 구체예에서, 브레이징 합금 쉬트(90)의 두께는 각 연마 입자의 적어도 약 10 내지 90%를 브레이징 재료(90)의 외부 또는 작업 표면 위로 돌출될 수 있도록 예정된다. 또다른 양태에서, 오버레이 재료(120)가 사용될 때, 연마 입자들은 각 연마 입자의 적어도 약 10 내지 약 90%가 오버레이 재료(120)의 외부 또는 작업 표면 위로 돌출될 수 있도록 선택되거나 배치될 수 있다.

가공하는 동안 연마 입자들(50)을 고정된 위치에 유지시키는 방법의 결과로서, 연마 입자들 사이에 고른 간격들이 형성될 수 있다. 게다가, 연마 그릿들은 기판(40) 위의 균일한 높이 또는 거리까지 확장할 수 있는데, 이는 CMP 패드에 적용될 때, 연마 그릿들은 패드 섬유질 내의 균일한 깊이까지 돌출하게 되는 것을 의미한다. 고른 간격 및 균일한 돌출은 CMP가 고르게 드레싱 또는 그루밍될 수 있게 하며, 이는 순차적으로 CMP 패드의 연마 효율성을 증가시키고, CMP 패드의 가용 수명을 연장시킨다. 연마 입자들을 브레이징 합금에 묻거나 부착시키는 상기 설명한 방법 이외에도, 당업자들은 연마 입자들을 기판에 고정시킨 후, 브레이즈를 그 위에 배치하는 것과 같은 적절한 대안 절차들을 알고 있을 것이다. 이러한 경우, 입자들은 상기 언급된 형판 방법을 사용하여 기판 위에 배치될 수 있으며, 아교, 또는 그밖의 다른 결합제에 의하여 제 위치에 지지될 수 있다. 이후 브레이즈 재료는 헹궈지거나, 연마 입자들 주위의 기판 위에 배치되고, 오버레이 재료가 첨가된다.

본원 발명은 상기 설명한 방법을 사용하여 생성될 수 있는 연마 입자 배치를 위한 널리 다양한 패턴들을 포함하지만, 본원 발명의 한 양태는 CMP 패드 드레서가 사용되는 특수한 필요성 및 조건들을 더욱 적절하게 충족시키는 특수한 예정 패턴의 인식물이다. 상기 패턴들을 구현하기 위하여, 각각의 그릿은 패턴 디자인에 따라 특수 위치에 배치되고 지지된다. 이러한 패턴들은 특수한 CMP 패드 드레싱 결과를 달성하기 위해 실제로 유용하며, 알 수 있는 바와 같이 특수한 그루밍 결과를 달성하기 위하여 다양해질 수 있다.

예를 들면, 많은 공지된 패드의 그루밍 결과는 그릿들을 특정한 배열로 배치함으로써 개선될 수 있다. 특히, CMP 패드가 가요성이기 때문에, 드레서에 의해 발생되는 하향 압력은 주어진 방향으로 움직이는 드레서의 리딩 에지와 패드가 접촉될 때 패드를 상승하게 또는 올려지게 한다. 상승하는 작용은 연마 입자들과 더 최대의 접촉을 가능하게 하기 때문에 드레서의 리딩에지에서 패드의 드레싱을 개선시킬 수 있지만, 이는 또한 드레서의 리딩 에지 아래 이미 통과된 패드 부분에서는 침적 작용을 유발할 수 있다. 심지어 어떠한 침적도 전혀 발생하지 않는다 하더라도, 패드는 일단 드레서 아래에서 다시 한 번 상승할 수 있게 되지 않기 때문에, 일반적으로 리딩 에지 후방에 있는 드레서 잔여 부분의 드레싱 작용은 리딩 에지의 드레싱 작용보다 덜 효과적이다 (즉, 연마 입자들의 첫번째 열은 드레서, 또는 회전하는 CMP 패드, 또는 모두의 방향성 거동에 의해 지정된 바에 따라 패드와 직면됨). 이와 같이, 드레싱 작업 부담의 대부분이 드레서의 리딩 에지에 있는 연마 입자들에 배치되며, 고르지 않은 입자 마모가 발생한다.

각 입자의 침투 깊이는 주로 두 개의 요인, 즉, 다른 입자들로부터의 분리 거리 및 돌출 높이에 의해 제어된다. 성긴 간격의 입자들은 빽빽하게 밀집된 입자들보다 더욱 공격적으로 드레싱 할 것이다. 그러므로, 본원 발명의 한 양태에서, 연마 입자들의 패턴은 내부 또는 중심 위치(즉, 리딩 에지에 후속하는 위치)에서 드레서 아래에 있는 동안 CMP 패드를 상승하게 하고, 그리하여 입자들이 리딩 에지의 연마 입자들에 후속하는 연마 입자들에 의해 드레싱되도록 배열될 수 있다. 실제로, 이러한 배열은 드레서의 작업 표면을 따라 리딩 에지의 다양성을 제공한다. 다시 말하면, 둘레에 있는 입자들은 중심에 위치한 입자들의 밀도 보다 더 큰 밀도를 가진다. 둘레의 입자들의 밀도는 중심 입자들의 밀도보다 적어도 약 1.25, 2, 또는 5배 더 클 수 있다. 또한 밀도는 둘레의 입자들에서 높고 중심 입자들에서 낮은 구배가 될 수 있다. 이러한 방식에서, 다양한 밀도들은 CMP 패드가 패드 드레서의 중심 부분 아래에 있는 동안 CMP 패드를 상승하게 하고, 드레싱 효율을 증가시킨다. 알게 되는 바와 같이, 다양한 입자 배열 또는 패턴들은 상기 작용들을 구현하는데 필요한 연마 입자들의 간격을 제공할 수 있으며 특수하게 필요로하는 드레싱 결과를 달성하기 위하여 사용될 수 있다.

도 7에서 실시예로서 설명되는 바와 같이, 본원 발명의 한 양태에서, 연마 입자들은 패드 드레서(30)의 리딩 에지(200)를 따라서만 배치된 연마 입자들을 가지기 위하여 배열될 수 있다. 이제 도 8을 보면, 본원 발명의 또다른 양태에서, 연마 입자들은 중심(210)에서 보다 리딩 에지(200)을 따라 더 고도로 밀집되도록 (즉 더 큰 밀도를 가지도록) 배열될 수 있다. 대조적으로, 본원 발명의 또다른 양태에서, 연마 입자들은 리딩 에지를 따라서 보다는 중심에 더 많이 밀집되도록 배열될 수 있다 (도시되지 않음). 또한 또다른 양태에서, 입자들은 둘레에 있는 입자들 보다는 패드 드레서의 중심 부분에서 더 많은 밀집도로 배열되어 분포될 수 있다. 또한, 중심 및 둘레 부분들 사이에 위치한 입자들은 중심 부분과 둘레 부분의 밀도 사이

의 밀도를 가지도록 배열된다. 이제 도 9를 보면, 본원 발명의 또다른 양태에서, 연마 입자들은 전술한 패드 상승을 가능하게 하기에 충분한, 각 입자들 사이의 간격으로 균일하게 분포되도록 배열될 수 있다. 한 양태에서, 균일하게 분포된 입자들은 격자를 형성할 수 있으며, 각 개별적인 그릿 크기의 약 1.5 내지 약 10배의 거리로 고르게 간격지어 질 수 있다. 당업자가 알게 되는 바와 같이, 연마 입자들은 또한 콘센트레이션에 있어서 리딩 에지로부터 CMP 패드 드레서의 중심을 향하여 증가하거나 감소하는 다양한 콘센트레이션 구배로 배열될 수 있다 (도시되지 않음).

또다른 구체예에서, 본원 발명은 드레서를 구비한 CMP 패드의 드레싱을 하는 동안 CMP 패드 드레서에서 중심에 위치한 초연마 입자들에 대한 작업 부하를 증가시키는 방법을 제공한다. 상기 방법은 둘레에 위치한 입자들의 CMP 패드 내부로의 침투는 감소시키고 중심에 위치한 입자들의 CMP 패드 드레서 내부로의 침투는 증가시키는 패턴으로 초연마 입자들을 배열한다. 몇몇 양태에서, 초연마 입자들은 예정된 패턴에 따라 CMP 패드 기판위의 특수한 위치에 각각 개별적으로 배치된다. 중심에 위치한 입자들에 대한 작업 부하는 둘레에 위치한 입자들의 작업 부하의 적어도 약 10% 내지 약 30% 이내까지 증가될 수 있다. 또한 작업 부하는 둘레의 입자들 또는 모든 입자들의 작업 부하와 실질적으로 동일할 수 있다.

중심에 위치한 입자들에 대한 작업 부하를 증가시키는 것은 여러가지 방식으로 구현될 수 있다. 예를 들면, 초연마 입자들은, 도 10에 도시된 바와 같이, 둘레의 입자들의 작업 말단으로부터 중심 입자들의 작업 말단을 향하여 상향의 기울기를 제공하는 패턴으로 배열될 수 있다. 작업 부하를 증가시키는 또다른 방법은, 상기 설명한 바와 같이, 중심에 위치한 입자들의 밀도보다 더 높은, 둘레에 위치한 입자들의 밀도를 제공하는 패턴으로 초연마 입자들을 고정시키는 것이다. 마지막으로, 도 11에 도시된 바와 같이, 상기 패턴은 둘레에 위치한 입자들의 애티튜드에 의해 제공되는 침투보다 CMP 패드 내부로 더 큰 입자 침투를 유발하는 애티튜드를 중심에 위치한 입자들에 제공하도록 배열될 수 있다.

도 10을 참고하면, 본원 발명은 둘레의 초연마 입자들(320)로부터 중심에 위치한 입자들(310)을 향하여 상향의 기울기(305)를 가지는 초연마 입자들에 결합된 기판(300)을 제공함으로써 중심에 위치한 초연마 입자들에 대한 작업 부하를 증가시키는 CMP 패드 드레서를 제공한다. 상향의 기울기는 둘레에 위치한 입자들로부터 중심에 위치한 입자들 쪽으로 입자 높이를 증가시킴으로써 생성될 수 있다. 결과적으로, 상향의 기울기는 중심의 입자들과 CMP 패드에 더욱 큰 접촉을 제공함으로써 작업 부하를 둘레의 입자들로부터 중심의 입자들로 전달한다. 증가된 접촉은 CMP 패드의 드레싱 및 패드 컨디셔너의 총 마모를 개선시킨다. 기울기는 패드 속도(velocity) 및 패드 가요성의 측정으로서 결정된다. 일반적으로, 패드는 패드가 리딩 에지 입자들과 접촉될 때 함몰하는 변형가능한 매질이다. 통상적으로, 패드의 함몰은 패드의 가요성 및 패드의 회전속도에 따라 증대될 것이다. 본원 발명의 바람직한 구체예에서, 기울기는 약 0.1% 내지 0.5%이며, 바람직하게는 기울기는 0.2%이다.

대안으로서, 기울기는 기판의 배열을 변형시킴으로써 얻어질 수 있다. 도 10에 도시된 바와 같이, CMP 패드 드레서의 기판은 실질적으로 편평하나, 몇몇 양태에서, 기판은 회전하는 CMP 패드의 함몰에 맞게 변형하기 위해 윤곽지어질 수 있다. 이러한 윤곽은 연마 입자들(310 및 320)의 작업 말단에 필요한 기울기를 제공할 수 있다. 이러한 경우, 기판 작업 표면 위의 입자들의 높이는 실질적으로 균일할 것이다. 기판은 통상적으로 금속성, 세라믹, 또는 가요성 재료로 제조된다. 한 구체예에서, 기판은 스테인레스 강일 수 있다. 몇몇 양태에서, 기판은 가공시에 고체로 되는 분말화된 재료일 수 있다. 또다른 양태에서, 분말은 크롬과 같은, 약 2 중량% 이상의 양의 탄화물 형성 원소와 조합된 니켈과 같은 금속의 브레이징 합금을 포함할 수 있다. 몇몇 양태에서, 기판은 본질적으로 브레이징 재료로 구성될 수 있다.

도 11은 CMP 패드를 드레싱하는 동안 CMP 패드 드레서의 중심에 위치한 입자들에 대한 작업 부하를 증가시키는 CMP 패드 드레서의 도시이다. 연마 입자들은 입자들의 애티튜드에 따라 상이한 속도로 마모한다. 일반적으로, 꼭지점(apex)의 애티튜드는 CMP 패드 내부로 더 많은 침투를 제공할 것이며 그밖의 다른 애티튜드 보다 더욱 공격적으로 그루밍할 것이다. 면의 애티튜드를 가지는 입자는 최소량의 침투를 제공하며, 패드를 드레싱함에 있어서 가장 적은 공격성을 띤다. 애티튜드로서 에지를 가지는 입자는 중간 정도의 그루밍 및 침투 특성을 제공한다. 도 11을 참고하면, 기판(400)은 복수의 초연마 입자들(410, 420, 430)을 예정된 패턴으로 수용한다. 패턴은 패드 드레서의 둘레에 위치한 입자들의 애티튜드에 의해 제공되는 침투보다 더 높은 입자 침투를 CMP 패드 내부로 유발하는 애티튜드를 중심에 위치한 입자들에 제공하도록 배열된다. 중심에 위치한 초연마 입자들(410)은 입자들의 작업 말단(405)에 꼭지점(apex)을 제공하는 애티튜드로 배향된다. 이러한 입자들은 패드를 더욱 공격적으로 다듬으며, 그밖의 다른 입자들에 의해 제공되는 애티튜드보다 더 큰 정도의 침투를 가진다. 둘레의 입자들(420)은 이들의 작업 말단에서 에지 또는 면(430)을 제공하는 애티튜드로 배향될 수 있다. 특히, 도 11의 구체예에서 도시된 바와 같이, 중심에 위치한 입자들은 이들의 작업 말단(405)에서 꼭지점(apex)을 제공하는 애티튜드로 배향되고, 둘레의 입자들의 애티튜드(430)는 이들의 작업 말단(405)에서 면이며, 이들 사이의 입자들(420)은 이들의 작업 말단에서 에지를 제공하는 애티튜드로 배향될 수 있다. 그러나, 그밖의 다른 전형적인 구체예에서, 둘레의 입자들과 중심의 입자들 사이에 위치한 입자들은 다른 유형 중 하나와 동일할 것이다. 하나의 추가 구체예에서 (도시되지 않음), 중심에 위치한 입자들은 이들의 작업 말단에 에지를 제공하는 애티튜드로 배향될 수 있으며, 둘레에 위치한 입자들은 이들의 작업 말단에 면을 제공하는 애티튜드로 배향될 수 있다.

상기 언급한 방법 및 장치들 이외에도, 본원 발명은 본원에 설명된 CMP 패드 드레서의 제조 방법을 제공한다. 한 양태에서, 이러한 방법은 기판을 제공하는 단계 및 둘레에 위치한 입자들의 CMP 패드 내부로의 침투를 감소시키고 중심에 위치한 입자들의 CMP 패드 내부로의 침투를 증가시키는 패턴으로 초연마 입자들을 기판에 부착하는 단계를 포함한다.

산업상 이용 가능성

수많은 변형 및 수정이 본원 발명의 원리 및 범위에서 벗어나지 않고 당업자에 의하여 고안될 수 잇으며, 첨부된 청구항들은 이러한 변형 및 배열을 뒷받침하는 것으로 간주된다. 그러므로, 가장 실용적이고 바람직한 본원 발명의 구체예로 생각되는 것과 관련하여 본원 발명을 특수하고 상세하게 상기와 같이 설명하였으나, 본원에 설명된 원리 및 개념에서 벗어나지 않고 크기, 재료, 형상, 형태, 기능, 작업 방식, 조합, 및 용도의 변화(이에 제한되는 것은 아님)를 포함한, 수많은 변형이 이루어질 수 있음이 당업자에게는 자명할 것이다.

도면의 간단한 설명

도면의 간단한 설명

도 1은 본원 발명의 한 구체예에 따른 디스크 기판에 연마 입자들을 고정시키기 위하여 전기도금법을 사용하는 선행 기술의 CMP 패드 드레서의 측면도이다.

도 2는 디스크 기판에 연마 입자들을 고정시키기 위하여 전통적인 브레이징법을 사용하여 제조된 선행 기술의 CMP 패드 드레서의 측면도이다.

도 3은 본원 발명의 한 구체예에 따라 제조된 CMP 패드 드레서의 측면도이다.

도 4는 본원 발명의 한 구체예에 따라, 브레이징 합금 쉬트의 표면위에 연마 입자들을 배치하기 위한 형판을 구비한 브레이징 합금 쉬트의 측면도이다.

도 5는 브레이징 합금 쉬트의 표면에 형판을 구비한 브레이징 합금 쉬트의 측면도이며, 연마 입자들이 형판의 개구들을 채우고 있다. 본원 발명의 한 구체예에 따라 편평한 표면은 브레이징 합금 쉬트 내부로 연마 입자들을 가압하는데 사용하기 위하여 도시되어 있다.

도 6은 본원 발명의 한 구체예에 따라 브레이징 합금 쉬트 내부로 가압된 연마 입자들을 가지는 브레이징 합금 쉬트의 측면도이다.

도 7은 본원 발명의 한 구체예에 따라, 실질적으로 오직 드레서의 리딩 에지를 따라서 연마 입자들이 존재하도록 기판에 결합된 연마 입자들을 가지는 CMP 패드 드레서의 작업 표면의 평면도이다.

도 8은 본원 발명의 한 구체예에 따라, 중심에서 보다 리딩 에지에서 더 많은 입자들이 존재하도록 기판에 결합된 연마 입자들을 가지는 CMP 패드 드레서의 작업 표면의 평면도이다.

도 9는 본원 발명의 한 구체예에 따라, 입자들이 두루 균일하게 분포되도록 기판에 결합된 연마 입자들을 가지는 CMP 패드 드레서의 작업 표면의 평면도이다.

도 10은 본원 발명의 한 구체예에 따라 제조된 CMP 패드 드레서의 측면도이다.

도 11은 본원 발명의 한 구체예에 따라 제조된 CMP 패드 드레서의 측면도이다.

도면

도면1

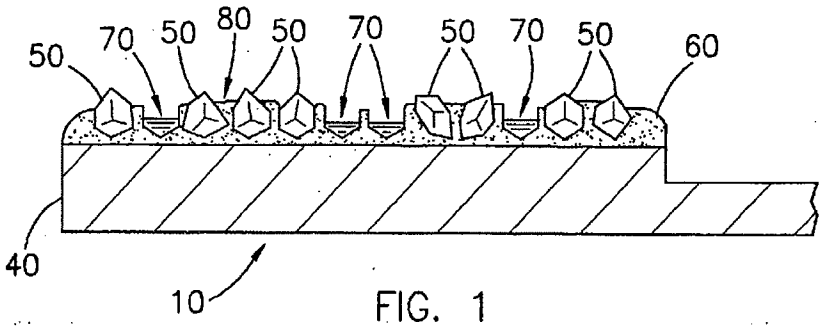


FIG. 1
(PRIOR ART)

도면2

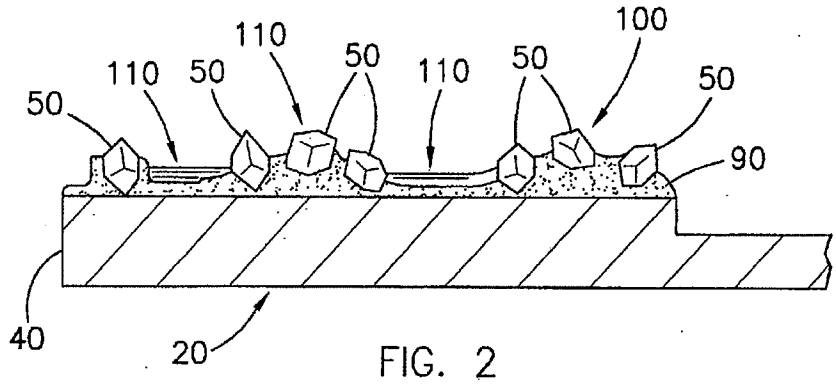


FIG. 2
(PRIOR ART)

도면3

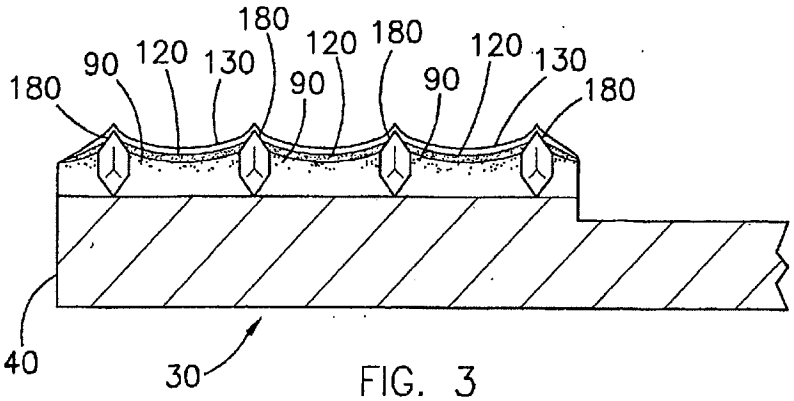
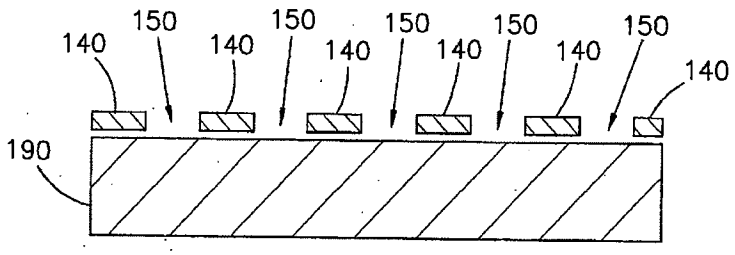
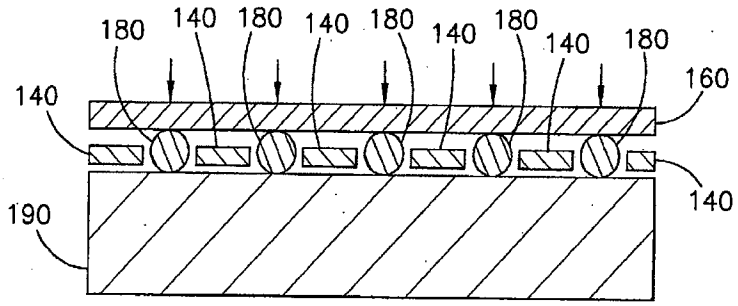


FIG. 3

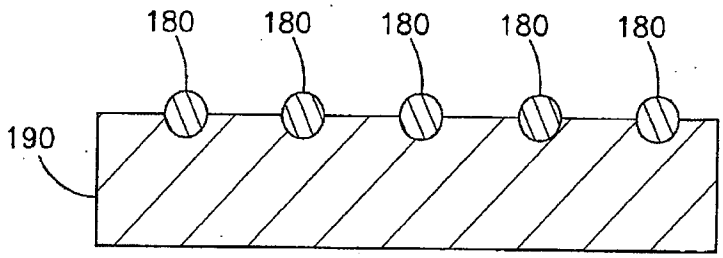
도면4



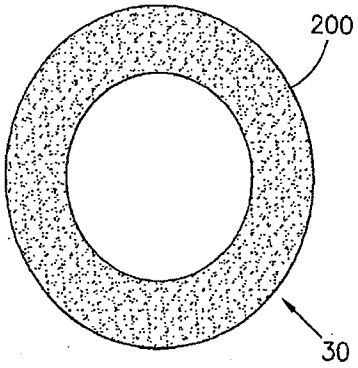
도면5



도면6



도면7



Ex. 1003, Page 197

도면8

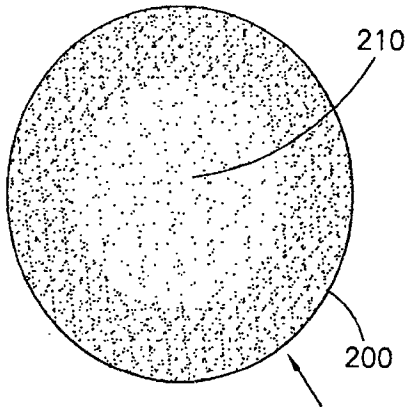


FIG. 8

도면9

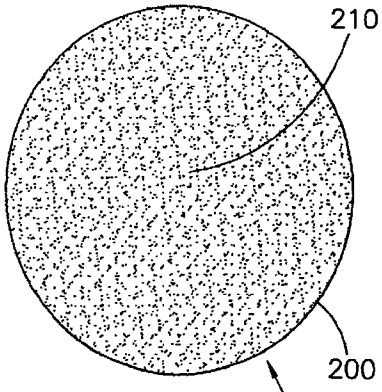


FIG. 9

도면10

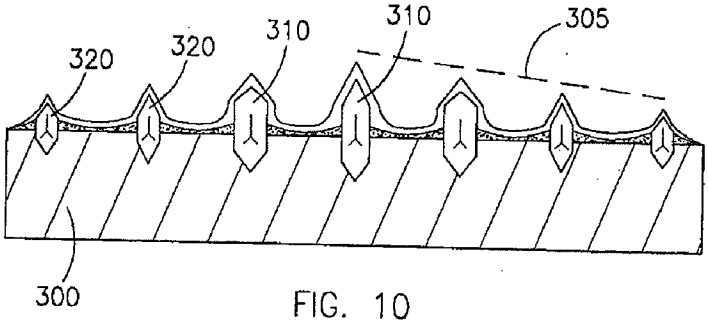
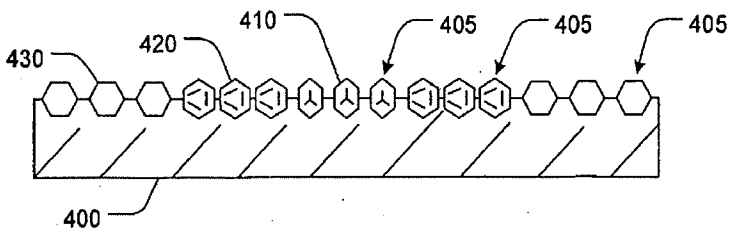


FIG. 10

도면11



Electronic Acknowledgement Receipt

EFS ID:	17204538
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/eileen fuessel
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	23-OCT-2013
Filing Date:	23-MAY-2012
Time Stamp:	13:10:16
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Foreign Reference	kr138.pdf	1099615 839367cfa03ad84f74e9abd48d79f30434980d5d	no	23

Warnings:	
Information:	

2	Foreign Reference	kr569.pdf	1373578 e2e093d38bfbf5d187e5223b20afa6ac42a8208f	no	23

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Total Files Size (in bytes):	2473193

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2001/0046835	11/2001	Wielonski et al.	
		2002/0139680	10/2002	George	
		2010/0022174	01/2010	Chou et al.	
		2010/0248595	09/30/2010	Dinh-Ngoc et al	
		2012/0241943	09/27/2012	Sung	
		2307461	01/1943	Ogden	
		6692547	02/2004	Kim	
		7494404	02/2009	Sung	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		KR 10/2007/0063569	06/19/2007	Sung		
		KR 10/2002/0036138	05/16/2002	Kinik Co.		

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1] Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

PLUS Search Results for S/N 13479148, Searched Thu Mar 27 15:49:03 EDT 2014

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20130165023 92
20120244790 69
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20010046835 59
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7901272 56
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The Patent Linguistics Utility System (PLUS) is a USPTO automated search system for U.S. Patents from 1971 to the present PLUS is a query-by-example search system which produces a list of patents that are most closely related linguistically to the application searched. This search was prepared by the staff of the Scientific and Technical Information Center, SIRA.

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20020173234 45

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

20551 7590 05/15/2014

THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

EXAMINER	
NGUYEN, GEORGE BINH MINH	
ART UNIT	PAPER NUMBER
3723	

NOTIFICATION DATE	DELIVERY MODE
05/15/2014	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

causse@tnw.com
patentdocket@tnw.com
rich@tnw.com

Office Action Summary	Application No. 13/479,148	Applicant(s) SUNG, CHIEN-MIN	
	Examiner GEORGE NGUYEN	Art Unit 3723	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address --

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-27* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-27* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *5/23/2012* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date *10/23/2013;06/20/2013;03/22/2013;02/01/2013;01/03/2013;11/06/2012*.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

The present application is being examined under the pre-AIA first to invent provisions.

DETAILED ACTION

Claims 1-27 are presented for examination.

Receipt is acknowledged of the IDS filed on October 23, 2013; June 20, 2013; March 22, 2013; February 01, 2013; January 03, 2013; November 6, 2012 which have been considered and placed of record in the file.

This application has been filed with formal drawings which are acceptable to the examiner.

Claim Rejections - 35 USC § 112

The following is a quotation of 35 U.S.C. 112(b):
(b) CONCLUSION.—The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the inventor or a joint inventor regards as the invention.

The following is a quotation of 35 U.S.C. 112 (pre-AIA), second paragraph:
The specification shall conclude with one or more claims particularly pointing out and distinctly claiming the subject matter which the applicant regards as his invention.

Claims 1-9 and 24 are rejected under 35 U.S.C. 112(b) or 35 U.S.C. 112 (pre-AIA), second paragraph, as being indefinite for failing to particularly point out and distinctly claim the subject matter which the inventor or a joint inventor, or for pre-AIA the applicant regards as the invention.

In claim 1, lines 5-9, the claimed limitations of " the protrusion difference between the highest 1% of the protruding tips are within **80 microns or less**" are unclear because how the highest 1% is determined. And it does not make sense that the protrusion difference of 80 microns is more than "the difference in protrusion distance between the

highest protruding tip and the second highest protruding tip of the monolayer of superabrasive particles is less than or equal to about **50 microns**". Therefore, the scope of the claim is unascertainable which renders the claim indefinite.

Claims 2-9 are also rejected because of their dependency on rejected claim 1.

In re claim 24, the step of "removing the adhesive transfer sheet … monolayer of superabrasive particles" render the claim indefinite because the abrasive particles are stuck on the adhesive transfer sheet; then if the adhesive transfer sheet is removed and the abrasive particles are also removed. Therefore, what is there to form the monolayer.

Claim Rejections - 35 USC § 102

The following is a quotation of the appropriate paragraphs of pre-AIA 35 U.S.C. 102 that form the basis for the rejections under this section made in this Office action:

> A person shall be entitled to a patent unless –
>
> (b) the invention was patented or described in a printed publication in this or a foreign country or in public use or on sale in this country, more than one year prior to the date of application for patent in the United States.

Claims 14-15, 20, 25, 26 are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by Dinh-Ngoc et al.'2010/0248595.

In re claim 14 , Dinh-Ngoc et al.'595 discloses A method of making a CMP pad dresser, comprising: disposing a first monolayer of superabrasive particles on a metal support layer; disposing a second monolayer of superabrasive particles on the metal support layer on a side opposite the first monolayer, wherein the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer; and bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the

metal support layer such that symmetrical forces due to the substantially similar distribution between the first monolayer and the second monolayer precludes substantial warping of the metal support layer ([0075-0076], Figs. 2A, such **symmetry having superior flatness and working surface distortion height with respect to layers of abrasive grains #221 and #223 reads on precludes substantial warping**).

In re claim 15, Dinh-Ngoc et al.'595 discloses wherein the bonding of at least one of the first monolayer and the second monolayer is by brazing with a braze material ([0061]).

In re claim 20, Dinh-Ngoc et al.'595 discloses wherein the superabrasive particles of the second monolayer are positioned to substantially align with the superabrasive particles of the first monolayer ([0076], **symmetry**).

In re claim 25, Dinh-Ngoc et al.'595 discloses a method of minimizing warpage of a CMP pad dresser during manufacture, comprising: substantially equalizing warping forces on opposing sides of a metal support layer during bonding of a plurality of superabrasive particles thereto, wherein warpage of the support layer is minimized during bonding due to the equalized forces on opposing sides ([0075-0076], Figs. 2A, such **symmetry having superior flatness and working surface distortion height with respect to layers of abrasive grains #221 and #223 reads on equalizing warping forces ... on opposing sides**).

In re claim 26, Dinh-Ngoc et al.'595 discloses wherein substantially equalizing forces includes arranging the plurality of superabrasive particles on opposing sides of the support layer such that the plurality of superabrasive particles has substantially the

same distribution on either side of the support layer to substantially equalize warping forces during bonding ([0076], **symmetry**).

Claim Rejections - 35 USC § 103

The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under pre-AIA 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.

2. Ascertaining the differences between the prior art and the claims at issue.

3. Resolving the level of ordinary skill in the pertinent art.

4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

Claims 1-9 and 27, as best understood, are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dinh-Ngoc et al.'2010/0248595.

In re claim 1, Dinh-Ngoc et al.'595 discloses a CMP pad dresser, comprising: a matrix layer #201/#203; a monolayer of a plurality of superabrasive particles #221 embedded in the matrix layer, wherein each superabrasive particle in the monolayer protrudes from

the matrix layer, and wherein the difference in protrusion distance #215 between the highest protruding tip #213 and the second highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 50 microns ([0075-0076], Figs. 2A, **flatness even not greater than 0.005cm or 50 microns**).

However, Dinh-Ngoc et al.'595 does not disclose the difference in protrusion distance between the highest 1% of the protruding tips of the monolayer of superabrasive particles are within about 80 microns or less.

Nevertheless, Dinh-Ngoc et al.'595 does show different tip levels in Fig. 2A.

Therefore, regarding to the protrusion difference range set forth in the claims, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have utilized the range set forth in the claims, since it has been held that where the general conditions of a claim are discloses in the prior art, discovering the optimum or workable ranges involves only routine skill in the art.

In re claims 2, 3, 4, 5, Dinh-Ngoc et al.'595 does show different tip levels in Fig. 2A.

Therefore, regarding to the protrusion difference range set forth in the claims, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have utilized the range set forth in the claims, since it has been held that where the general conditions of a claim are discloses in the prior art, discovering the optimum or workable ranges involves only routine skill in the art.

In re claim 6, Dinh-Ngoc et al.'595 discloses further comprising a rigid support #301 coupled to the matrix layer #205/#223 (Fig. 3).

In re claim 7, Dinh-Ngoc et al.'595 discloses a circular pad conditioner in Figs. 12B-C. However, Dinh-Ngoc et al.'595 does not disclose annular configuration as set forth in the claims. Nevertheless, the particular configuration of the annular configuration is anything more than one of numerous configurations a person of ordinary skill in the art would find obvious for purpose of providing conditioning surfaces for the particular shape of the part being worked on. In re Dailey, 149 USPQ 47 (CCPA 1976).

In re claims 8-9, the claimed limitations are apparently disclosed in the reference. In re claim 27, Dinh-Ngoc et al.'595 does show different tip levels in Fig. 2A. Therefore, regarding to the protrusion difference range set forth in the claims, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have utilized the range set forth in the claims, since it has been held that where the general conditions of a claim are discloses in the prior art, discovering the optimum or workable ranges involves only routine skill in the art.

Claims 16-18 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dinh-Ngoc et al.'895 in view of Goers'7,198,553.

In re claim 16, Dinh-Ngoc et al.'895 has been discussed above, but does not disclose heat and pressure as set forth in the claim.

Nevertheless, Goers'553 discloses a method of forming an abrasive article #2 including arranging abrasive particles #6 in the matrix material #8, and applying heat and pressure to the mixture to cause the corrosion resistant powder to sinter (Figs. 1-2, col. 6, lines 30-67). The advantage of heat and pressure bonding step is to have

abrasive particles remained affixed to the substrate #4 over extended periods of operation under adverse operating conditions (col. 2, lines 13-15).

Thus, it would have been obvious to one skilled in the art at the time the invention was made to have modified Dinh-Ngoc et al.'895 bonding step with a heat and pressure bonding step as taught by Goers'553 to have abrasive particles remained affixed to the substrate #4 over extended periods of operation under adverse operating conditions (col. 2, lines 13-15).

In re claim 17, Goers'553 discloses wherein the bonding of at least one of the first monolayer and the second monolayer further includes: disposing a sintering compound on the metal support layer in contact with at least one of the first monolayer and the second monolayer (col. 7, lines 10-25, stainless steel powder; and sintering the sintering compound to bond the at least one of the first monolayer and the second monolayer to the metal support layer (col. 7, (1), stainless steel become sintered).

In claim 18, Goers'553 discloses further comprising infiltrating the sintering compound with a braze material during bonding (col. 7, line 19-25, (3) and (4)).

Claims 19 and 24, as best understood, is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dinh-Ngoc et al.'895 in view of Tselesin'5,380,390.

In re claim 19, Dinh-Ngoc et al.'895 has been discussed above, but does not disclose the step of heat and pressure monolayer directly to the metal layer support.

Nevertheless, Tselesin'390 discloses a method of making patterned abrasive article including step of utilizing adhesive transfer sheet #10B and template #14 to form

patterned abrasive particles on the adhesive transfer sheet, and transferring said patterned abrasive particles on the adhesive transfer sheet on preform #15. And pressure is exerted by the opposed plates #16. When the pressure is exerted on the assembly, the particles #14 will be urged into the preform. One might force the particles #14 completely into the preform so the particles are totally surrounded by the matrix material, or one might leave a portion of the particles protruding from the preform. this is a matter of design choice depending on the particular use of the resulting abrasive material (Fig. 3, col. 4, lines 36-69). Subsequent treatment with heat and/or pressure will complete the abrasive material (Abstract).

Thus, it would have been obvious to one skilled in the art at the time the invention was made to have modified Dinh-Ngoc et al.'895 with step of directly bonds the abrasive layer to the metal support layer as taught by Tselesin'390 in order to yield a predictable abrasive article depending on the particular use of the resulting abrasive articles (col. 4, line 54-55)

In re claim 24, Tselesin'390 discloses a method of making patterned abrasive article including step of utilizing adhesive transfer sheet #10B and template #14 to form patterned abrasive particles on the adhesive transfer sheet, and transferring said patterned abrasive particles on the adhesive transfer sheet on preform #15 (Fig. 3, col. 4, lines 36-69).

Double Patenting

The nonstatutory double patenting rejection is based on a judicially created doctrine grounded in public policy (a policy reflected in the statute) so as to prevent the unjustified or improper timewise extension of the "right to exclude" granted by a patent and to prevent possible harassment by multiple assignees. A nonstatutory double patenting rejection is appropriate where the claims at issue are not identical, but at least one examined application claim is not patentably distinct from the reference claim(s) because the examined application claim is either anticipated by, or would have been obvious over, the reference claim(s). See, e.g., *In re Berg*, 140 F.3d 1428, 46 USPQ2d 1226 (Fed. Cir. 1998); *In re Goodman*, 11 F.3d 1046, 29 USPQ2d 2010 (Fed. Cir. 1993); *In re Longi*, 759 F.2d 887, 225 USPQ 645 (Fed. Cir. 1985); *In re Van Ornum*, 686 F.2d 937, 214 USPQ 761 (CCPA 1982); *In re Vogel*, 422 F.2d 438, 164 USPQ 619 (CCPA 1970); and *In re Thorington*, 418 F.2d 528, 163 USPQ 644 (CCPA 1969).

A timely filed terminal disclaimer in compliance with 37 CFR 1.321(c) or 1.321(d) may be used to overcome an actual or provisional rejection based on a nonstatutory double patenting ground provided the reference application or patent either is shown to be commonly owned with this application, or claims an invention made as a result of activities undertaken within the scope of a joint research agreement. A terminal disclaimer must be signed in compliance with 37 CFR 1.321(b).

The USPTO internet Web site contains terminal disclaimer forms which may be used. Please visit http://www.uspto.gov/forms/. The filing date of the application will determine what form should be used. A web-based eTerminal Disclaimer may be filled

out completely online using web-screens. An eTerminal Disclaimer that meets all requirements is auto-processed and approved immediately upon submission. For more information about eTerminal Disclaimers, refer to http://www.uspto.gov/patents/process/file/efs/guidance/eTD-info-I.jsp.

Claims 10, 14-23, and 25-26 are provisionally rejected on the ground of nonstatutory double patenting as being unpatentable over claims 1, 12, 13, 14, 15, 16, 17, 18, 20, 21 of copending Application No. 13/239,198. Although the claims at issue are not identical, they are not patentably distinct from each other because they are not patentably distinct from each other because the subject matter of the application claims is fully disclosed in the patent application and covered by copending claims. The copending claims are inclusive for they are drafted using the "comprising-style" format and cover the subject matter of the application claims. Since application claims has obtained the right to exclude others from making or using the subject matter set forth in the claims of this application by virtue of the copending claims, the issuance of the application into the patent without a terminal disclaimer as provided for under 37 CFR section 1.321 (b) would amount to an extension of this right.

This is a provisional nonstatutory double patenting rejection because the patentably indistinct claims have not in fact been patented.

Conclusion

The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Please see PTO-892.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to GEORGE NGUYEN whose telephone number is (571)272-4491. The examiner can normally be reached on Monday -Friday from 8 AM-4 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Hail Joseph can be reached on 571-272-4485. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

George Nguyen
Primary Examiner
Art Unit 3723

/GEORGE NGUYEN/
Primary Examiner, Art Unit 3723

Notice of References Cited	Application/Control No. 13/479,148	Applicant(s)/Patent Under Reexamination SUNG, CHIEN-MIN	
	Examiner GEORGE NGUYEN	Art Unit 3723	Page 1 of 2

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*	E	US-5,492,771 A	02-1996	Lowder et al.	428/565
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*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
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	P					
	Q					
	R					
	S					
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	Examiner GEORGE NGUYEN	Art Unit 3723	Page 2 of 2

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Complete if Known	
Application Number	13/479,148
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First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		PCT/US2012/039199; filed 05/23/2012; Chien-Min Sung; International Search Report dated 12/18/2012	
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		U.S. Application 12/168,110; filed 07/05/2008; Chien-Min Sung; notice of allowance dated 01/18/2013	

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		U.S. Application 12/726,786; filed 03/18/2010; Chien-Min Sung; notice of allowance dated 09/04/2013	

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CONFIRMATION NO. 7248

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/479,148	05/23/2012	451	3723	02074-24012.NP

APPLICANTS

INVENTORS

Chien-Min Sung, Tansui, TAIWAN;

**** CONTINUING DATA ***************************

This appln claims benefit of 61/489,074 05/23/2011

**** FOREIGN APPLICATIONS ***************************

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06/04/2012

Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and Acknowledged /GEORGE BINH MINH NGUYEN/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		TAIWAN	2	27	5

ADDRESS

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P.O. Box 1219
SANDY, UT 84091-1219
UNITED STATES

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Complete if Known	
Application Number	13/416,201
Filing Date	3/9/2012
First Named Inventor	Chien-Min Sung
Art Unit	1731
Examiner Name	
Attorney Docket Number	00802-T5100.CIP9

		US Application 13/239,198; filing date 09/21/2011; Chien-Min Sung	
		US Application 13/416,201; filing date 03/09/2012; Chien-Min Sung	
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Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		U.S. Application 12/255,823; filed 10/22/2008; Chien-Min Sung; notice of allowance dated 12/26/2012	

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U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2010/0261419	10/14/2010	Chien-Min Sung	
		2007-0266639	11/22/2007	Chein-Min Sung	
		2010/0248595	09/30/2010	Dinh-Ngoc	

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Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		JP 2007-044823	02/22/2007	Soken		

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		6196911	03/2001	Preston et al.	
		2010/0203811	08/2010	Phillipossian et al.	

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Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

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Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		U.S. Application 12/726,786; filed 03/18/2010; Chien-Min Sung; office action dated 03/19/2013	
		U.S. Application 13/362,917; filed 01/31/2012; Chien-Min Sung; office action dated 04/10/2013	

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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	Art Unit
	GEORGE NGUYEN	3723

CPC- SEARCHED		
Symbol	Date	Examiner
B24b53/12;53/017	5/9/2014	GN

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
451	443,444,548,56,	5/9/2014	GN
51	295,309	5/9/2014	GN

SEARCH NOTES		
Search Notes	Date	Examiner
Inventor search	5/9/2014	GN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

	/GEORGE NGUYEN/ Primary Examiner.Art Unit 3723

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
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S17	672	first near2 monolayer near2 second	US-PGPUB;	OR	OFF	2013/07/16

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			11:42
S18	81761	rigid near2 support	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:43
S19	0	S17 with S18	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:43
S20	341	sung-chien-min.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:47
S24	655	b24b53/07.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:04
S25	3143	b24b53/017.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:07
S26	608	451/443.ccls.	USPAT	OR	OFF	2014/02/24 11:31
S27	331	451/444.ccls.	USPAT	OR	OFF	2014/02/24 11:34
S28	912	451/548.ccls.	USPAT	OR	OFF	2014/02/24 11:37
S29	1838	b24b53/12.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:40
S34	6	("20040203325" | "20070266639" | "20100203811" | "20100248595" | "20120241943" | "6196911").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/02/25 09:10
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S40	1203	tip adj (level leveling)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:42
S41	113033	"451"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:43

S42	8	S40 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:43
S43	14761	"51"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:52
S44	3	S40 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:53
S45	1212	tip adj (level leveling leveled)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:54
S46	8	S45 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:54
S47	59	protrusion adj difference	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 13:42
S48	4102	heat near2 pressure near2 bonding	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 13:59
S49	9	S48 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:00
S50	263	sintering adj compound	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	OFF	2014/05/07 14:05

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S51	3	S50 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:06
S52	4	S50 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:06
S53	1160	adhesive near2 transfer near2 sheet	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 15:46
S54	12	S53 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 15:46
S55	971	aperture near2 template	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:09
S56	0	S53 with S55	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:10
S57	0	S53 same S55	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:10
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EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S21	608	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S22	53464	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S23	1	S21 same S22	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S30	635	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38
S31	55259	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38
S32	19881	(superabrasive abrasive) adj particles	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:39
S33	1	S30 same S31 same S32	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:39

5/9/2014 8:56:13 AM
C:\Users\gnguyen\Documents\EAST\Workspaces\13479148.wsp

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Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 2008/0014845 A1	01/17/2008	Yimaz et al.	
		US 2009/0094902 A1	04/16/2009	Hou	
		US 2011/0104989 A1	05/05/2011	Boutaghou et al.	
		US 2013/0225052 A1	08/29/2013	Song et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature		Date Considered	

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Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

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		US Application 13/407,634; filing date 02/28/2012; Chien-Min Sung; office action dated 06/13/2014	

Examiner Signature		Date Considered	

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Electronic Acknowledgement Receipt

EFS ID:	19563004
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	11-JUL-2014
Filing Date:	23-MAY-2012
Time Stamp:	20:35:26
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	80789 a0986d4438cd22ce2d7482cc3d9d0c2f5264b58c	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	106050 41571c3ada02d85b3ac91ab7eb196ed17e7ffc7b	no	1
Warnings:					
Information:					
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3	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	77672 939867ff20846a8105eeeb70c05f1272e4881a8f	no	1
Warnings:					
Information:					
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4	Non Patent Literature	OAJune132014.pdf	1219527 c6ab327c0249609ed2db6aa3ba08af7575d5c327	no	31
Warnings:					
Information:					
		Total Files Size (in bytes):	1484038		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: George Nguyen FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: July 11, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☐ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☒ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

☒ 37 C.F.R. § 1.704(d), within 30 days of receipt of a first citation in any communication from a patent office in a counterpart foreign or international application or from the Office, in accordance with 37 C.F.R. § 1.97 and 1.98.

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☒ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☒ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement

meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 11th day of July, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
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Sandy, Utah 84091-1219
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First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 6159286	12/2000	Sung	
		US 5919084	07/1999	Powell, et al.	
		US 2004/0238946	12/2004	Tachibana, et al.	
		US 2008/0296756	12/2008	Koch, et al.	
		US 7791188	12/2008	Sung	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		CN 1351922	06/05/2002	China Emerg Wheel Entpr. Co. Ltd.		
		CN 1494984	05/12/2004	Read Co. Ltd		
		EP 0238434	03/1987	United Tech. Corp.		
		EP 0264674	09/30/1987	Norton Christensen, Inc.		
		EP 0280657	08/31/1988	Diabrasive International		
		EP 0331344	02/1989	Minnesota Mining and Manuf		
		EP 0712941	05/22/1996	Agency of Ind. Sci. & Tec		
		GB 2239011	06/1991	Anthony et al.		
		JP 06182184	07/1994	Sumitomo Electric Industires		
		JP 10128654	05/1998	Toshiba Corp.		
		JP 10180618	07/1998	Nippon Kokan KK		
		JP 11048122	02/1999	Hitachi Ltd.		
		JP 11077536	03/1999	Asahi Diamond Ind.		
		JP 2000343436	12/12/2000	Noritake Diamond Ind. Co. Ltd.		
		JP 2000167774	06/20/2000	Toho Titanium Co. Ltd.		

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		JP 2003/071718	03/12/2003	Nippon Steel Corp.		
		JP 2004/025401	01/29/2009	Airtec Japan KK		
		KR 200339181	01/31/2004	Jang		
		WO 95/27596	10/1995	Ultimate Abrasive System		
		WO 94/27883	12/08/1994	Zeller Plastik Keehan Graebner DE		
		WO 96/06732	03/07/1996	Roberts		
		WO 98/10897	03/1998	Norton Company		
		WO 98/45091	10/15/1998	Sung		
		WO 98/45092	10/15/1998	Sung		
		WO 98/51448	03/1998	Norton Company		
		WO 02/31078	04/2002	Fries		
		WO 2004/094106	11/04/04	Intel Corporation		
		WO2006/124792	11/23/2006	Sung		
		WO 2007/032946	03/22/2007	Sung		
		WO2008/063599	05/29/20078	Sung		

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NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		U.S. Application 13/239, 189; filed 09/21/2011; Chien-Min Sung; office action dated 12/21/2012	
		U.S. Application 12/059,422; filed 03/31/2008; Chien-Min Sung; office action dated 01/24/2013	
		U.S. Application 13/153,176; filed 06/03/2011; Chien-Min Sung; office action dated 12/06/2013	

Examiner Signature		Date Considered	

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(19) Europäisches Patentamt
European Patent Office
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(11) Publication number: **0 238 434**
A2

(12) # EUROPEAN PATENT APPLICATION

(21) Application number: **87630036.9**

(22) Date of filing: **19.03.87**

(51) Int. Cl.[4]: **C 23 C 24/00**

(30) Priority: **21.03.86 US 842591**

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(84) Designated Contracting States:
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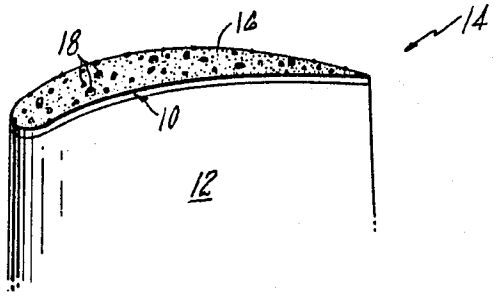
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L-1015 Luxembourg (LU)

(54) **Method for depositing a layer of abrasive material on a substrate.**

(57) Techniques are described for the formation of an abrasive surface layer (14) on an article (12). The surface layer (14) is characterized by a single layer of particles (18) which are evenly spaced apart, in a high density arrangement, within a metallic matrix (16). In the deposition of the particles (18) on the article (12), a vacuum is drawn through a perforated plate (42), wherein the location of each perforation (44) corresponds to the desired location of one particle (18) on the article surface (11). The vacuum holds one particle (18) over each perforation (44) in the plate (42), then the plate (42) is positioned over the article (12) and the vacuum level adjusted so that the particles (18) fall onto the article (12). The matrix (16) is then deposited by plasma arc spraying a superalloy powder. The invention is particularly suited to the formation of an abrasive layer on the tip surface of a blade used in a gas turbine engine.

FIG. 1



EP 0 238 434 A2

Description

Method for Depositing a Layer of Abrasive Material on a Substrate

Cross Reference

This invention is related to the copending and commonly assigned application "Abrasive Surface Coating Process for Superalloys", U.S. Serial No. 624,446, to Eaton et al, filed June 25, 1984.

Technical Field

The present invention relates to a method for depositing particulate material on a substrate. More specifically, it relates to a method for depositing a surface layer containing spaced apart abrasive particulate on the tip surface of a turbine engine component.

Background

Gas turbine engines and other turbomachines have rows of rotating blades contained within a generally cylindrical base. As the blades rotate, their tips move in close proximity to the case. To maximize engine operating efficiency, the leakage of the gas or other working fluid around the blade tips should be minimized. As has been known for some time, this may be achieved by blade and sealing systems in which the blade tips rub against a seal attached to the interior of the engine case. Generally, the blade tip is made to be harder and more abrasive than the seal; thus, the blade tips will cut into the seal during those portions of the engine operating cycle when they come into contact with each other.

One type of blade tip is described in U.S. Patent No. 4,249,913 to Johnson et al, entitled "Alumina Coated Silicon Carbide Abrasive", of common ownership herewith. In the Johnson et al invention, silicon carbide abrasive particles of 0.20-0.76 mm average diameter are coated with a metal oxide such as alumina and incorporated by powder metal techniques in nickel or cobalt base matrix alloys. A powder metal compact containing up to about 45 volume percent particulate may be made which is then bonded to the tip of the blade. The resulting abrasive blade tip is particularly well suited for rubbing metal as well as ceramic airseals; the latter type of seals have found wide use in modern gas turbine engines.

As described in greater detail in the copending and commonly assigned application "Abrasive Surface Coating Process for Superalloys" to Eaton et al, U.S. Serial No. 624,446, which is incorporated by reference, improved techniques for the fabrication of blade tips, relative to the type of methods described in Johnson et al, are desired. Specifically, the blade tip should be as thin as possible, yet still provide the required abrasive characteristics. The quantity of abrasive silicon carbide should be minimized, due to its high expense.

Components having thin layers of abrasive particles which are randomly distributed in a matrix material are known. For example, coated abrasives made from alumina, silica and silicon carbide are common products, as are metal bonded diamond and cubic boron nitride grinding tools. Such tools are often made by electrodeposition techniques. In U.S. Patent No. 4,227,703, such techniques are used to deposit an abrasive layer on a turbine blade tip. However, the limited composition of electrodeposited matrix alloys limits the usefulness of this method. Sprayed deposits containing metal and ceramic abrasives are also well known. See, e.g., commonly assigned U.S. Patent No. 4,386,112. However, such processes for spraying abrasive and matrix metal particles are inherently inefficient in that only a fraction of the sprayed material actually hits and adheres to the surface. These difficulties are especially significant in light of the relatively small size, e.g., about 6 by 50 mm, and curved shape of a typical turbine blade tip.

When an abrasive layer is provided on a superalloy turbine blade tip, its method of application must be metallurgically compatible with obtaining or maintaining the desired properties of the superalloy substrate. Since turbine blade alloys reflect a highly refined metallurgical art, there are limits on the techniques used with abrasive layer fabrication. Also, the abrasive layer is not a structural material and its weight imposes stresses on the blade substrate during use, i.e., when the blade rotates at high speed. Thus it is highly desirable that the minimum thickness abrasive layer be applied. Since blades are finished to length tolerances of 0.05 mm or less, this means that both the preparation of the substrate and the application of the abrasive layer must be carried out with high precision. All these considerations place severe restraints on the kinds of materials and processing techniques which are useful.

Disclosure of the Invention

An object of the invention is a method for providing a single layer of spaced apart particles on the surface of an article. Another object of the invention is to deposit such particles in a high concentration and uniform distribution on a turbine blade tip. Yet another object of the invention is to provide an abrasive layer having high temperature operating capability on the tip surface of a turbine blade.

According to the invention, a method for depositing a single layer of particles in a desired pattern on the surface of an article comprises the steps of (a) drawing a vacuum through a transfer tool having a plurality of apertures arranged in said desired pattern, the size of each aperture being such that the vacuum holds only one particle in overlying relation to each aperture; (b) positioning the tool and the particles held thereto over the article surface; and (c) decreasing the vacuum level such that the particles fall onto the surface, their position on the surface substantially corresponding with the position of the apertures. Preferably, a layer of adhesive is present on the surface so that when the

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particles drop onto it, they are adhesively attached to the surface. Most preferably, the particles have a metal cladding thereon, and the article is then heated to volatilize the adhesive and sinter bond the clad particles to the surface.

The invention is particularly useful in the fabrication of an abrasive layer on the tip surface of a rotor blade used in a gas turbine engine. For desired operating characteristics, the particle density per unit area of blade tip surface must be maximized, while at the same time the interparticle contact must be minimized. Also, the particles must be securely bonded to the blade tip to withstand the stresses of engine operation. To fabricate such an abrasive layer on a blade tip, after the metal clad particles are sinter bonded to the tip surface, a matrix alloy material is deposited on the surface so as to cover the particles and to fill in the spaces between the particles. The particulate bearing matrix is then simultaneously heated and pressed to eliminate any voids in the matrix material and securely bond the matrix to the substrate and, by interdiffusion, to the cladding on each particle. The abrasive layer is then machined to a relatively flat surface, and then part of the matrix is chemically removed to cause portions of the particles to project into space when blades having such an abrasive layer are installed in an engine, these exposed particles will rub the seal during engine operation, and minimize the leakage of working fluids around the blade tips, thus improving engine operating efficiency.

The abrasive particles are particularly sized with respect to the matrix layer thickness. Control over the particle sizing and aspect ratio are necessary to insure that a portion of most of the particles projects into space, while at the same time, all of the particles are securely bonded to the blade tip surface. Particles sized between Nos. 35-40 U.S. Sieve Series (0.42-0.50 mm nominal openings) are used when the matrix layer thickness is about 0.38 mm. Most preferably, the particles are uniformly spaced apart in a regular pattern on the blade tip surface. Depending on the expected interaction between the abrasive layer and the seal during engine operation, the particle density may be varied between about 35 to 110 particles per cm^2. This relatively close spacing necessitates using particles with aspect ratios less than 1.9 to 1, so that less than about 15% of the particles will contact one another after they are bonded to the tip surface.

The abrasive layer produced according to the invention is economical in the use of materials and has good durability when interacting with ceramic seals.

The foregoing and other subjects, features and advantages of the present invention will become more apparent from the following description of preferred embodiments and accompanying drawings.

Brief Description of the Drawings

Figure 1 generally shows the radially outer portion of a typical gas turbine blade having an abrasive layer made according to the invention;

Figure 2 shows in side view the appearance of a prior art abrasive layer;

Figure 3 shows in side view the appearance of an abrasive layer produced according to the teachings of the present invention;

Figures 4-7 show simplified, schematic views of the method by which abrasive particles are placed on the surface of a turbine blade tip according to the present invention;

Figure 8 shows a perspective view of Figure 6;

Figure 9 shows in side view the appearance of the abrasive particles enveloped in a matrix material;

and

Figure 10 shows the abrasive layer machined to a flat surface.

Best Mode for Carrying Out the Invention

In an example of the practice of the invention, and referring to Figures 1 and 3, an abrasive layer 10 is formed on the tip surface 11 of the airfoil portion 12 of a gas turbine blade 14. The blade 14 is preferably made of a nickel base superalloy (such as the single crystal alloy of U.S. Pat. No. 4,209,348), while the abrasive layer 10 is comprised of a nickel base superalloy matrix 16 and alumina coated silicon carbide particles 18. As will be evident, other materials may be used in the practice of the invention.

The abrasive layer 10 is subjected to very high stresses during engine operation, and therefore it is important that the layer 10 have a certain configuration and properties to perform its function. In particular, the particles 18 must be disposed on the tip surface 11 in a certain manner to obtain optimum performance.

In a prior art abrasive layer 20 for a turbine blade 21 shown in Figure 2, there are randomly disposed abrasive particles 22 within a matrix metal 24. A braze type bond joint 26, such as described in U.S. Patent No. 3,678,570, holds the layer 20 on the blade tip 32. In such a prior art abrasive layer 20, there sometimes tends to be a brick of particles 22 at the blade leading and trailing edges, 34, 36, respectively. Some of the particles 22 touch each other, which results in the inefficient use thereof.

Referring to Figs. 1 and 3, the abrasive layer 10 made according to the invention is characterized by a single layer of abrasive particles 18 surrounded by matrix material 16. Use of a single layer of abrasives 18 minimizes the mass of the entire layer 10, thus reducing the centripetal force on the blade 14 as it rotates during engine operation. The matrix metal 16 has a thickness W less than the overall thickness T of the particles 18. As a result, a portion of each particle 18 projects into space, thereby enabling favorable rubbing interaction with metal or ceramic seals during engine operation. For optimum performance, the unexposed portion of the particles 18 must be surrounded by matrix metal 16, and the particles 18 must be closely spaced apart from each other. Further, the matrix metal 16 as well as particles 18 must be securely bonded to the blade tip 11. In the invention, at least about 80-90% of the particulate surface area (excluding that surface area

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exposed at the blade tip) is surrounded by matrix metal 16 rather than being in contact with another particle 18. Also, the particles 18 are, in general, evenly and densely spaced on the blade tip 11. Densities of about 35-110 particles per cm^2 of tip surface 11 are obtained with the invention method of application, with about 50 particulates per cm^2 being preferred.

As shown in Fig. 3, the particles 18 have a thickness (length), T, and the matrix thickness W is about 50-90 percent of the particle thickness T. Silicon carbide particles of No. 35-40 U.S. Sieve Series Size (nominally 0.42-0.50 mm) have been found useful in the practice of the invention; up to U.S. No. 20 (0,83 mm) size also appears useful.

Figures 5-8 show how the particulates 18 are laid on the blade tip surface 11 where they will be subsequently permanently adhered. Prior to placing the silicon carbide particulates on the surface 11, they are first coated with about 0.010 mm of vapor deposited alumina according to the aforementioned Johnson et al patent, and then clad with a layer of metal, such as vapor or electrodeposited nickel, to a thickness of about 0.002-0.050 mm. Procedures for applying nickel coatings to ceramic particulates are commercially available and also are revealed in U.S. Patent Nos. 3,920,410, 4,291,089 and 4,374,173. If the ceramic particulate material is inherently resistant to reaction with the matrix material then the alumina coating is not necessary. (Neither the alumina coating nor metal cladding are shown in the Figures).

Just before the particles 18 are laid on the surface of the blade tip 11, a polymer adhesive 48 which is capable of being volatilized at less than about 540° C is applied to the surface 11. The purpose of the adhesive 48 is to hold the abrasive particles 18 in place after they are deposited on the blade tip 11. A 1-20 volume percent polystyrene in toluene solution is preferred.

As noted above, the particles 18 in the abrasive layer 10 should be densely arranged on the blade tip 11 in a uniformly spaced apart pattern. As shown in Figs. 4-8, to deposit the particles 18 in such a manner, a vacuum (suction) is drawn through a transfer tool having a plurality of apertures which are arranged to correspond with the desired, spaced apart pattern of particles on a blade tip. As is shown in Fig. 8, which shows the preferred means for depositing the particles, the apertures are perforations 44 in a rigid plate 42. The size of each perforation 44 or aperture is such that when the plate 42 is brought near a source of the particles 18, the vacuum draws the particles 18 against the plate 42, and only one particle 18 is held over each aperture. While not shown in the Figures, some particles 18 may be attracted to the plate 42 or to other particles 18 by, e.g., electrostatic forces, rather than held thereto by the vacuum. Such excess particles are dislodged from the plate 42 by gently tapping the plate 42, taking care not to dislodge the particles 18 held by the vacuum. The perforations 44 are particularly dimensioned relative to the particle size. The diameter of each perforation 44 must be large enough such that the force of the vacuum is sufficient to draw the particles 18 against the plate 42. At the same time, the peforations 44 must be small enough to prevent the particles 18 from passing therethrough. Preferably, the diameter of each perforation 44 is about 3/4 of the particle size.

As is seen in Fig. 8, the area of the plate 42 covered by the particles 18 is slightly larger than the actual blade tip surface 11. This is accomplished by constructing the container 46, which holds the loosely lying particles, in the shape of an oversized blade tip; once the plate 42 is brought near the container and the vacuum turned on, the particles 18 will be attracted to the plate 42 in the pattern shown in Fig. 8. Preferably, the base 49 of the container 46 is a screen or mesh type material.

Once the particles 18 are securely held by the vacuum to the plate 42 as shown in Figs. 5 and 8, the plate 42 is positioned over the blade tip 11 so that the perforations 44 (and the particles 18 overlying them) are aligned with the desired position of the particles 18 on the blade tip 11, as shown in Figure 8. As noted above, the tip 11 is coated with a layer 48 of adhesive. Once the plate 42 is properly positioned over the blade tip 11, the vacuum level is adjusted so that the particles 18 drop onto the adhesive coated tip 11 (Fig. 7). The distance A between the particles 18 and the tip 11 should be minimized so that when the particles 18 are released from the plate 42, they do not bounce off of the tip 11, or stray significantly from their intended position on the tip 11.

Of course, when the particles 18 are released from the plate 42, it is possible that a few particles 18 will stray from the spaced apart relation they had when held to the plate 42, and as a result, there may be some slight agglomeration of particles 18 on the blade tip 11. Also, when the vacuum is drawn on the plate, it is possible that not every perforation 44 will be overlaid by a particle 18. However, use of the plate 42 as described above allows the deposition of a single layer of generally spaced apart particles 18 on the tip surface 11, in sufficient densities (i.e., particles per cm^2) required for turbine blade tip applications. While interparticle contact on the blade tip surface 11 is undesired, experience has shown that there are typically only a few particles 18 (less than about 15%), which touch each other.

After the particles 18 are deposited on the blade tip surface 11, the blade 14 is heated to volatilize the adhesive 48, which also causes solid state bonding (sintering) of the metal cladding to the tip surface 11. For nickel clad particles, the heat treatment is preferably carried out at about 1080° C for 2 hours, in a vacuum or inert gas atmosphere. Use of such a protective atmosphere precludes oxidation of the cladding and blade tip 11.

Next, the particles 18 are oversprayed with a layer of matrix material 16 deposited by plasma arc spraying to a thickness T' as shown in Fig. 9. A nickel base superalloy of the type generally described in the aforementioned Johnson et al patent may be used. The preferred matrix composition is, by weight percent, about 25 Cr, 8 W, 4 TA, 6 Al, 1.0 Hf, 0.1 Y, 0.23 C, balance Ni. The blade 14 is positioned with respect to the plasma arc device so that the tip cross section is generally perpendicular to the axis

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along which the molten matrix particles travel. The blade 14 is suitably masked around its periphery that errant spray does not deposit on the sides of the blade 14. The matrix material 16 is applied to a thickness of about 0.6-1.3 mm, preferably 1.1-1.3 mm.

Although the sprayed layer of matrix material 16 will have about 95 percent theoretical density, it will nonetheless be characterized by some porosity or voids. The voids are characteristic of the metal spraying process, and would be produced by any such "line of sight" deposition process. Metal spraying is used because it is one of the few processes capable of applying a superalloy, with all its diverse constituents. Another process that may be used is a physical vapor deposition process, since such process has been shown to be capable of applying MCrAlY coatings and the like. See U.S. Pat. No. 4,153,005 to Norton et al.

Next, the blade is subjected to a hot isostatic pressing procedure. Generally, this comprises deforming the matrix material 16 beyond its yield or creep-limit point at an elevated temperature. Preferably, the part is subjected to argon pressure while at elevated temperature, to close the aforementioned pores and voids, and to enhance the bond between the matrix 16, particles 18, and blade tip 11. For the specific superalloy matrix material described above, a temperature of about 1,100° C and a gas pressure of about 138 MPa applied for two hours is sufficient. Other hot pressing procedures may be used to consolidate the matrix material 16 and achieve the object of densification and bonding.

Next, the rough surface of the abrasive layer 10, as shown in Fig. 9, is machined using a conventional procedure such as grinding to produce a smooth, planar suface, as shown in Fig. 10. After the machining process, the thickness of abrasive particles 18 and matrix material 16 is T. Finally, the surface of the abrasive layer 10 is contacted with an etchant or other substance which will attack and remove some of the matrix material 16, causing the particles 18 to project into space. For example, electrochemical machining can be used, as is described in U.S. Patent No. 4,522,692 to Joslin. This step reduces the matrix thickness to a dimension W, which is about 50-90 percent of the dimension T, and results in the shape schematically shown in Fig. 3.

While Figures 4-8 show the preferred embodiment of the invention, i.e., the use of a perforated plate 42 to deposit the particles 18 on the blade tip 11, the apertures in the transfer tool may be defined by other means. One arrangement within the scope of the invention are hollow cylinders such as tubes or needles, which are spaced apart relative to each other such that the apertures (the cylinder ends) are arranged in the same pattern as the perforations in the plate. When a vacuum is drawn through the cylinders, only one particle will overlie each cylinder end. The particles are dropped from the cylinders in the same manner as they are dropped from the plate, as described above.

It has been found that there is a criticality in the aspect ratio of the particles 18, relevant to obtaining an abrasive layer 10 which contains a high density of uniformly spaced apart particles 18. When the particles are long and thin (i.e., have a high aspect ratio), they will of course tend to lie on their sides either when laid on the blade tip surface 11 initially or in the interval between the volatilization of the adhesive agent and the attainment of a metallic bond. Such laying-at-length disrupts the uniformity of placement and causes undue interparticle contact. Thus, the invention is best practiced when the aspect ratio of the particulates is less than about 1.9 to 1 and preferably is about 1.5 to 1 or less. The aspect ratio is defined herein as the average ratio of the longest particle dimension to the cross sectional dimension, as such is measured on a Quantimet Surface Analyzer (Cambridge Instruments, Cambridge, England).

The present invention is especially useful in providing a more effective abrasive layer (after the matrix is partially chemically milled away) compared to abrasive layers of the prior art. Suppose abrasive layers having the same volume percent of identically sized and shaped particles are made, first using the invention technique and second, using the prior art powder metal technique, as represented in Fig. 2. The area of abrasive particulate exposed at the surface of the invention and prior art layers, after the grinding operation, will be approximately the same. But the particulate deposited according to the invention will be distributed considerably more uniformly. And when the matrix is partially removed from the invention abrasive layer by electrochemical machining, about the same amount of surface area will be exposed on each particle, and the particles will all be about equally well-bonded to the blade tip. In contrast, owing to the non-uniform distribution of particles in prior art structures, when the matrix is electrochemically machined, those particles which were mostly contained in the matrix which is removed will of course be lost. The net result is that there will be less area of abrasive particles remaining at the free surface, and the prior art abrasive layer will be less effective in wearing the ceramic seal it rubs during engine operation.

While in the preferred embodiment of the invention the abrasive particles are placed in a uniform distribution on the blade tip, applications are contemplated in which there need be a greater or lesser concentration of particles at one or another portion of the tip. To achieve such a distribution of particles, the pattern of perforations in the plate is modified accordingly.

Although this invention has been shown and described with respect to a preferred embodiment, it will be understood by those skilled in the art that various changes in form and detail thereof may be made without departing from the spirit and scope of the claimed invention.

Claims

1. A method for depositing a single layer of particles on the surface of an article, wherein the particles are spaced apart from each other

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on said surface in substantially noncontacting relation in a desired pattern, comprising the steps of:

(a) drawing a vacuum through transfer tool means having a plurality of apertures spaced apart from each other in said desired pattern while the tool means is adjacent to a container of the particles, wherein the vacuum holds one particle over each aperture;

(b) positioning the article relative to the apertures such that each particle substantially overlies its desired location on the article surface; and

(c) adjusting the vacuum level such that the particles are released from the tool means and drop onto the article surface to form said desired pattern.

2. The method of claim 1, further comprising the step of applying an organic adhesive to the surface of the article prior to said step of adjusting, such that when the particles drop onto the surface from the plate, they are held on the surface of the article by the adhesive.

3. The method of claim 2, wherein the particles are metal clad ceramic, and further comprising the step of heating the article having the particles thereon to an elevated temperature to remove the adhesive and to bond the particles to the article surface.

4. The method of claim 2, wherein between about 35-110 particles per cm^2 are deposited on the article surface, the particle size being between about Nos. 20 and 40 U.S. Sieve Series.

5. The method of claim 4 wherein the aspect ratio of the particles is less than about 1.9:1.

6. The method of claim 1, wherein the article is a blade for a gas turbine engine.

7. A method for depositing a single layer of particles on the tip surface of a turbine blade, wherein the particles are spaced apart from each other on said tip surface in substantially noncontacting relation in a desired pattern, comprising the steps of:

(a) drawing a vacuum through transfer tool means having a plurality of apertures spaced apart from each other in said desired pattern while said tool means is adjacent to a container of the particles, wherein the vacuum holds one particle over each aperture;

(b) positioning the blade tip relative to the apertures such that each particle substantially overlies its desired location on the blade tip surface;

(c) adjusting the vacuum level through the tool means such that the particles drop onto the blade tip surface to form said desired pattern;

(d) depositing on the blade tip surface article a layer of matrix material to fill in the spaces between the particles; and

(e) removing a portion of the matrix material such that the thickness of the matrix material is less than the thickness of the particles.

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FIG. 1

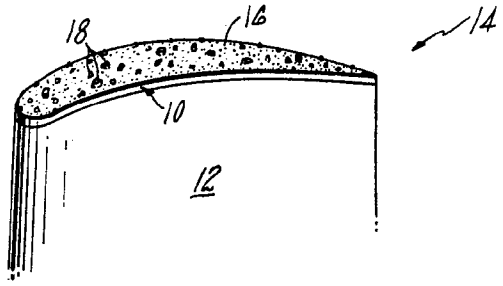
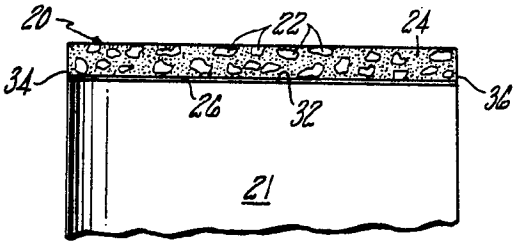


FIG. 2 PRIOR ART



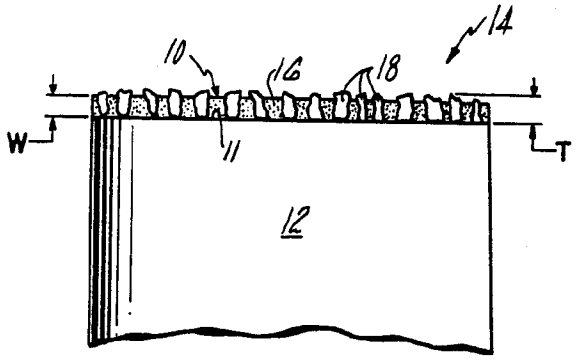


FIG. 3

FIG. 4

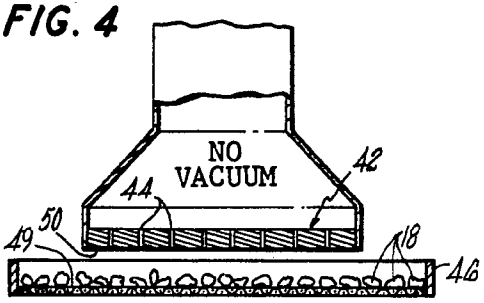


FIG. 5

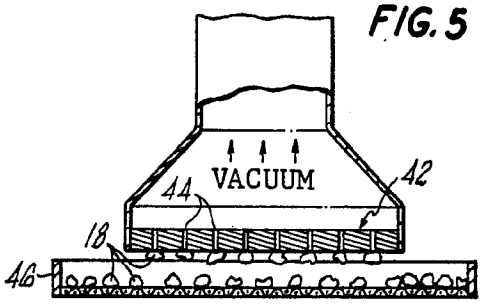


FIG. 6

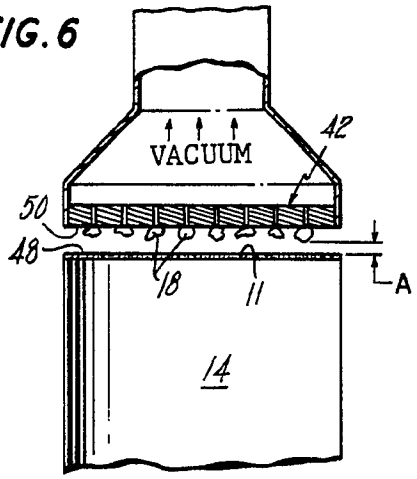
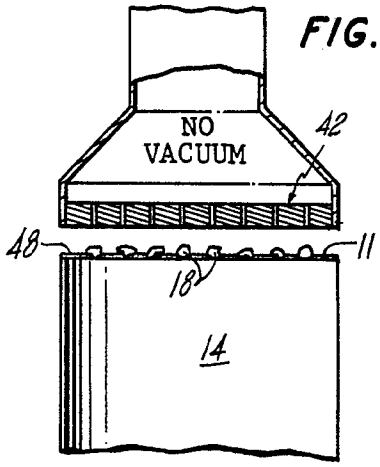


FIG. 7



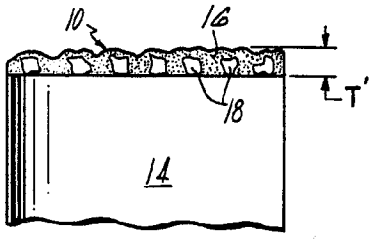


FIG. 9

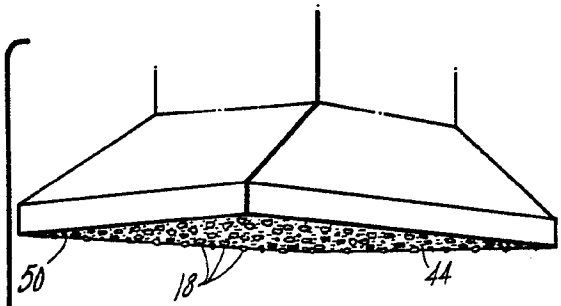
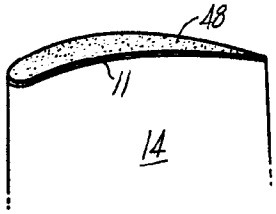


FIG. 8



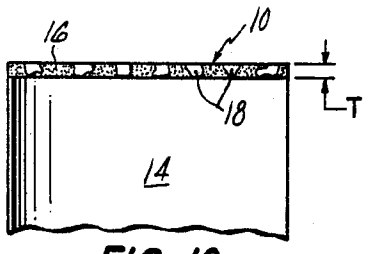


FIG. 10

CN1494984

Sign in

Patents Application Grant English Chinese

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Sander for polishing cloth and polishing cloth sanding method using said sander

CN 1494984 A

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Applicant	株式会社利德
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External Links: SIPO, Espacenet

ABSTRACT translated from Chinese

The invention provides a polishing cloth with grinding and the use of the sander polishing method for polishing cloth, the polishing cloth with the polishing device to adjust the grinding surface of the state, even in the abrasive polishing surface of the tip shape of the state of generating individual differences can also cause a uniform polishing cloth surface, but also the polishing cloth surface given adaptation workpiece appropriate polishing performance, the grinding device is configured, the metal base (2) of the circumferential edge portion with polished surface (4) a polishing cloth with a sander (1), the grinding surface (4), respectively, are juxtaposed alternately different from each other abrasive particle consisting of a first and second particle group (5), (6), in the metal substrate (2), set the abrasive grains can be adjusted to each of these groups (5,6) maximum particle size of the abrasive grains contained in the front end plane (S1), (S2) between the height difference (δ) of the adjusting mechanism (7).

DESCRIPTION translated from Chinese

Polishing cloth with a sander and use the sander polishing cloth polishing method

Technology

The present invention relates to a chemical mechanical polishing (Chemical MechanicalPolishing; hereinafter referred to as CMP) in the distribution network during the polishing cloth or foreign material removing clogging on the occasion of use, and the polishing cloth with polishing cloths with its grinding method.

BACKGROUND

In general, a silicon wafer substrate for manufacturing a semiconductor integrated circuit such as a silicon wafer substrate, or the process of micro-electronic circuits, for removing exist irregularities on the surface of the substrate or the purpose of crystal defects by CMP processing. In this CMP processing, a predetermined load while the wafer substrate is attached to the polishing apparatus to suppress the fixed disk constituted by the foamed polyurethane polishing cloth on the side of the slurry supplied to the polishing liquid known that both the wafer and the polishing cloth rotating polishing.

As the slurry in CMP, with iron oxide, barium oxide, cerium oxide, aluminum oxide, colloidal silica polishing particles suspended in potassium hydroxide, dilute hydrochloric acid, dilute nitric acid, aqueous hydrogen peroxide, ferric nitrate, slurry of the polishing solution etc., these are based on the polishing rate and the wafer or a wafer substrate to be processed on the type of object to said selected appropriately.

This CMP processing, in order to use the same or more than the polishing cloth to polish the wafer repeatedly, with an increase in the number of CMP processing, the removed workpiece polishing debris or aggregated fine particles into the polishing cloth holes and cause clogging, the wafer polishing rate decreases. Therefore, it is necessary to regularly or periodically be removed after distribution network clogging the surface of the polishing cloth, polishing cloth reproduction surface roughness of the surface to restore the polishing

CLAIMS (10) translated from Chinese

1 A polishing cloth with sanders, is rotatable on the surface of the metal substrate is formed from a polished surface polished with the polishing cloth, characterized in that the grinding surface in the circumferential direction of the juxtaposed multiple a particle group, in the metal substrate, for all or part of the particle group, setting can be adjusted by a plurality of abrasive grains are formed in the distal end of said polishing surface reference plane height difference adjustment mechanism.

(2) as claimed in claim 1, wherein the polishing with a polishing cloth, characterized in that the adjusting mechanism of a particle group, are fixed to the composition and the metal base of the adjusting mechanism are formed separately on a base, along The polished surface of the metal substrate of the particle group in the peripheral portion juxtaposed annularly.

3 as claimed in claim 1, wherein the polishing with a polishing cloth, characterized in that the abrasive grains are formed from the group of the polished surface and the peripheral edge of the annular disk shape in parallel with the periphery of the grinding surface at an angle The shape of the helical segments, small round shape is selected among one or both of the flat shape.

4 as claimed in claim 3, wherein the polishing with a polishing cloth, characterized in that the particle group are formed from the planar shape is selected among the two kinds of planar shape, the plane shape of two different particle group In the polished surface in the circumferential direction alternately juxtaposed.

5 as claimed in claim 1 or 2, wherein the polishing with a polishing cloth, characterized in that the juxtaposed surfaces of the polishing abrasive grains group is a group of the same size of each abrasive particle group is formed, or, by different abrasive particle size particle group is formed to form two.

As claimed in claim 5, wherein the polishing with a polishing cloth, characterized in that the juxtaposed surfaces of abrasive grains in the

speed of operation is known as grinding, used in this operation is referred to as polished cloth with sander tool.

Because the diamond abrasive grains in the polishing cloth in polishing is an excellent material, so that the use of diamond abrasive grains of the polishing cloth with sanders, nickel-plated stainless steel by electrodeposition of diamond abrasive grains is generally useful method of the. In addition to metal brazing material made with the aid of the brazed diamond grit on stainless steel (for example, see JP-A No. Hei 10-012579), by sintering the diamond abrasive material and the holding and fixing the reaction sintering method (such as , see JP-A No. 2001-179638). Also for the polishing cloth to obtain a stable ability to remove the surface layer of the object, also proposed are arranged at equal intervals in a CMP polishing cloth polishing abrasive grains (for example, see JP-A No. 2000-141204, Laid-Open Publication No. 2002-127017) .

However, in this prior art the polishing cloth with sanders, since in its structure, can not be avoided due to the tip shape of the abrasive grinding surface in a manner to produce individual differences, so even with the same polishing cloth sanders is difficult to cause a homogeneous surface polishing cloth, in addition, the surface state of the polishing cloth is necessary to be adjusted according to the workpiece, for example, formed on the surface of the silicon wafer wafer interlayer oxide film, the surface condition by polishing a rough cloth state, caused by mechanical polishing cloth to remove the polishing processing speed enhancement factor, in addition, the Cu wiring, for the presence of the surface of the polishing cloth polishing liquid (slurry) of the factors that caused by chemical reactions caused by mechanical polishing cloth ratio more factors removal processing purposes, it is necessary to maintain a certain degree of surface roughness of the polishing cloth, therefore, on the polishing surface of the polishing cloth with the polishing cloth is sanders, it is necessary to prepare the required number of, grinding state of the surface of the object to be processed adaptation, there is such a problem costs.

polishing base, the abrasive particle size different from each other formed by a first and a second particle group particle group to form, these first and second particle group in the polished surface of the particle group in the circumferential direction alternately juxtaposed.

As claimed in claim 6, wherein the polishing with a polishing cloth, characterized in that the first particle group of the same particle size of the abrasive grains or both formed.

As claimed in claim 1 or 2, wherein the polishing cloth with the polishing, characterized in that each particle group, each of the abrasive particles in the polishing surface of said two-dimensionally arranged with regularity, mutually adjacent The minimum abrasive particles form a regular triangle or a parallelogram lattice arranged.

9 A polishing cloth for polishing method using a claims 1 to 8 as described in any one of the polishing cloth with a sander polishing cloth, characterized in that by means of the adjusting mechanism, the abrasive grains adjacent to each other plane of said group setting of a certain height difference between, grinding the polishing cloth.

10 A polishing cloth for polishing method using a claimed in claims 6 to 8 wherein any one of the polishing cloth with a sander polishing cloth, characterized in that, by means of the adjusting means, the polished surface of the first 1 particle group in a height adjustment of the reference plane than the second particle group in a certain amount of height above the reference plane, polishing the polishing cloth.

SUMMARY OF THE INVENTION

The present invention solves the technical problem, is to provide a polishing cloth can be adjusted by means of a grinding surface of the grinding device in the state, even if the shape of the abrasive polishing surface of the front end of the state of generating individual differences, the grinding surface can also be resulting in a uniform adjustment of the surface of the polishing cloth, or can be imparted to the surface of the polishing cloth to adapt appropriate workpiece polishing performance of the polishing and the polishing cloth with the polishing cloth with its grinding method.

To solve the above problems, the present invention is polished with the polishing cloth to be rotatable in the metal substrate is formed on a surface made of polished surface polished with the polishing cloth, characterized in that the grinding surface in the circumferential direction, a plurality of parallel particle group, in the metal substrate for all or a portion of a particle group, can be adjusted by a plurality of abrasive grains are formed of the front plane of the polished surface of the step difference adjusting mechanism.

If the polishing cloth with the polishing device, since the adjusting mechanism by means of a plurality of abrasive grains can be adjusted in each of the above groups plane height difference, even in the abrasive polishing surface of the tip shape of the state of individual differences arising may also adjust the particle group of the plurality of difference in height of the plane, polished to adjust the surface state of the polishing cloth surface resulting in uniform, or the surface of the polishing cloth can be polished surface polishing cloth, giving adapt workpiece appropriate polishing performance. In this case, the high particle group plane mainly used for polishing the surface of the abrasion cloth, base particle group is mainly used for low surface roughness of the polishing cloth adjusted.

In the polishing cloth with the polishing vessel, it can be taken as a group of the adjusting mechanism of abrasive particles, are fixed to the metal substrate with said composition formed separately on a base of the adjustment mechanism, along the polished surface of the metal substrate The peripheral edge portion of the particle group are juxtaposed annularly.

If the above particle group respectively from the periphery of the grinding surface of the annular plate shape in parallel with the periphery of the grinding surface of the angled shape of the helical segments, small round shape is selected among one or both of the plane formed in the shape, it is best removed by the polishing cloth of a polishing slurry of the cutting chips or agglutination easily discharged to the outside.

In the grain group, respectively, a planar shape is formed by selecting from the two planar shape of the occasion, the plane shape of two different grinding surface of the particle group in the circumferential direction are alternately arranged side by side is appropriate.

In addition, the polished surface of juxtaposed groups of the abrasive grains may be made of each of the same size of abrasive grains formed by the same group, or by a different abrasive particle size particle group is formed to form two .

Moreover, in parallel provided on the polished surface of the particle group, the abrasive particle size different from each other are formed a first group and a second abrasive grain group to form the occasion, the first particle group and the the second particle group in the circumferential direction of the grinding surface juxtaposed alternately be appropriate. In this case, the abrasive particle size may be from the same or two different grain size of abrasive grains to form the first group.

Here, in the above group of abrasive, abrasive particles in the polishing surface of said two-dimensionally arranged with regularity, the abrasive particles adjacent to each other resulting in the smallest lattice triangle or a parallelogram if arranged, can to further improve the stability and uniformity of polishing.

Further, the above problem can be by the adjusting mechanism, adjacent to each other between the reference surface of said particle group setting of a certain height difference, grinding polishing cloth of the polishing cloth for polishing method to solve.

In the polishing cloth for polishing method, a plurality of abrasive grains by the first group and the second particle group group to form the occasion, by means of the adjusting means, the polished surface of the first particle group basis Height adjustment of the surface than the second particle group in a certain amount of height above the reference plane, polishing the polishing cloth is suitable.

If such a polishing cloth with the present invention and a polishing cloth with its grinding polishing method, since the adjustment mechanism can be adjusted by means of the particle group in the front end by the abrasive grains are formed in said reference surface Polished surface height difference, even abrasive surface of the tip shape of the state of polished produce individual differences can also cause a uniform polishing cloth surface, and that the surface of the polishing cloth can also be given a suitable adaptation of the workpiece polished performance.

BRIEF DESCRIPTION

Figure 1A ~ 1D are said polishing cloth of the present invention with a polishing abrasive cluster configuration The different shapes of the first embodiment of a perspective diagram.

Figure 2A ~ 2D is a diagram of the present invention sander polishing abrasive cloth with the configuration of cluster shape different from the first perspective view of a second embodiment.

1A in Figure 3 is a cross-sectional view of line III-III.

2A in Figure 4 is a cross-sectional view of IV-IV.

Figure 5 is shows the first abrasive grains in a group 5 a schematic view of the arrangement state.

Figure 3 Figure 6 is a partially enlarged view.

Specific embodiments

Figure 1A ~ 1D shows the polishing cloth of the present invention the particle group with sanders shaped configuration different from the first embodiment. 1 is polished by the polishing cloth with the front side at its center with a circular concave portion 2a, and in its periphery surface of the metal substrate 3 is formed on the polished surface 4 made of an annular disk-shaped metal substrate 2 is constituted, In the polished surface 4, respectively, a plurality of annularly arranged in parallel along the circumferential direction of the separate first and second particle group 5,6. In other words, along the metal substrate surface 3 of the metal substrate 2 is the periphery a plurality of annularly arranged side by side forming the polishing abrasive surface groups 5,6 4.

Moreover, as shown in Figure 3, the metal substrate 1 is provided with a regulating mechanism 7, so that each particle group in the 5 and 6 to contain the maximum grain size of the front end of the plane as the reference surface S1, S2, the can be adjusted on the polished surface 4, 5 and 6 of the plurality of abrasive grains of each group plane S1, S2 each level difference between δ.

This is not necessarily required in the metal base 2 is provided the concave portion 2a.

Specifically, the adjusting mechanism 7 by the base station 7a, 7b and gaskets adjusting screw 7d composition, wherein the abutment surface 7a of the fixed abrasive group 5 or 6, and down slidably fitted into the opening in the metal base 2 the surface 3 of the concave portion 7e; adjusting screw 7b is provided in the base 7a of the back, screwed from the metal substrate 2 in the recessed portion 7e of the bottom surface of the metal substrate 2 on the back side of the through screw hole 7c; When adjusting the fixed the grains of the base 7a of the group at the 5,6 position, the height of the reference plane, the spacer clip 7d in the back surface of the base 7a of the recess between the bottom 7b. Moreover, the adjusting mechanism are fixed to the base 7 7a plurality of abrasive grains on the surface of the metal cluster 5,6 substrate 2 along the peripheral edge portion annularly juxtaposed, forming the polished surface 4.

Therefore, in order to adjust the reference surface of the particle group in 5,6 S1, S2 of the height position of the spacer having a desired thickness into the metal base 7d concave portion 7e 2, through the means of the adjusting screw clamp 7b 7e on the bottom surface of the recess and the back surface of the base 7a between the respective particle group can be adjusted at the datum 5,6 S1, S2 of the metal substrate surface 3 of the height position, i.e. a plurality of abrasive grains group 5, 6 of the plane S1, S2 each level difference between δ, polished surface 4 can be adjusted state. Furthermore, in the present embodiment, the means of adjustment mechanism 7, the plane S1, S2 of the metal substrate surface 3 of the height can be within the range of 0 ~ 300μm regulation.

Among the grain group, base particle group is mainly used for high abrasion polishing cloth, base particle group is mainly used for low surface roughness of the polishing cloth adjusted. That is, since by applying the grinding load is concentrated on the whole high abrasive effect on the plane base, the load applied per unit area increases, so that they wear mainly used for polishing cloth, on the other hand, lower plane The particle group to some extent the burden of the load, the high plane of said polishing abrasive cloth group causes reduced wear rate. Furthermore, the mutual height difference between the reference plane δ becomes great occasions, as a particle group in the low plane burden load completely, so that they do not play a polishing cloth to the effect of reducing the wear rate. This group of a plane is also low polishing abrasive cloth cutting chips function effectively discharged.

In addition, polishing with the polishing cloth 1 is, the plurality of abrasive grains each different size from the group of 5,6 abrasive grains formed by the first and the second group 5 group 6 to form abrasive grains, these two grinding 5,6 swarm metal substrate 2 along the peripheral edge portion of the circumferential direction are alternately arranged side by side polished surface 4 is formed.

Specifically, the first particle group 5, shown in Figure 5, Figure 6, the size of the size of two grains 50, 51 are formed, the abrasive grains 50, 51, shown in Figure 5, 7a, the base surface of the polished surface 4 of the aforementioned two-dimensionally on a regular manner equally arranged adjacent to each other resulting in the smallest abrasive particles each triangle or a parallelogram lattice rows. Moreover a large interval between the abrasive particles 50 smaller than the interval between the abrasive particles 51 to be wide.

By thus granularity of the size of two grains are arranged in a regular manner equally possible to further improve the stability and uniformity of polishing.

On the other hand, in the second particle group 6, although it can be in particle size of the first abrasive grains group 5 different or more of the same particle size abrasive grit size in both forms to form any kind, but preferably in conjunction with the first particle group 5 Similarly, the abrasive are two-dimensionally arranged in a regular manner equally.

Here, the group forming the abrasive grit 5,6, diamond abrasive grains can be used for example, the abrasive particle size, in general, it is best defined in JIS B 4130 # 325 / # 400 ~ # 60 / # 80 range.

Further, forming the first abrasive grains group 5 is not necessarily required particle size mentioned above is the size of two grains 50 and 51, it can be the same size of abrasive particles (see Fig 2A ~ 2D embodiment of FIG.). Further, the adjustment mechanism 7 is not necessarily required in the first and second abrasive grains group 5 group 6 of the two prescription settings, or only part of the particle group, i.e., the first or the second particle group 5 mill one group of six tablets set. In this case, adjusting mechanism 7 is not set particle group, the base station 7a fixed to the metal substrate directly to the peripheral portion 2.

Thus, if each particle group with grains of different size, or different sizes of the abrasive grit group manipulation mixing, large size of the abrasive wear is mainly used for the polishing cloth, the small size of the abrasive mainly used for polishing cloth surface roughness adjusted by the adjustment of their size, can be a surface roughness of the polishing cloth ended for a particular CMP of the object state.

Further, as shown in Fig 1A ~ Figure 1D, the polishing cloth with sanders 1, the first and second abrasive grains group 5 group 6 of the planar shape of the shape from the small circle, as with the metal base 2 grinding the peripheral surface 4 is parallel to the peripheral edge of the annular disk shape, and the metal substrate 2 is polished surface of the peripheral edge 4 of the peripheral edge of the angled shape of helical segments by selecting one or two. Figure 1A shows a group of two grains are small round shape of the case 5, 6, Figure 1B shows the first group 5 is a small round shape of the abrasive grains and the second abrasive sheet group 6 is a spiral shaped case, Figure 1C 5,6 shows two groups are abrasive annular disk shape of the occasion, Figure 1D shows two groups 5,6 are abrasive spiral slice shape of the occasion. By such a planar shape is formed as a particle group 5,6 3 along the surface of the metal substrate is a metal substrate 2 are arranged in the peripheral edge portion of the annular grinding surface 4 is formed, because the grinding and polishing cloth to remove cutting chips or aggregation easy to sanders slurry discharged outside, in addition you can adjust its discharge performance.

Furthermore, the particle group 5,6, as shown in Figure 6, the abrasive material 52 to maintain the resilient holding is formed by means of an adhesive agent 8 such as the holding of the holding of the abrasive material 52 is fixed to the adjustment mechanism 7 in abutment surface 7a of the particle group is fixed to the base 5, 6, 7a.

Further, as the retaining material 52, although in the case of abrasive grains of diamond, the diamond abrasive grains can be used and reaction sintering of silicon and / or silicon alloy, but as long as is appropriate for the holding of the holding abrasive material is not particularly limited, by the General solder plating of nickel or the engagement means is also possible to maintain.

Next, by the polishing cloth on a polishing device 1 is polished polishing cloth will be described by means of the adjusting mechanism 7, the interaction of adjacent first and second abrasive grains group 5 group 6 of the plane S1 , S2, the setting of the metal substrate surface 3 of a certain height difference between the δ, grinding the polishing cloth. In other words, by means of the adjusting mechanism 7 is adjusted to the first reference surface S1 group 5 abrasive than one group 6 of the second reference surface S2 abrasive grains of the metal substrate surface 3 of the height of the vertical direction of a higher amount δ, by appropriately adjusting the polished surface 4 of the state of the polishing cloth can be polished surface of the workpiece to accommodate desired state.

If like polishing cloth with the polishing device 1, since by adjusting the plane S1, S2 of the level difference δ, the polished surface 4 can be adjusted to the state can play the desired polishing performance, not even in the polished surface 4 individual differences generated in a state, it can cause a uniform polishing cloth surface, and can be imparted to the surface of the polishing cloth to adapt appropriate workpiece polishing performance.

Figure 2A ~ 2D illustrate the present invention with a sander polishing abrasive cloth cluster shape different from the first configuration of Embodiment 2. In the present embodiment, the polishing with a polishing cloth 10, the plurality of abrasive grains group by only 5 of the first particle group composed of grains by the same group of 5 of these metal substrate 2 along the periphery of the ring juxtaposed shaped to form a polished surface 4.

In addition, the particle group 5 planar shape, as in the first embodiment, same as the case may be from the small round shape, as with the polished surface 4 of the periphery of parallel annular disk shape, and the polished surface 4 of the peripheral edge into a certain angle choosing the shape of a spiral slice. Figure 2A shows a group 5 are all small round grain shape of the occasion, Figure 2B shows the shape of the particle group and the screw 5 is a small round sheet shape having the planar shape of the two different abrasive grains in the polishing surface 4 group 5 alternately in the circumferential direction of the case of juxtaposed, Fig 2C shows particle group in the shape of the annular plate 5 are all occasions, Figure 2D shows the particle group in the shape of helical segments 5 are all occasions.

On adjusting mechanism 7 includes other structures, as in the first embodiment together, so description is omitted here to avoid repetition.

Further, in the above-mentioned polishing cloth 10 is polished with a polishing cloth, as shown in Figure 4, by means of adjustment mechanism 7 adjacent to each other in a group 5 of the abrasive grains set between plane S1 of the metal substrate surface 3 of a certain The height difference δ and sanding.

If like polishing cloth with the polishing device 10, then polished with the polishing cloth 1 is also used because it can properly adjust the particle group in the adjacent plane 5 of the height difference δ between S1 and the state of the polished surface 4 Adjust to the desired state, so even if the polishing surface 4 not only the state of individual differences generated, it can cause a uniform polishing cloth surface, and can be imparted to the surface of the polishing cloth to adapt appropriate workpiece polishing performance.

Furthermore, the adjusting mechanism 7 itself a configuration, not limited to the constitution described above with reference to FIG, may be used within the scope of the fine particle group in the plane vertical to adjust the various institutions.

The following detail together with comparative examples illustrate the present invention and a polishing cloth with grinding sander polishing using the polishing cloth of the embodiment of the method. However, the present invention is not limited in any way to these examples.

[First Embodiment] As the first abrasive grain group 5, respectively, with the equivalent particle size # 120 / # 140 is in the range of 150 ~ 170μm diamond abrasive grains 50, and the equivalent size # 325 / # 400 in the range of 55 ~ 65μm diamond abrasive grains 51, 50, 51 through the holding these grains reaction sintering material 52, 50, 51 to obtain abrasive grain held by the holding material 52 is a sintered body.

At this time, the two abrasive grains 50 and 51 are arranged in the surface are arranged, including particle size # 120 / # 140 abrasive grains 50 of the front of the plane, containing the grain size # 325 / # 400 abrasive grains 51 steps of the plane of the front end 40 ~ 60μm, and the abrasive grains 50 and 51 adjacent to each other resulting in a minimum grid of equilateral triangles, size # 120 / # 140 abrasive grains 50 are spaced at equal intervals of 2.0mm, size # 325 / # 400 abrasive grains 51 is spaced intervals of 0.4mm.

On the other hand, as the second group 6 of the abrasive grains, with a grain size equivalent to # 60 / # 80 is in the range of 250 ~ 320μm diamond abrasive grains, these are arranged at equal intervals of 0.8mm.

Moreover, in the thus obtained sintered body made by machining, processed into a predetermined size and shape, forming the first and second abrasive grains group 5 group 6, the particle group in these rings were used 5,6 epoxy resin bonded to the adjustment mechanism 7 in φ100mm diameter stainless steel SUS316L of the base 7a. Furthermore, in the present embodiment, the above first and second abrasive grains group 5 group 6 is taken as the planar shape as shown in FIG 1D polished surface 4 and the peripheral edge of the angled shape of the helical segments.

The polishing cloth made of such a sander to 19.6kPa pressure to 100rpm rotational pressure in the polyurethane foam polishing cloth, with that polishing cloth 80rpm same direction while rotating each of the supply side of the wet silica containing 25ml polishing slurry (卉 yeah Robotics system SS-25) while grinding polishing cloth.

In this case, the adjusting mechanism 7 by means of the above 4 on the polished surface of said first abrasive grains group 5 end of the second reference surface S1 and the abrasive grains group 6 S2 plane end surface of the metal substrate 3, adjusted to a height difference δ three levels 15,30,60 μm, measured speed grinding (polishing cloth wear rate) and the surface state of the polishing cloth (polishing cloth surface roughness), the measurement of the wafer with the polishing cloth polishing rate These measurement results are shown in Table 1.

Furthermore, in this embodiment, n is the number of samples taken to the number 20 is calculated in each sample measured in the measurement values of each of the above average (Ave) are shown in Table 1. And σn-1 in Table 1 represents the standard deviation of each measurement. In addition, the polishing rate of the wafer was measured using wafer ADE Corporation flatness measuring device (ultragage 9800), based on the measurement results before and after polishing calculating the average polishing rate.

Table 1

Image not available. View PDF

Shown in table 1 of this, if the present invention is a polishing cloth with sanders, can be adjusted in a plurality of abrasive particle group of the particle group of the particle size or height difference between the reference plane δ, the polished surface adjustment into the desired state, in particular, to ascertain the particle group by the above difference in height between the reference surface speed big difference δ wear. Thus, with a polishing cloth with sander can perform stable under various conditions of grinding polishing cloth.

Also, if the measured value of the above embodiment, the description of the following measured value is compared to the comparative example to improve the overall performance, and because the standard deviation of various measured values are very small, the resulting discrete small polishing cloth can be used for polishing cloth polishing sander gives stable performance.

[Comparative Example 1] corresponds with the size # 80 / # 100 is in the range of 210 ~ 250μm diamond abrasive grains with abrasive grains spaced intervals of 0.25mm arranged in such state, the use made of the nickel plating is fixed a prior art CMP polishing cloth sanders, as in the first embodiment under the same conditions grinding polyurethane foam polishing cloth. The grinding results are shown in Table 2.

[Comparative Example 2] corresponds with the size # 120 / # 140 is in the range of 150 ~ 170μm diamond abrasive grains, the grains are arranged in the surface of the sintered body, arranged adjacent to each other, a first result of the smallest grains lattice is a regular triangle, the side of the abrasive grains to become 2.1mm equally spaced intervals, using the composition of the abrasive grains group planar shape, as shown in Figure 2C, and polishing the surface parallel to the peripheral edge of the annular disk the shape of the polishing cloth with sanders, as in the first embodiment under the same conditions grinding polyurethane foam polishing cloth. Results grinding it together with the first comparative example are shown in Table 2.

[Comparative Example 3] with the first embodiment of the first particle group in the same, respectively, with equal size # 120 / # 140 is in the range of 150 ~ 170μm diamond abrasive grains, and grain size equivalent to # 325 / # 400 The range is 55 ~ 65μm diamond abrasive grains. Moreover, these abrasive particles, abrasive particles are arranged in the surface of the sintered body containing Granularity arranged 120 / # 140 abrasive front of the plane, containing the grain size # 325 / # 400 in the plane of the front end abrasive steps a 40 ~ 60μm, and the abrasive grains adjacent to each other resulting in a minimum grid of equilateral triangles, size # 120 / # 140 abrasive interval of intervals of 2.0mm, size # 325 / # 400 grit intervals of 0.4 mm in intervals. Moreover, with the arrangement of abrasive grains having such a group is formed as shown in Figure 2C and polished surface parallel to the periphery of annular disk shape, polished surface of the metal substrate along the periphery of which are arranged annularly The polishing cloth with a grinding device, as in the first embodiment under the same conditions grinding polyurethane foam polishing cloth. Results grinding it together with the first and second comparative examples are shown in Table 2.

Table 2

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REFERENCED BY

Citing Patent	Filing date	Publication date	Applicant	Title
US8414362	Mar 2, 2010	Apr 9, 2013	Chien-Min Sung	Methods of bonding superabrasive particles in an organic matrix

CLASSIFICATIONS

International Classification	B24B53/02, B24B53/017, B24D13/14, B24D7/06, H01L21/304, B24B53/12, B24D3/10
Cooperative Classification	B24D7/06, B24B53/017
European Classification	B24B53/017, B24D7/06

LEGAL EVENTS

Date	Code	Event	Description
Nov 14, 2012	C17	Cessation of patent right	
Sep 13, 2006	C14	Granted	
Jul 14, 2004	C10	Request of examination as to substance	
May 12, 2004	C06	Publication	

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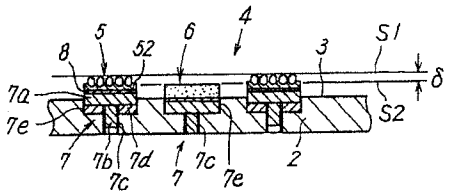
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权利要求书 2 页 说明书 12 页 附图 4 页

[54] 发明名称 抛光布用打磨器和使用该打磨器的抛光布的打磨方法

[57] 摘要

本发明提供一种抛光布用打磨器和使用该打磨器的抛光布的打磨方法，使可调整抛光布用打磨器中的打磨面的状态，即使在磨粒的前端形状等打磨面的状态中产生个体差异，也可以造成均一的抛光布表面，而且能够对抛光布表面赋予适应被加工物的适当的抛光性能，上述打磨器构成为，在金属基体(2)的周缘部上备有打磨面(4)的抛光布用打磨器(1)中，在该打磨面(4)上分别交互地并列设置由彼此不同的粒度的磨粒组成的第 1、第 2 磨粒群(5)、(6)，在上述金属基体(2)上，设置能够任意调节这些各磨粒群(5、6)中包含的粒度最大的磨粒的前端的基准面(S1)、(S2)间的高低差(δ)的调节机构(7)。



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1. 一种抛光布用打磨器，是在能够旋转的金属基体的表面上形成打磨面而成的抛光布用打磨器，其特征在于，

在上述打磨面上，在其圆周方向上并列设置多个磨粒群，

在上述金属基体上，对全部或一部分磨粒群，设置能够调节由多个磨粒的前端分别形成的基准面的上述打磨面上的高低差的调节机构。

2. 如权利要求 1 中所述的抛光布用打磨器，其特征在于，有上述调节机构的磨粒群，分别固定于构成与上述金属基体分开形成的上述调节机构的基台上，沿着上述打磨面中的金属基体的周缘部各磨粒群环状地并列设置。

3. 如权利要求 1 中所述的抛光布用打磨器，其特征在于，上述磨粒群分别形成为从与上述打磨面的周缘平行的环形片形状、与上述打磨面的周缘成一定的角度的螺旋片形状、小圆形状之中选择的一种或两种的平面形状。

4. 如权利要求 3 中所述的抛光布用打磨器，其特征在于，上述磨粒群分别形成为从上述平面形状之中选择的两种平面形状，

这些平面形状不同的两种磨粒群在打磨面的圆周方向上交互地并列设置。

5. 如权利要求 1 或 2 中所述的抛光布用打磨器，其特征在于，并列设置在打磨面上的各磨粒群是由彼此同一粒度的磨粒所形成的磨粒群，或者，由不同的粒度的磨粒所形成的两种磨粒群来构成。

6. 如权利要求 5 中所述的抛光布用打磨器，其特征在于，并列设置在打磨面上的磨粒群，由彼此不同的粒度的磨粒所形成的第 1 磨粒群和第 2 磨粒群来构成，

这些第 1 磨粒群和第 2 磨粒群在打磨面的圆周方向上交互地并列设置。

7. 如权利要求 6 中所述的抛光布用打磨器，其特征在于，上述

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第 1 磨粒群由同一粒度的磨粒或者两种粒度的磨粒来形成。

8. 如权利要求 1 或 2 中所述的抛光布用打磨器，其特征在于，在各磨粒群中，各磨粒颗粒在前述打磨面上二维地具有规律性地排列，相互邻接的磨粒颗粒形成的最小格子为正三角形或者平行四边形地排列。

9. 一种抛光布的打磨方法，是用权利要求 1～8 中所述的任何一项抛光布用打磨器打磨抛光布的方法，其特征在于，

借助上述调节机构，在相互邻接的磨粒群的上述基准面间设置一定的高低差，打磨上述抛光布。

10. 一种抛光布的打磨方法，是用权利要求 6～8 中所述的任何一项抛光布用打磨器打磨抛光布的方法，其特征在于，

借助上述调节机构，上述打磨面中的第 1 磨粒群的基准面的高度调节成比第 2 磨粒群的基准面的高度高出一定量，打磨上述抛光布。

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抛光布用打磨器和使用该打磨器的抛光布的打磨方法

技术领域

本发明涉及在机械的化学抛光（Chemical Mechanical Polishing；以下简称 CMP）中在进行抛光布的布网孔堵塞或异物去除之际使用的抛光布用打磨器和用它的抛光布的打磨方法。

背景技术

一般来说在硅晶片基板上制造半导体硅晶片基板或集成电路等微细电子电路的过程中，出于去除存在于基板表面上的凹凸或结晶缺陷的目的用 CMP 加工。在此一 CMP 加工中，一边以规定的载荷把晶片基板压住粘贴于抛光装置的固定盘的由泡沫聚氨酯构成的抛光布上，一边供给称为浆液的抛光液，使晶片与抛光布两方旋转而进行抛光。

作为上述 CMP 加工中的浆液，用使氧化铁、碳酸钡、氧化铈、氧化铝、胶态二氧化硅等的抛光颗粒悬浮于氢氧化钾、稀盐酸、稀硝酸、过氧化氢水溶液、硝酸铁等抛光液中的浆液，这些是根据抛光速度和晶片或晶片基板上的前述被加工物的种类适当选择。

此一 CMP 加工，为了用同一抛光布多张或者多次重复地抛光晶片，随着 CMP 加工的次数的增大，所去除的被加工物的碎屑或凝集的抛光颗粒进入抛光布的微细的孔而引起堵塞，晶片的抛光速度降低。因此有必要经常或者定期地进行去除布网孔堵塞后的抛光布的表层，再生抛光布表面的面粗糙性而恢复抛光速度的被称为打磨的作业，在此一作业中使用被称为抛光布用打磨器的工具。

因为金刚石磨粒在抛光布的打磨中是优良的材料，故研究了利用金刚石磨粒的抛光布用打磨器，通过镀镍在不锈钢上电沉积金刚石磨粒的方法一般被实用化了。除此以外提出了借助金属钎料把金刚

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石磨粒钎焊于不锈钢上的方法（例如，参照特开平 10－012579 号公报），通过烧结使金刚石磨粒与保持料反应烧结而固定的方法（例如，参照特开 2001－179638 号公报）。此外出于得到稳定的抛光布的表层去除能力的目的，还提出了均等间隔地排列磨粒的 CMP 抛光布打磨器(例如,参照特开 2000－141204 号公报、特开 2002－127017 号公报）。

可是，在上述这种现有技术中的抛光布用打磨器中，因为在其结构上，无法避免因磨粒的前端形状等在打磨面的方式上产生个体差异，故即使使用同一抛光布用打磨器也难以造成均一的抛光布表面，此外，抛光布的表面状态有必要根据被加工物进行调整，例如，对在硅晶片表面形成层间氧化膜的晶片，通过抛光布的表面状态成为粗糙状态，抛光布引起的机械去除加工的因素增强而抛光速度提高，此外，对于 Cu 配线，出于使存在于抛光布表面的抛光液（浆液）的化学反应引起的因素比抛光布引起的机械去除加工的因素更强的目的，有必要维持某种程度的一定的抛光布的表面粗糙度，因此，关于打磨该抛光布的表面的抛光布用打磨器也是，有必要准备需要数量的、打磨面的状态适应上述被加工物的，存在着成本提高这样的问题。

发明内容

本发明将要解决的技术课题,在于提供一种通过能够调整抛光布用打磨器中的打磨面的状态，即使在磨粒的前端形状等打磨面的状态中产生个体差异，也可以通过该打磨面的调整造成均一的抛光布表面，或者，能够对抛光布表面赋予适应被加工物的适当的抛光性能的抛光布用打磨器和用它的抛光布的打磨方法。

为了解决上述课题,本发明的抛光布用打磨器是在能够旋转的金属基体的表面上形成打磨面而成的抛光布用打磨器，其特征在于，在上述打磨面上，在其圆周方向上并列设置多个磨粒群，在上述金属基体上设有对全部或一部分磨粒群，能够调节由多个磨粒的前端

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分别形成的基准面的上述打磨面中的高低差的调节机构。

如果用上述抛光布用打磨器，则由于借助上述调节机构可以任意调节多个磨粒群中的上述各基准面的高低差，所以即使在磨粒的前端形状等打磨面的状态中产生个体差异也可以通过调节上述多个磨粒群中的基准面的高低差，调整打磨面的状态，造成均一的抛光布表面，或者，可以对抛光布表面即抛光布的抛光面，赋予适应被加工物的适当的抛光性能。在此一场合，基准面高的磨粒群主要用于抛光布表面的磨耗，基准面低的磨粒群主要用于抛光布的表面粗糙度的调整。

在上述抛光布用打磨器中，也可以取为有上述调节机构的磨粒群，分别固定于与上述金属基体分开形成的构成上述调节机构的基台上，沿着上述打磨面中的金属基体的周缘部各磨粒群环状地并列设置。

如果上述磨粒群分别以从与上述打磨面的周缘平行的环状片形状、与上述打磨面的周缘成一定的角度的螺旋片形状、小圆形状之中选择的一种或两种的平面形状形成，则最好由打磨所去除的抛光布的切削屑或凝集的浆液容易向外部排出。

在上述磨粒群分别形成为从上述平面形状之中选择的两种平面形状的场合，这些平面形状不同的两种磨粒群在打磨面的圆周方向上交互地并列设置是适当的。

此外，并列设置在打磨面上的各磨粒群也可以由彼此同一粒度的磨粒所形成的同一的磨粒群，或者，由不同的粒度的磨粒所形成的两种磨粒群来构成。

而且，在并列设置在上述打磨面上的磨粒群，由彼此不同的粒度的磨粒所形成的第 1 磨粒群和第 2 磨粒群来构成的场合，把这些第 1 磨粒群和第 2 磨粒群在打磨面的圆周方向上交互地并列设置是适当的。在此一场合，可以由同一粒度的磨粒或者不同的两种粒度的磨粒来形成上述第 1 磨粒群。

这里，虽然在上述各磨粒群中，磨粒颗粒在前述打磨面上二维地

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具有规律性地排列，相互邻接的磨粒颗粒造成的最小格子如果成为正三角形或者平行四边形地排列，则可以进一步提高打磨的稳定性和均匀性。

进而，上述课题可以通过靠上述调节机构，在相互邻接的磨粒群的上述基准面间设置一定的高低差，打磨上述抛光布的抛光布的打磨方法来解决。

在上述抛光布的打磨方法中，在多个磨粒群由上述第 1 磨粒群和第 2 磨粒群来构成的场合，借助上述调节机构，上述打磨面中的第 1 磨粒群的基准面的高度调节成比第 2 磨粒群的基准面的高度高出一定量，打磨上述抛光布是合适的。

如果用这种本发明的抛光布用打磨器和用它的抛光布的打磨方法，则由于可以借助调节机构任意调节在各磨粒群中由磨粒的前端分别形成的磨粒基准面的上述打磨面上的高低差，所以即使磨粒的前端形状等打磨面的状态中产生个体差异，也可以造成均一的抛光布表面，而且，对抛光布表面也可以赋予适应被加工物的适当的抛光性能。

附图说明

图 1A～图 1D 是表示使本发明的抛光布用打磨器的磨粒群的配置形状不同的第 1 实施方式的立体图。

图 2A～图 2D 是表示使本发明的抛光布用打磨器的磨粒群的配置形状不同的第 2 实施方式的立体图。

图 3 是图 1A 中的 III－III 剖视图。

图 4 是图 2A 中的 IV－IV 剖视图。

图 5 是表示第 1 磨粒群 5 中的磨粒的排列状态的示意图。

图 6 是图 3 中的局部放大图。

具体实施方式

图 1A～图 1D 示出本发明的抛光布用打磨器的磨粒群的配置形状

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不同的第 1 实施方式。抛光布用打磨器 1 由在其表侧的中心有圆形的凹部 2a，和在其周围的金属基体表面 3 上形成环状的打磨面 4 而成的圆盘状的金属基体 2 来构成，在上述打磨面 4 上，分别环状地并列设置多个沿着其圆周方向独立的第 1 和第 2 磨粒群 5、6。换句话说，沿着金属基体表面 3 即上述金属基体 2 的周缘部环状地并列设置多个磨粒群 5、6 形成上述打磨面 4。

而且，如图 3 中所示，在上述金属基体 1 上设有调节机构 7，以便在各磨粒群 5、6 中以包含粒度最大的磨粒的前端的平面为基准面 S1、S2 时，可以任意调节在打磨面 4 上，上述多个磨粒群 5、6 中的各基准面 S1、S2 间相互的高低差 δ。

这里，没有必要一定在上述金属基体 2 上设置上述凹部 2a。

具体地说，上述调节机构 7 由基台 7a、调节用螺栓 7b 和垫片 7d 构成，其中，基台 7a 的表面上固定磨粒群 5 或 6，上下滑动自如地嵌入开口于上述金属基体 2 的表面 3 的凹部 7e; 调节用螺栓 7b 设在该基台 7a 的背面，螺纹配合于从上述金属基体 2 的凹部 7e 的底面向该金属基体 2 的背面侧贯通的螺纹孔 7c; 当调节固定于上述基台 7a 的磨粒群 5、6 处的基准面的高度位置时，垫片 7d 夹在上述基台 7a 的背面与上述凹部 7b 的底面之间。而且，分别固定于上述调节机构 7 的基台 7a 的表面上的多个磨粒群 5、6 沿着上述金属基体 2 的周缘部环状地并列设置，形成上述打磨面 4。

因而，为要调节上述磨粒群 5、6 的基准面 S1、S2 的高度位置把具有所需厚度的垫片 7d 放入上述金属基体 2 的凹部 7e 内，通过借助上述调节用螺栓 7b 夹持于该凹部 7e 的底面与上述基台 7a 的背面之间，可以调节上述各磨粒群 5、6 处的基准面 S1、S2 对金属基体表面 3 的高度位置，即多个磨粒群 5、6 处的各基准面 S1、S2 间相互的高低差 δ，可以调整打磨面 4 的状态。再者，在本实施方式中，借助调节机构 7，上述基准面 S1、S2 对金属基体表面 3 的高度可以在 0～300 μm 的范围内调节。

上述磨粒群当中，基准面高的磨粒群主要用于抛光布的磨耗，基

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准面低的磨粒群主要用于抛光布的表面粗糙度的调整。即，因为通过加在打磨器总体上的载荷集中地作用于基准面高的磨粒群，每单位面积的负载载荷增大，故它们主要用于抛光布的磨耗，另一方面，基准面低的磨粒群负担载荷到某种程度，使上述基准面高的磨粒群引起的抛光布的磨耗速度降低。再者，在基准面间相互的高低差δ变得极大的场合，因为成为基准面低的磨粒群完全不负担载荷，故成为它们不发挥使抛光布的磨耗速度降低的效果。此一基准面低的磨粒群还在抛光布的切削屑的排出中有效地起作用。

此外，在抛光布用打磨器 1 中，上述多个磨粒群 5、6 由彼此粒度不同的磨粒所形成的第 1 磨粒群 5 与第 2 磨粒群 6 来构成，这两种磨粒群 5、6 沿着上述金属基体 2 的周缘部在其圆周方向上交互地并列设置形成打磨面 4。

具体地说，上述第 1 磨粒群 5，如图 5、图 6 中所示，由大小两种粒度的磨粒 50、51 来形成，这些磨粒 50、51，如图 5 中所示，在基台 7a 的表面上即前述打磨面 4 上二维地有规则性地均等地排列，相互邻接的磨粒颗粒彼此造成的最小格子成为正三角形或者平行四边形地排列着。再者大的磨粒颗粒 50 彼此的间隔比小的磨粒颗粒 51 彼此的间隔要宽。

通过像这样把大小两种粒度的磨粒有规则性地均等地排列，可以进一步提高打磨的稳定性和均匀性。

另一方面，在上述第 2 磨粒群 6 中，虽然也可以以粒度与上述第 1 磨粒群 5 的磨粒不同的同一粒度的磨粒或者多种粒度的磨粒这两种形式中的任何一种来形成，但是最好是与上述第 1 磨粒群 5 同样，磨粒二维地有规则性地均等地排列。

这里，作为形成上述磨粒群 5、6 的磨粒，可以用例如金刚石磨粒，该磨粒的粒度，一般来说，最好是 JIS B 4130 中规定的#325／#400～#60／#80 的范围。

此外，形成上述第 1 磨粒群 5 的磨粒，没有必要一定如上所述是大小两种粒度的磨粒 50、51，也可以是同一粒度的磨粒（参照图 2A～

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图 2D 的实施方式）。此外，上述调节机构 7 没有必要一定在第 1 磨粒群 5 和第 2 磨粒群 6 的两方中设置，也可以仅在磨粒群的一部分，即第 1 磨粒群 5 或第 2 磨粒群 6 的一方中设置。在此一场合，未设置调节机构 7 的磨粒群，基台 7a 直接固定于金属基体 2 的周缘部。

这样一来，如果每个磨粒群用不同粒度的磨粒，或者在各磨粒群中使不同粒度的磨粒混合，大粒度的磨粒主要用于抛光布的磨耗，小粒度的磨粒主要用于抛光布的表面粗糙度的调整，通过它们的粒度的调整，可以把抛光布的表面粗糙度弄成适合特定对象物的 CMP 加工的状态。

进而，如图 1A～图 1D 中所示，在抛光布用打磨器 1 中，上述第 1 磨粒群 5 和第 2 磨粒群 6 的平面形状可以从小圆形状、成为与上述金属基体 2 的周缘即打磨面 4 的周缘平行的环形片形状、与上述金属基体 2 的周缘即打磨面 4 的周缘成一定角度的螺旋片形状之中选择一种或两种。图 1A 示出两个磨粒群 5、6 都是小圆形状的场合，图 1B 示出第 1 磨粒群 5 是小圆形状而第 2 磨粒群 6 是螺旋片形状的场合，图 1C 示出两个磨粒群 5、6 都是环形片形状的场合，图 1D 示出两个磨粒群 5、6 都是螺旋片形状的场合。通过把形成为这种平面形状的磨粒群 5、6 沿着金属基体表面 3 即金属基体 2 的周缘部排列成环状，形成打磨面 4，因打磨而去除的抛光布的切削屑或凝集的浆液容易向打磨器外部排出，此外可以调整其排出性能。

再者，上述磨粒群 5、6，如图 3、图 6 中所示，磨粒靠保持料 52 保持而形成，通过借助粘接剂 8 等把保持该磨粒的保持料 52 固定于上述调节机构 7 中的基台 7a 的表面，该磨粒群 5、6 固定于上述基台 7a。

此外，作为上述保持料 52，虽然在磨粒为金刚石的场合，可以利用和金刚石磨粒反应烧结的硅和／或硅合金，但是只要是适合于磨粒的保持的保持料没有特别限制，靠一般的电镀镍或借助钎料的接合来保持也是可能的。

接下来就对由上述抛光布用打磨器 1 进行的抛光布的打磨方法进行说明，借助上述调节机构 7，在交互邻接的第 1 磨粒群 5 和第 2

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磨粒群 6 的各基准面 S1、S2 间，设定对金属基体表面 3 的一定的高低差 δ，打磨上述抛光布。换句话说，借助上述调节机构 7，调节成上述第 1 磨粒群 5 的基准面 S1 一方比上述第 2 磨粒群 6 的基准面 S2 上述金属基体表面 3 的垂直方向的高度高出一定量 δ，通过适当调整上述打磨面 4 的状态，可以把上述抛光布表面打磨成适应被加工物的想要的状态。

像这样如果用上述抛光布用打磨器 1，则因为通过调节基准面 S1、S2 的高低差 δ，可以把打磨面 4 的状态调节成可以发挥想要的抛光性能，故不仅即使在打磨面 4 的状态中产生个体差异，也可以造成均一的抛光布表面，而且可对抛光布表面赋予适应被加工物的适当的抛光性能。

图 2A～图 2D 示出本发明的抛光布用打磨器的磨粒群的配置形状不同的第 2 实施方式。在本实施方式的抛光布用打磨器 10 中，多个磨粒群仅由上述第 1 磨粒群 5 组成，通过把这些同一的磨粒群 5 沿着金属基体 2 的周缘部并列设置成环状而形成打磨面 4。

此外，该磨粒群 5 的平面形状，与上述第 1 实施方式的场合同样，可以从小圆形状、成为与上述打磨面 4 的周缘平行的环形片形状、与上述打磨面 4 的周缘成一定角度的螺旋片形状之中选择。图 2A 示出磨粒群 5 全都是小圆形状的场合，图 2B 示出磨粒群 5 为小圆形状和螺旋片形状，具有这两种不同的平面形状的磨粒群 5 在打磨面 4 的圆周方向上交互地并列设置的场合，图 2C 示出磨粒群 5 全都是环形片形状的场合，图 2D 示出磨粒群 5 全都是螺旋片形状的场合。

关于包含调节机构 7 的其他构成，因为与上述第 1 实施方式共同，所以为了避免重复这里省略说明。

而且，在用上述抛光布用打磨器 10 打磨抛光布时，如图 4 中所示，借助调节机构 7 在相互邻接的上述磨粒群 5 的基准面 S1 间设定对金属基体表面 3 的一定的高低差 δ 并进行打磨。

像这样如果用上述抛光布用打磨器 10，则与上述抛光布用打磨器 1 同样，因为可以适当调节上述邻接的磨粒群 5 的基准面 S1 间的

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高低差δ而把打磨面 4 的状态调整成想要的状态，故不仅即使在打磨面 4 的状态中产生个体差异，也可以造成均一的抛光布表面，而且可对抛光布表面赋予适应被加工物的适当的抛光性能。

再者，上述调节机构 7 本身的构成，不限于参照图说明的上述构成，可以采用在微细的范围内可以上下调整磨粒群的基准面的各种机构。

以下与比较例一起具体地示出本发明的抛光布用打磨器和使用该打磨器的抛光布的打磨方法的实施例。但是，本发明不受这些实施例的任何限定。

〔第 1 实施例〕

作为第 1 磨粒群 5 的磨粒，分别用相当于粒度#120／#140 的处于 150～170 μm 的范围的金刚石磨粒 50，与相当于粒度#325／#400 的处于 55～65 μm 的范围的金刚石磨粒 51，通过把这些磨粒 50、51 与保持料 52 反应烧结，得到磨粒 50、51 被保持于保持料 52 的烧结体。

此时，把上述两种磨粒 50、51 在磨粒排列面上排列成，包含粒度#120／#140 的磨粒 50 的前端的平面，与包含粒度#325／#400 的磨粒 51 的前端的平面的级差为 40～60 μm，并且邻接的磨粒 50、51 彼此造成的最小格子为正三角形，粒度#120／#140 的磨粒 50 的间隔为 2.0 mm 的等间隔，粒度#325／#400 的磨粒 51 的间隔为 0.4 mm 的等间隔。

另一方面，作为第 2 磨粒群 6 的磨粒，用相当于粒度#60／#80 的处于 250～320 μm 范围的金刚石磨粒，把这些排列成 0.8 mm 的等间隔。

而且，在把这样做所得到的烧结体通过机械加工，加工成规定的尺寸·形状，形成第 1 磨粒群 5 和第 2 磨粒群 6 后，把这些磨粒群 5、6 分别用环氧树脂粘接于调节机构 7 中的 SUS316L 不锈钢制的直径φ100 mm 的基台 7a 上。再者，在本实施例中，把上述第 1 磨粒群 5 和第 2 磨粒群 6 的平面形状取为图 1D 中所示的与打磨面 4 的周缘成

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一定角度的螺旋片形状。

把这样做成的抛光布用打磨器以 19.6kPa 的压力压在以 100 rpm 旋转的泡沫聚氨酯制抛光布上，与该抛光布同一方向以 80 rpm 旋转，同时一边供给每分 25 ml 包含湿二氧化硅的抛光浆液（キャボット制 SS－25）一边进行抛光布的研磨。

此时，借助上述调节机构 7 把前述打磨面 4 上的前述第 1 磨粒群 5 的磨粒前端基准面 S1 与前述第 2 磨粒群 6 的磨粒前端基准面 S2 对金属基体表面 3 的高低差 δ 调节成 15、30、60μm 三个水准，测定打磨速度（抛光布的磨耗速度）与抛光布的表面状态（抛光布的表面粗糙度）后，测定用该抛光布的晶片的抛光速度，这些测定结果示于表 1。

再者，在本实施例中，n 数即取样数取为 20，算出在各试样中所测定的上述各测定值的平均值（Ave）示于表 1。而且表 1 中 σ_{n-1} 表示各测定结果的标准偏差。此外，在晶片的抛光速度的测定中用 ADE 公司制的晶片平坦度测定器（ultragage 9800），根据抛光前后的测定结果算出平均抛光速度。

表 1

			实施例		
磨粒间隔	第 1 磨粒群	#120／#140	2.0 mm		
		#320／#400	0.4 mm		
	第 2 磨粒群	#60／#80	0.8 mm		
磨粒基准面的高低差 δ（μm）			15	30	60
抛光布的磨耗速度（μm／Hour）		Ave.	69.2	108	122
		σn－1	1.33	1.25	1.78
抛光布的表面粗糙度 Ra（μm）		Ave.	4.12	4.05	4.19
		σn－1	0.12	0.15	0.14
晶片抛光速度（nm／min）		Ave.	126	129	121
		σn－1	6.7	7.2	5.6
划痕发生率（%）			0.00	0.00	0.00

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如此一表 1 中所示，如果用本发明的抛光布用打磨器，则可以调节多个磨粒群中的磨粒的粒度或各磨粒群基准面间的高低差 δ，把打磨面调整成想要的状态，特别是，弄清了通过上述磨粒群的基准面的高低差 δ 磨耗速度有很大差别。因此，借助一个抛光布用打磨器可以在种种条件下进行稳定的抛光布的打磨。

此外，如果用上述实施例的测定值，则与以下说明的比较例的测定值相比总体上性能提高，而且因为各种测定值的标准偏差非常小，所以所得到的抛光布中离散极小，可以给抛光布用打磨器赋予稳定的抛光性能。

〔第 1 比较例〕

用把粒度相当于#80／#100 的处于 210～250 μm 的范围的金刚石磨粒以磨粒间隔 0.25 mm 的等间隔地排列的状态，使用由电镀镍固定而成的现有技术中的 CMP 抛光布打磨器，在与第 1 实施例同一条件下研磨泡沫聚氨酯制抛光布。其研磨结果示于表 2。

〔第 2 比较例〕

用把粒度相当于#120／#140 的处于 150～170μm 的范围的金刚石磨粒，在烧结体的磨粒排列面上，排列成邻接的第 1 磨粒彼此造成的最小格子为正三角形，其一边的磨粒间隔成为 2.1 mm 的等间隔，使用由该磨粒组成的磨粒群的平面形状为，如图 2C 中所示的，与打磨面的周缘平行的环形片形状的抛光布用打磨器，在与第 1 实施例同一条件下研磨泡沫聚氨酯制抛光布。其研磨结果与第 1 比较例一起示于表 2。

〔第 3 比较例〕

与第 1 实施例的第 1 磨粒群同样，分别用粒度相当于#120／#140 的处于 150～170 μm 的范围的金刚石磨粒，和粒度相当于#325／#400 的处于 55～65 μm 的范围的金刚石磨粒。而且，把这些磨粒，在烧结体的磨粒排列面上排列成包含粒度#120／#140 的磨粒的前端的平面，与包含粒度#325／#400 的磨粒的前端的平面的级差成为

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40～60 μm，并且邻接的磨粒彼此造成的最小格子为正三角形，粒度#120／#140 的磨粒的间隔为 2.0 mm 的等间隔，粒度#325／#400 的磨粒的间隔为 0.4 mm 的等间隔。而且，用具有这种磨粒排列的磨粒群，形成为图 2C 中所示的成为与打磨面的周缘平行的环形片形状，在打磨面中沿着金属基体的周缘部环状地排列而成的抛光布用打磨器，在与第 1 实施例同一条件下研磨泡沫聚氨酯制抛光布。其研磨结果与第 1、2 比较例一起示于表 2。

表 2

		第 1 比较例	第 2 比较例	第 3 比较例
金刚石粒度		#80／#100	#120／#140	①#120／#140 ②#325／#400
磨粒间隔		0.25 mm	2.1 mm	①2.1 mm ②0.4 mm
磨粒保持方法		电镀	烧结	
抛光布的磨耗速度（μm／Hour）	Ave.	61.6	189	138
	σn－1	7.84	14.6	2.43
抛光布的表面粗糙度 Ra（μm）	Ave.	3.01	3.32	3.45
	σn－1	0.36	0.36	0.13
晶片抛光速度（nm／min）	Ave.	105	98.3	120
	σn－1	35.2	25.3	9.6
划痕发生率（%）		0.52	0.00	0.00

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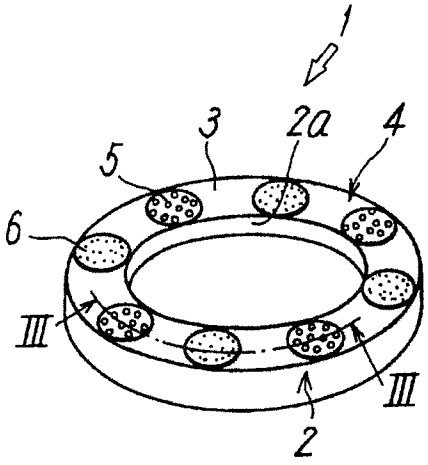


图 1A

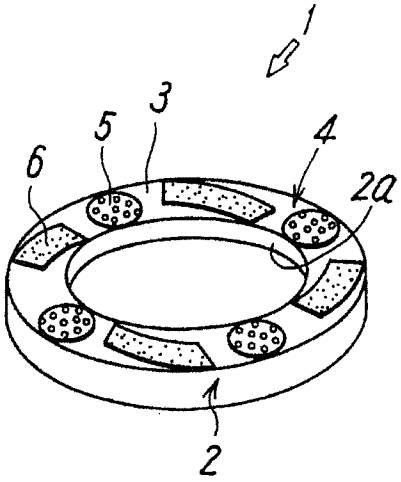


图 1B

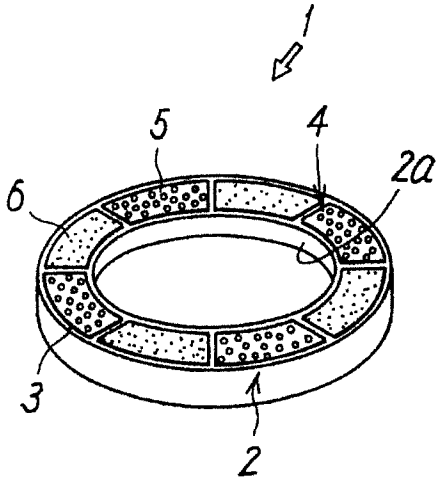


图 1C

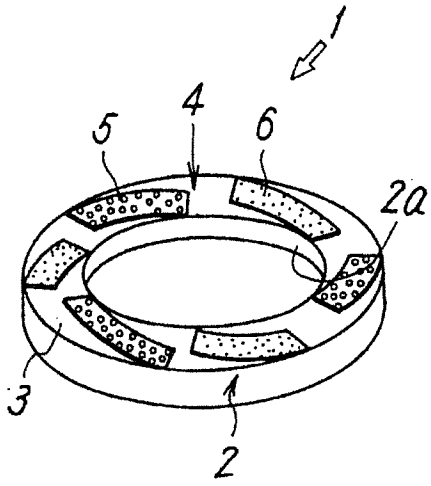


图 1D

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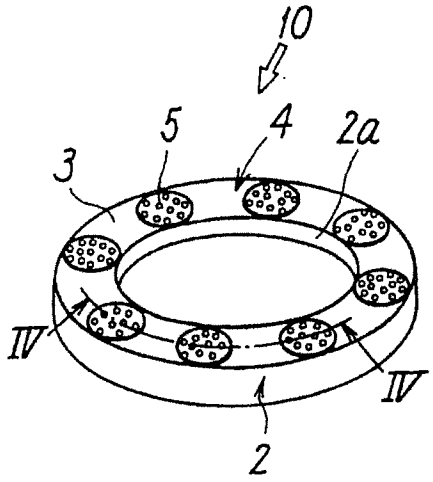


图 2A

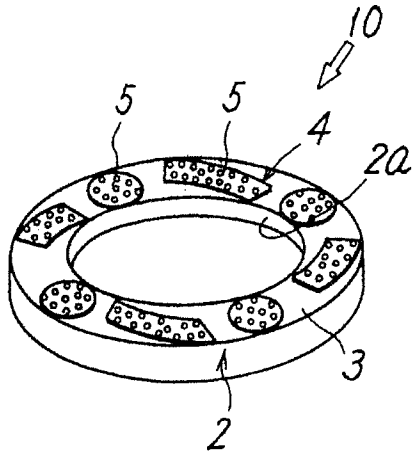


图 2B

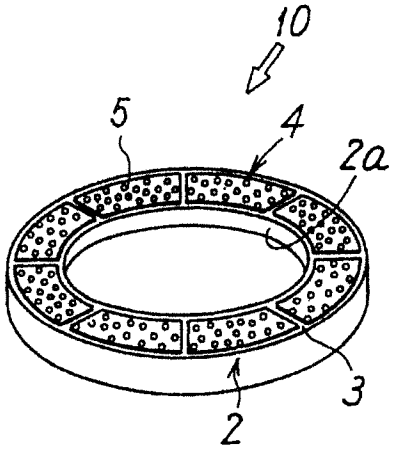


图 2C

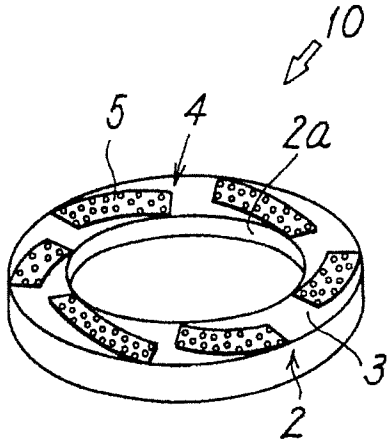


图 2D

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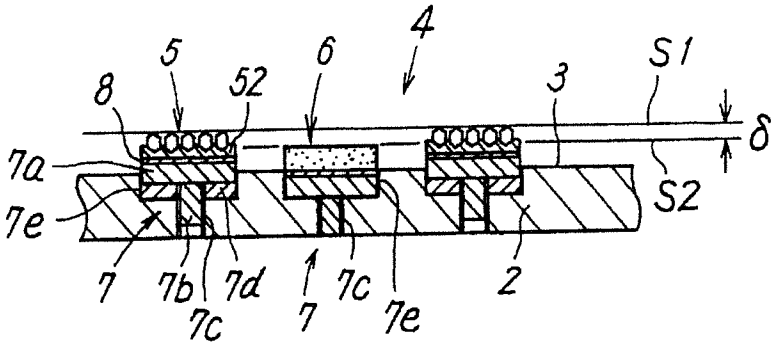


图 3

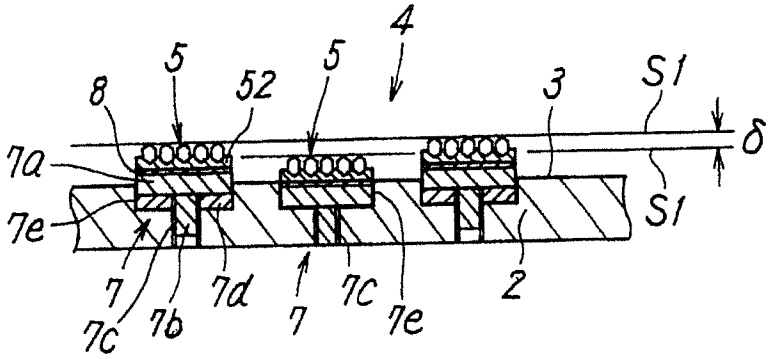


图 4

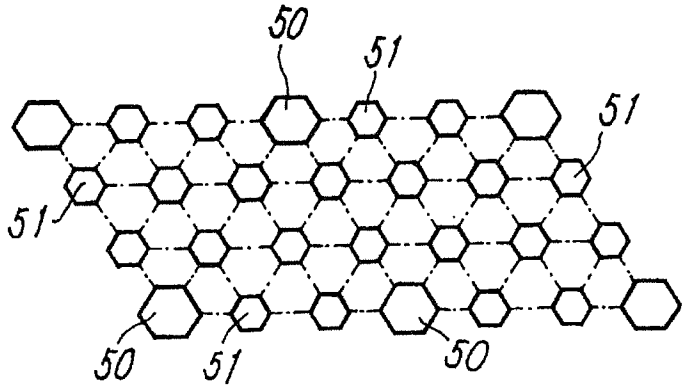


图 5

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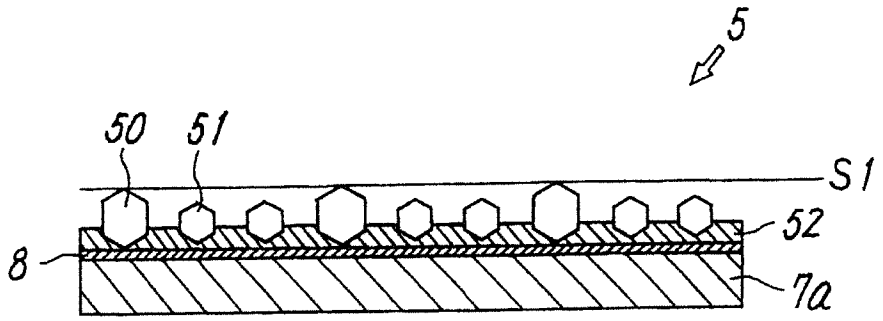


图 6

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(54) Low pressure bonding of PCD bodies and method.

(57) A temperature stable diamond product (30) having a temperature stability up to about 1,200°C comprising a metal matrix carrier, at least one diamond piece (31a-31f) of a predetermined geometrical shape and which is temperature stable up to about 1,200°C having at least one surface (41) contacting at least a portion of said carrier (32), each diamond piece (31a-31f) being coated with a metal which is a carbide former on at least the portion thereof contacting said metal matrix carrier, said carbide forming coating being of a thickness of at least about 1 micron and including a relatively thin portion of a carbide material adjacent to said portion thereof contacting said diamond piece, and said temperature stable diamond product (30) being characterized by a chemical bond between said temperature stable diamond and said coating and said coating and the portion of said matrix carrier (32) which is in contact with said coating.

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LOW PRESSURE BONDING OF PCD BODIES AND METHOD

Field of Invention

The present invention relates to an improved synthetic diamond product and method of making the same and more particularly to an improved and novel temperature stable diamond assembly which may be of a variety of sizes, shapes, and thickness, the diamond assembly being formed by an improved and novel bonding method which does not require the comparatively high temperatures and pressures normally used in the synthesis of synthetic diamond products thus to provide a diamond assembly which may be relatively large and in which the diamond, preferably in the form of a temperature stable synthetic polycrystalline diamone, is firmly and chemically bonded on or to a support structure.

Background of the Invention

Various types of synthetic diamond products are known and commercially available. Typically such products are used industrially for material removal purposes, for example drilling products such as core bits, mining bits, drilling bits for oil and gas, saw products, cutting tools, grinding wheels, and products such as wire-drawing and extruding dies, bearing surfaces, dressers, lead bonding tools and abrasives.

These synthetic diamond materials may vary somewhat in their character, one being an unleached polycrystalline product having a temperature stability of up to about 700-750 degrees C., see United States Patents 3,745,623 and 3,608,818. This synthetic diamond product itself is usually formed by diamond-to-diamond bonds and is carried on a substrate which may be cemented tungsten carbide, for example. The substrate is usually preformed and contains cobalt, the diamond product being formed and affixed to the substrate at very high temperatures and pressures, usually referred to as the diamond stable region of temperature and pressure, as set forth in prior patents and other literature, and typically above 50 kbar and at a temperature above 1,200 degrees C.

In this processing the cobalt in the substrate is used as a binder for the tungsten carbide and as a solvent/catalyst for the formation of diamond-to-diamond bonds. The presence of cobalt results in somewhat limited temperature stability of the diamond as noted. It is not uncommon to refer to these products as polycrystalline diamond products (PCD) as contrasted to single crystal diamonds.

PCD elements offer the advantage that upon fracture, only a relatively small fragment of the PCD element is lost as compared to a single crystal diamond in which fracture takes place along a plane with the possibility of losing a relatively large piece of the diamond.

Unleached PCD elements may be formed with the high temperature and high pressure apparatus as disclosed, for example, in United States Patent 2,941,248. PCD products thus far described are available in varoius sizes and shapes, for example circular, half-circles, quarter round, square, rectangular, half-rounds with a pointed section, and the like. The PCD face or disc, joined to a bacing member of tungsten carbide or the like is sometimes mounted, by brazing, on a steel tool body or tungsten carbide slug support. The PCD materials may be as small as several millimeters to as large as 50 millimeters in diameter, see for example United States Patent Application Serial Number 906,169, filed September 11, 1986, and assigned to the same assignee (CHP 6149).

Inclusions such as cobalt, iron or nickel present in unleached PCD elements as residual material initially used as solvents/catalysts in the synthesis of the PCD tend to reduce the temperature stability of the PCD to well below 1,200 degrees C., for example, to about 750 degrees C.

The fabrication of the larger diameter materials requires rather large and expensive processing equipment capable of generating high pressures and temperatures. The temperatures and pressures are those in the diamond forming region of the phase diagram for carbon, see for example United States Patents 4,108,614 and 4,411,672. The length of the substrate or backing is a limitation since the processing equipment must be capable of fabricating a diamond facing on a rather long piece which takes up room in the press. The result is that in at least one instance, the length of the backing, axially to the rear of the PCD face, is rather short and after formation, a longer tungsten carbide member or member of other material is attached to the formed product by any one of several well known procedures, and as described in United States Patent 4,200,159, for example.

In one typical use of these products, for example in oil and gas drilling bits and core bits, the usual practice is to form the bit body and thereafter to mount the PCD cutting element in the bit body. The bit body may be steel and the PCD cutter is a slug type cutter which is press fitted into apertures in the bit body. These procedures are well known. The difficulty with the use of steel bodies is that the body and/or the cutter assembly may be sub-

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ject to erosion by the relatively abrasive flow of the drilling fluid used to clean and cool the bit. Thus, the practice has been to hard face the steel body or to use a carbide slug. In the case of matrix body bits which offer erosion resistance, the practice has been to mount the PCD cutter, normally having an added backing or of a sufficiently long length integrally formed as one piece, by brazing the cutter to the matrix body. One of the problems associated with this procedure, in addition to the increased cost, is the desire to use a relatively high temperature braze material and the need to keep the PCD face cool to prevent thermal damage (above about 750 degrees C.) to the cutter face during the brazing operation. Even so, a large number of bits have been made as described by a variety of bit manufacturers.

Another commercially available form of PCD, sold under the mark GEOSET, is an unbacked leached product, see United States Patents 4,224,380 and 4,288,248, which has a temperature stability of up to 1,200 degrees C., but which may have a porosity of up to about 15% and may not be as impact resistant as desired in a particular application. The temperature stability of these PCD products offers the advantage that they can be processed during the infiltration of the matrix material used to form the bit body and may be exposed to the relatively high tempeatures used during the infiltration procedure without degradation of the PCD, thus eliminating the need for brazing. In general, temperature stability is also an advantage in the cutting action of the PCD during use. For the purposes of this invention, temperature stability means that the PCD element, regardless of type, is stable to about 1,200 degrees C. without significant deterioration in its properties and will be referred to herein as TSPCD. Typical temperature stable leached PCD material is available under the trademark GEOSET, which cobtains porosity.

Temperature stable PCD elements are known which are not porous and are not leached. A typical such material, available under the trademark SYNDAX-3 is a PCD in which silicon is present in the form of silicon carbide.

Significantly, the TSPCD materials are not commercially available as backed products, as contrasted to the previously described low temperature products. The TSPCD materials are available as unbacked materials in a wide variety of shapes and sizes, for example, triangular, square, cylindrical with flat ends or pointed at one end, round discs, rectangular, ovoid, and the like. These products may also be cut to form other shapes by using a laser or other means.

While temperature stability is not required in all uses, there are many applications in which it is required. Further, there are processing steps such as brazing in which the PCD part may be exposed to temperatures above 750 degrees C. In these instances it is necessary to cool the PCD part or to otherwise prevent it from being exposed to the higher temperature. As a result, there are limitations in the processing of such unstable PCD products which tend to limit the use thereof.

TSPCD elements, are available in a limited range of sizes that are generally too small for individual use in many applications. To overcome this problem, TSPCD elements have been formed into a mosaic type of structure in which the individual TSPCD elements are mounted and mechanically affixed in a support structure, e.g., a hot-pressed segment or the like, see United States Patent Applications Serial Number 797,058; 794,569 and 797,569, filed respectively on November 14,1985, November 4, 1985 and November 13,1984, and all assigned to the same assignee as this application.

While these mosaic structures have been operated satisfactorily and provide a large PCD cutter having temperature stability, the mosaic elements lack the advantages of the large one piece PCD cutters (up to 50 mm diameter or more) which are not temperature stable but which have been used in oil and gas drill bits and core bits. Even though the bits using the mosaic cutters avoid the necessity of having to braze the mosaic into the matrix of the bit, the mosaic cutters do not function as a large one piece PCD with the result that the individual mechanically mounted TSPCD elements can be broken free of the supporting structure. A mechanical type of mounting also limits the shape and size and contour of the cutter, even though the assembly is temperature stable.

Another problem with mosaic cutters is that bending stresses tend to cause release of the mechanically mounted TSPCD elements. Moreover, unlike a large integral brazed PCD cutter of the same size in which only small portions of the PCD are fractured off during use, the tendency in the mosaic cutters is to release the TSPCD elements as the supporting structure around the TSPCD is abraded away and support for the TSPCD is reduced, i.e., the individual TSPCD element is lost rather than losing on a small fragment.

In general there is a need for a TSPCD containing product in which one or more TSPCD elements are firmly anchored or locked into or mounted on a suitable support, which optionally may be mounted to another structure. It is desirable to

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mount one or more of such TSPCD elements by more than merely a mechanical mounting, and preferably it is desired that the mounting be by a firm chemical bond.

United States Patent 3,650,714 of March 21, 1972, issued to Farkas, describes a method for coating natural single crystal diamond particles in the range of 200 to 250 mesh with either titanium or zirconium. The coating is applied from dry powder, the resultant material is then heated in a graphite mold, under vacuum conditions for between 10 and 15 minutes at a temperature in the range of 850 to 900 degrees C. The relatively low temperature of heating to form a carbide at the interface indicates that the titanium or zirconium coating is quite thin. The result is said to be a coated diamond particle in which the coating is about 5% by weight of the resultant product and in which a carbide is formed at the interface, with the outer surface of the coating being non-carbided. The calculated thickness of the coating is about 0.445 of a micron for 200 mesh material and 0.344 of a micron for 250 mesh material. Since subsequent processing in an oxidizing atmosphere would result in the formation of an oxide which is not easily wetted by other materials, the coated natural diamond particles are overcoated with either nickel or copper with a film thickness of between 0.002 and 0.005 of an inch (between 50.8 and 127 microns thick). This outer coating is said to serve as a protective coating to prevent oxidation of the titanium or zirconium or their carbides during subsequent processing under oxidizing conditions. The subsequent processing described is hot or cold pressing and subsequent sintering or infiltration with brazing alloys.

An important difficulty with the above procedure and the resulting product is that the carbide containing coating is quite thin, substantially less than one micron, with the result that under certain types of subsequent processing such as with the use of liquid binders in infiltration, as for example in the formation of an infiltrated matrix for earth boring bits, the liquid binder penetrates the protective coating and the relatively thin carbide containing coating. The problem would be particularly acute with PCD elements since their surface is rather "rocky" and irregular and includes a certain amount of surface porosity. Thin coatings such as described in Farkas would contain substantial imperfections and voids that would permit the liquid infiltrating binde to attack the carbide interface between the PCD and the coating and to separate the coating from the PCD In addition, the processing of such coated diamonds, whether PCD elements or natural, in an oxidizing atmosphere is not practical since any imperfection or dissolution of the outer nickel or copper coating, for instance by the action of the liquid binder, would result in the oxidation and destruction of the underlining titanium and titanium carbide layer.

Also known in the prior art are products which might generically referred to as diamond impregnated products. Typically these products are composed of natural or synthetic diamond particles which may be of a variety of mesh sizes. Whereas a large integral PCD element may be between 70% and 97% by volume of diamond material, depending upon the processing, the amount of residual inclusions or porosity, the impregnated products generally have a much lower volume percent of diamond, typically less than 40%. The result is that the impregnated product performs better as an abrasive or cutting element than does the same material without the diamond grit, but the problem is that the small diamond particles are easily lost as the surrounding supporting structure is abraded away. To improve the retention of the diamond grit in the supporting structure it has been proposed to coat the particles of the grit with various metals such as tungsten, tantalum, columbium, niobium or molybdenum, and the like by chemical vapor depostion techniques using a fluidized bed procedure, see for example United States Patents 3,871,840 and 3,841,852. The products there described are about 25% by volume of diamond grit of particle size from 40 to 100 mesh and represent an improved impregnated product in contrast to an improved large diamond product. The coated diamond grit is formed into various shapes by a hot pressing procedure or by infiltration at an elevated temperature.

Coatings have also been used to form diamond products as contrasted to impregnated products. For example, United States Patent 3,879,901 describes the vacuum deposition of a metal such as molybdenum or titanium on diamond materials with subsequent processing at 60 Kbar and between 1,200 and 1,400 degrees C. to form a diamond product in contrast to a diamond impregnated product. In another instance, see United States Patent 4,378,975, an abrasive body with diamond is formed by forming a green body by cold pressing with a nickel based alloy. The green body is then sintered at 950 degrees C. with a diamond volume of between 10% and 40 % by volume.

It is also known in the sintering of synthetic diamond to use a thin coating of between 300 and 6,000 Angstroms of a strong carbide former, with a second coating of copper with subsequent processing at 5 Kbar at a temperature of 600 to 700 degrees C. in an inert atmosphere, see United States Patent 3,356,473. In United States Patent

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3,464,894 it is proposed to form a chemically bonded coating of titanium such that a titanium-carbon bond is formed followed by processing at 62,000 atmospheres of pressure.

In general, the coating procedures of the prior art are related to pretreatment of diamond forming materials which are thereafter processed at relatively high temperatures and pressures to form a diamond element or to form a coating on diamond grit used to form an impregnated product in which the volume of diamond is well below about 50% by volume.

The provision of improved methods for the fabrication of large TSPCD products, which are temperature stable in the range of about 1,200 degrees C. and which may be fabricated at lower pressures and temperatures than have been used in the synthesis of diamond products, would have unique advantages. For example, the cost for fabrication equipment is vastly reduced as well as the cost for each of the products. The ability to fabricate various shapes and sizes and thickness, i.e., to be free of the shape and size limitations of high-temperature and high pressure equipment, would also offer advantages from a processing and application point of view.

One of the significant advantages of the present invention is the ability to fabricate a TSPCD product of a particular configuration and in which the TSPCD starting element or elements are firmly anchored in place. For example, the use of a TSPCD structure in accordance with this invention in various types of cutting tools and lead bond tools as may be used in semiconductor chip processing to form electrical connections to the chip elements through accurate control and positioning of a heated TSPCD faced lead bond tool, or in diamond tracing tools, for example, offers unique advantages as compared to current practices.

Thus, it is an object of this invention to provide a temperature stable diamond product of various sizes and shapes and capable of being used in various products, but which is substantially less expensive than the diamond products currently available and which may be firmly bonded to a supporting structure.

Another object of this invention is to provide an improved and novel process using relatively low temperatures and pressures for the fabrication of a diamond product from smaller temperature stable diamond elements in which the diamond product is temperature stable.

Still another object of this invention is the provision of an improved relatively low temperature and relatively low pressure process for the formation of a temperature stable diamond product.

Yet another object of this invention is the provision of an improved temperature stable diamond cutting element for us in earth boring and core bits which is less expensive than comparable sized elements and which may be fabricated at relatively low temperatures and pressures into shapes and sizes not presently economically feasible.

It is also an object of this invention to provide a mor effective method and means of attaching a temperature stable PCD to a tool or supporting body.

Another object of this invention is to bond TSPCD elements by a chemical bond so that they can be firmly attached to a tool body.

Yet another object of this invention is to bond TSPCD elements to form a specific pattern of cutting elements so that the wear mechanism, such as regenerating sharp cutting edges as the cutter wears, can be controlled.

It is also an object of this invention to form an improved diamond product in which the bonded PCD pieces form an integral part rather than a collection of individual elements.

It is also an object of this invention to provide a strong substrate backing to TSPCD, in which the properties of the backing can be adjusted to suit specific applications.

Brief Description of the Invention

In accordance with the present invention, a temperature stable synthetic polycrystalline diamond (PCD) product is provided which is fabricated from smaller TSPCD elements by improved relatively low pressure and low temperature procedures.

In general the products of the present invention may be formed by either liquid state infiltration or solid state sintering to affix a relatively thin PCD element on a hard ceramic substrate. The method includes the common steps of coating a temperature stable polycrystalline diamond element with a selected carbide former, preferably one which is stable against oxidation, arranging the coated elements in a mold in a predetermined relation with each other. Thereafter, a hard ceramic powder such as tungsten carbide powder containing an organic binder is placed over and around the assembled coated TSPCD elements. The powder is preferably monosized, although bimodial sizes and mixtures may be used.

The resulting assembly is cold pressed to compact the powder to about 50 volume percent, i.e., about 50% of the volume is porosity which will later be filled up by sintering or infiltration. The thus pressed assembly may then optionally be cold

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isostatic pressed to increase the volume percent of the powder to about 60-65%. The cold isostatic pressed part has sufficient integrity to be handled and machined, if that is needed.

Thereafter if liquid state infiltration is used, the formed part is first heated to vaporize off the organic binder and then infiltrated preferably in a vacuum or under inert or reducing atmosphere with a metal binder which melts and fills the voids in the hard ceramic powder and binds it together. The infiltration also causes the metal binder and powder to bond metallurgically to the coating of the TSPCD since the binder wets the outer portion of the coating which partially dissolves in or reacts with the binder for the matrix or matrix carrier powder to form a solid solution of binder and coating metal at the interface. The binder is fluid or near fluid at this point in the processing. It is believed that the bond from the coating is through the binder for the matrix carrier powder.

The metal binder is preferably one which has a melting point within the temperature stable range of the TSPCD and which possesses strength and toughness. In this operation, the coated TSPCD elements are bonded together into a unitary assembly of a TSPCD. The infiltration is carried out at a temperature below the thermal degradation temperature of the TSPCD elements, above the melting point of the binder, and below the melting point of the metal of the coating. In accordance with the invention, a thin carbide layer is formed at the interface between the TSPCD and the carbide former coating. This carbide layer may be formed either before the powder is placed around the elements by heating the elements under carbide forming conditions or simultaneously with the infiltation or sintering. In either case the heating is controlled to promote formation of a relatively thin carbide layer on that portion of the surface of the TSPCD which has been coated by the carbide former. During the controlled heating, under carbide forming conditions, carbon diffuses from the PCD into the coating to form a carbide.

During the heating, it is believed that the temperature used to form the carbide is more important than the rate of heating. The evidence suggests, in the case of a tungsten coating for example, that the coating on the diamond can form a carbide above about 950 degrees C. and preferably at about 1,100 degrees C. no matter how fast the heating is conducted. Thus, heating at 1,100 degrees C. for about 15 minutes is normally sufficient. A longer time of heating at 1,100 degrees C. can increase the thickness of the carbide, but in general longer heating periods at high temperatures may damage the diamond because of too much carbide formation and results in an ineffective chemical bond being formed. If the heating is excessive, the result is that more and more of the carbon from the TSPCD diffuses into the coating with possible damage to the PCD. Thus, while the dimension of the thickness of the coating of the carbide forming metal may vary within wide limits, the dimension of the carbide coating, for a single coating which is stable against oxidation, such as tungsten, should be in the range of at least about 1 micron and up to about 15 to 30 microns, for reasons which will be discussed.

The thickness of the carbide forming metal coating may be as low as one micron, although coating thicknesses above about 3 microns provide stronger bonding strength. Films of above about 30 microns in thickness may be used, but increasing the thickness above about 30 microns does not seem to increase bond strength appreciably over the strengths achieved in the range of 10 to about 30 microns. Film thicknesses of 1 to about 3 microns are acceptable in some applications, but substantially increased bond strength is achieved above about 3 microns fot the binder system tested. Coatings of less tha about 1 micron tend to result in unacceptable separating of the coating from the TSPCD element during infiltration or sintering.

The resulting product of the invention has a chemical bond from the TSPCD to the coating to the matrix carrier. The term "matrix carrier" as used herein describes the powder and binder material which is placed around or in contact with the TSPCD element or elements and which is processed in accordance with this disclosure. The matrix carrier is to be distinguished from the more generic term "matrix" which generally refers to the supporting structure in which the matrix carrier is mounted, for exaple a drill bit body. the term "chemical bond" is used herein to refer to the strong bonds that are formed between the diamond and the metal coating through the medium of the carbide layer at the interface, and between the exterior surface of the metal coating and the matrix carrier. While not fully understood, it is believed that the former is an atom to atom level bond between the carbon of the diamond and the carbide layer. The latter is believed to be a metallurgical bond in which the binder alloy used in the liquid state infiltration or with the sintered material of the matrix carrier if solid state sintering is used. This contrasts sharply with the mechanical bonds that were formed in the prior art systems.

The term "diamond product" used herein and in the claims includes cubic boron nitride.

A solid state sintering operation (also referred to as tungsten powder activated sintering) may also be used to bind the TSPCD element to the matrix carrier. This operation involves vacuum sintering or sintering in a controlled atmosphere or hot pressing

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or hot isostatic pressing of the cold pressed part. If processed by solid state sintering, the materials used for coating and for the backing and the like have to be adjusted to reflect the different but related processing. Here again, if the formation of the carbide layer is simultaneous with the sintering operation, control of the heating and the duration of the heating is such that a relatively thin carbide layer is formed. Since this form of processing does not use a binder for matrix carrier formation, a portion of the coating wets the powder and bonds to the powder during sintering, again forming the chemical bond described. In the case of solid state sintering of tungsten, it is preferred to use a sintering activator such as nickel or nickel-iron. The activator is placed around the tungsten particles and promotes the sintering of the matrix carrier and the bonding to the coating of the TSPCD.

Various shapes and sizes may be formed in accordance with the present invention, and the testing thereof indicates that the bond between adjacent TSPCD elements is stronger than that which may be achieved through merely mechanical mounting of the TSPCD part or parts in a support matrix carrier.

The methods described above permit the formation of a wide variety of shaped cutting elements for use in various cutting and abrading devices. Large and shaped diamond bearings may be fabricated. The larger or shaped TSPCD product of this invention may be processed with a backing or supporting element of a variety of shapes and configurations and compositions. Relative thick and shaped TSPCD products may be fabricated at relatively low pressures and temperatures. In general, however, the principal advantage of this invention is the ability to provide a TSPCD structure in which one or more TSPCD elements are firmly anchored in a support structure by a bond which is significantly stronger than a mere mechanical mounting. The result is that the assembly of several TSPCD pieces in the form of a predetermined pattern will result in action of the part as one large diamond rather than as a plurality of diamonds held together as an aggregrate.

Brief Description of the Drawings

Figure 1 is a flow chart depicting the steps in formation of a TSPCD product in accordance with the present invention;

Figure 2 is a plan view of one form of a TSPCD product in accordance with the present invention;

Figure 3 is a side view as seen along the line 3-3 of Figure 2;

Figure 4 is an enlarged fragmentary view illustrating the bonding path between adjacent TSPCD elements in accordance with this invention;

Figure 5 is a view in perspective of a TSPCD product having a single TSPCD element in accordance with this invention;

Figure 6 is a plan view of one form of bearing in accordance with this invention;

Figure 6a is a sectional view taken along the line 6a-6a of Figure 6;

Figure 7 is a view in perspective of a dressing tool in accordance with the present invention;

Figure 8 is a plan view of a saw blade segment in accordance with this invention;

Figure 8a is a sectional view as seen along the line 8a-8a of Figure 8;

Figure 9 is a sectional view of a lead bonding tool in accordance with this invention;

Figure 10 is a plan view of a TSPCD product in accordance with this invention in which a multiplicity of individual elements is bonded together into a larger TSPCD structure;

Figure 11 is a perspective view of another form of TSPCD product in accordance with this invention;

Figure 11a is a view, partly in section and partly in elevation, illustrating the mounting and use of the product illustrated in Figure 11;

Figures 12a to 12d are diagrammatic views of various structures and the test protocol for three point testing;

Figure 13 is a view in perspective of another form of TSPCD product in accordance with this invention;

Figure 13a is a view similar to that of Figure 13 but illustrating a modified form of product in accordance with this invention;

Figure 14 is a view in section illustrating still another form of product in accordance with this invention;

Figure 15 is a view, in persepctive, of a twist drill in accordance with the present invention;

Figure 16 is a view in perspective of still another product in accordance with this invention;

Figure 17 is a perspective view of one form of earth boring bit in accordance with this invention, and

Figure 18 is an enlarged fragmentary view of the cutters illustrated in Figure 17 and produced in accordance with this invention.

Detailed Description of the Invention

In accordance with this invention the starting diamond material is preferably a temperature stable polycrystalline diamond material composed of aggregate diamond particles having a size in the

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range of submicron to over 100 microns, for example, although the particle sizes need not be uniform; i.e., mixtures of particles of the sizes indicated may be used as is known in the art. The TSPCD should contain at least 60% by volume of diamond aggregates, as described, and the product may be leached or unleached with some diamond to diamond bonding or diamond to metal bonding in the assembly. For products to be used in cutting or abrasive operations where the surface finish of the cut or abraded part is important, it is preferred that the smaller particles of diamond be used, for example, below about 15 microns. By way of exaple, wire drawing dies may require smaller particle sizes in order to provide a certain surface finish on the drawn wire product.

The TSPCD element may be as small as 250 microns, (i.e., 10 mils) on an edge and as large as one carat or more. It is preferred that the edge length of the starting TSPCD be above 1,000 microns (i.e., one millimeter) since pieces of this size are easier to manipulate or handle. Typically, TSPCD elements of a size of three pieces per carat (0.165 of an inch per side triangles) are easily handled.

In some instances the smaller particle sizes of TSPCD material below 250 microns may be used as a grit in the material used to bind the larger TSPCD elements described in order to provide an impregnated support or to increase the amount of diamond material between adjacent larger TSPCD elements.

It is preferred that the TSPCD startng material be of a regular geometrical shape which may be any of the shapes already mentioned. The principal reason for a fixed and known geometrical shape is that it vastly simplifies the arrangement of the TSPCD elements in the desired relationship for processing and thus offers maximum control of placement, spacing and overall configuraton and content of the final part. Since one of the advantages of the present invention is the ability to form large TSPCD sturctures, it is also preferred that the geometrical shape be such that the TSPCD starting elements have side surfaces or faces which can be positioned in a close and controlled spacing to an adjacent TSPCD element, e.g., triangular, square, rectangular and the like, it being understood, as will be discussed in detail, that a TSPCD structure may include TSPCD elements of different geometrical configurations.

In the processing in accordance with this invention, as diagrammatically illustrated in the flow chart of Figure 1, the starting TSPCD material 10 is preferably cleaned by heating in hydrogen at about 800 to 1,000 degrees C. for about 10 to 60 minutes as indicated at 12. Other cleaning procedures may be used provided they are effective to remove oxidants and other surface contaminants. Thereafter the cleaned TSPCD material is surface coated with a metal by any one of several known procedures to form an essentially continuous coating which is essentially free of discontinuities. For reasons which will become apparent, the presence of discontinuities in the coating tends to promote lifting of the carbide containing coating off the surface of the TSPCD or provide a defect through which other materials may migrate to adversely affect the underlying TSPCD.

One such coating procedure is chemical vapor deposition by which a metal compound such as a chloride or a fluoride is heated to decompose the compound to form a mist of the metal which then deposits on the TSPCD material. Another procedure is fused salt bath coating methods.

Tungsten is preferred as the coating metal because it is a strong carbide former, not subject to excessive oxidation damage, has similar thermal expansion characteristics as the TSPCD elements, and is not easily dissoved by the liquid binder metals during later processing. Other metals may be used are any one of the Group IVA, VA, VIA, VIIA metals and alloys and mixtures thereof and silicon, such as tantalum, molybdenum, titanium, niobium, vanadium, zirconium, manganese, molybdenum/manganese, or tungsten/manganese. As a class, these materials have a melting point higher than the temperatures used in subsequent processing and are strong carbide formers and form a strong bond to the diamond. Metals of Group VIIIA, such as cobalt, iron and nickel are less preferable because of the tendency to weaken the TSPCD by back conversion of the diamond or possibly by other means. Zirconium and titanium have been observed to have a volume expansion in response to elevated temperatures which is more than that of diamond but less than that of cobalt and iron, but these materials are subject to oxidation damage in subsequent processing in normal atmospheres unless protected by an overcoating of nickel or copper or some other material. Even so, care must taken to assure that the carbide containing coating is sufficiently thick to prevent penetration by the surrounding metal should the copper or nickel or other coating dissolve into the matrix carrier.

For chemical vapor deposition one may use the hexahalides, tetrahalides, pentahalides, e.g., the hexa-, tetra-and penta-forms of the bromides, chlorides fluorides of the metals mentioned. The thickness of the coating on the TSPCD may vary so long as it is greater than about one micron, but it is preferred that the coating be between about 1

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micron and up to 30 microns. Thicker coatings may be used but do not seem to increase the bond stregth over that acieved in the range of 20 to 30 microns.

The application of the coating does not necessarily result in a chemical bond to the TSPCD at this point in the processing. As near as has been determined, the processing temperature used in chemical vapor deposition is not sufficiently high to form a chemical bond as indicated by the essential absence of any diffused carbon into the metal of the coating and the absence of any metal of the coating being diffused into the TSPCD. While it is believed that the coating is essentially uniform in dimension and essentially covers the entire outer exposed surface of the TSPCD, it is not essential to form an aboslutely continuous coating. In the case of porous leached TSPCD elements, the coating should be thick enough to bridge over the pores in the TSPCD surface so that it is effectively coated with the metal.

Of the carbide forming materials described, tungsten is the most preferred for several reasons. When a tungsten coating, previously converted to a carbide at the interface of the TSPCD as described herein, is furnaced in a graphite mold or oxidative environment, the tungsten is relatively stable against oxidation as compared to titanium, for example, unless the titanium is protected by an overcoating. Another reason for the preferance is that the thermal expansion of tungsten or tungsten carbide is close to the thermal expansion of diamond. Further, tungsten dissolves in the binder at a relatively slow rate. The overcoating requires a second coating operation and thus increases cost. Further, if the overcoating is not continuous, for example if there are defects which expose portions of the underlying oxidation sensitive coating, subsequnet processing in an oxidizing environment may destroy the metal and the carbide interface or a local portion of the underlying diamond material or both. So too, there are some types of matricies, which tend to dissolve the oxidation protective layer deposited over the oxidation sensitive carbide formers with the result that the oxidation protective material dissolves or is otherwise absorbed in the matrix and a gap tends to form between the partially oxidized coating and the surrounding structure, thereby resulting in a marked reduction in the strength of the bond between the coating and the surrounding structure. Ideally, the bond between the outer surface of the coating and the matrix carrier is a metallurgical bond which is not easily formed if the coating is not of compatible material or if it is oxidized.

More particularly, if the matrix or infiltratant includes copper or nickel or alloys thereof, as is normally the case in abraseive resistance matrix carrier, the matrix or infiltrant rapidly dissolves the oxidation protective layer so that the presence of a thin carbide forming layer, even if overcoated with an oxidation resistant material tends not to produce as strong a metallurgical bond as is the case with tungsten.

The use of materials such as zirconium or titanium or chromium may be acceptable provided those coatings are sufficiently thick to essentially prevent adverse reactions which cause damage to the carbide layer or to the underlying diamond since copper and nickel in the binder in contact with the coating will protect the coating from oxidation during infiltration. This is especially true where the matrix composition or the infiltrant is a material as above or hereinafter described. Thus, even if there is penetration of the infiltrant or a component of the matrix through or into the oxidation protective layer, oxidation sensitive material may be used as the coating, provided they are sufficiently thick. Thicknesses of less than one micron tend to be subject to susbsequent processing problems, even if coated with an oxidation protective layer. Thickes layers, especially above about 3 microns tend to provide improved bonding but not as great as that provided by tungsten.

An important advantage of this invention is the ability to form a backing or supporting structure for the TSPCD elements of widely varying configuration and composition. The backing is formed in situ as the TSPCD elements are bonded chemically together andto the support structure.

To assist in handling, it is preferred to compress the powder and the TSPCD elements in an axial compression opertion. Ultimately the backing or support structure will achieve a volume percentage of metal and/or metal carbide and/or abrasive particel (e.g., oxides or non-metal carbides) which is in the range of 40% to 80%. Optionally, the compacted structure may be further compressed by isostatic pressing in which the volume percentage is increased to about 60% to 90%. If the structure is to be sintered, isostatic pressing is preferred.

The hard ceramic powders used to form the matrix carrier may be metal carbide such as tungsten carbide, titanium carbide, tantalum carbide, molybdenum carbide, and cemented tungsten carbide (tungsten carbide cemented with cobalt). Alternatively, it could be made of other hard ceramic powders such as alumina or titanium or silicon nitride. The abrasive particles may be alumina,

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silicon carbide or silicon nitride. For applications such as earth boring bits, where strength and toughness are important, tungsten carbide is the preferred hard ceramic powder.

The particular powder used and the particle size or sizes is related to the desired volume percent of the matrix powder, the final product which in turn is related to the hardness (rigidity) and impact resistance (toughness) of the backing or support structure. Also a consideration is the type of processing, e.g., liquid state infiltration or solid state sintering.

In the case of liquid state infiltration, the hard ceramic powder, for example tungsten carbide, has a particle size which is typically below 325 mesh (Tyler), i.e., below 44 microns (Standard), for example 30 microns. The size distribution and the percentage distribution may vary depending upon the supplier. However, the size may also be varied. For example the same packing efficiency may be obtained by appropriate selection of particle sizes, e.g., 30 microns and 6 microns in a ratio of 70% to 30%.

A preferred infiltrating material is a copper-tin-titanium-manganese alloy. If the alloy does not include manganese or nickel, thinner coatings of about 1 micron may be used, as will be discussed.

In the case of solid state sintering, for example using a tungsten powder, the powder particles are preferably coated with a metal such as nickel, for example 0.35 weight percent. This may be doen by mixing tungsten powder of a particle size of 0.5 microns with a solution of nickel nitrate in alcohol, followed by heating at about 90 degress C. to evaporate the alcohol with the result that the nickel nitrate is deposited on the tungsten powder. the nickel nitrate coated tungsten powder was then heated at 800 degrees C. for 3 hours in a reducing atmosphere (hydrogen) to eliminate the nitrate. The processed tungsten powder was then ball milled for 24 hours using tungsten rods as the milling media and then sieved and screened to 200 mesh (74 microns). The purpose of the nickel, as will be described, is to act as a diffusion activator for the tungsten. Other binder materials which may be used are tantalum, molybdenum, and nickel based alloys, copper-nickel alloys and cobalt based alloys.

In either liquid state infiltration or solid state sintering, the appropriate powder of the appropriate particle size or sizes is mixed with a temporary binder material which is preferably an organic material as indicated at 15. The temporary binder is used to coat the powder material to form a temporary adhesive bond between the powder particles during the initial compression step. Since this temporary binder remains in the processed product through the cold isostatic pressing operation, it should preferably be a material which is present in a relatively low volume percentage. If the volume percentage of the temporary binder needed to achieve a temporary bond is too high, this may affect the volume percentage of the powder in the final product, i.e, too great an amount of the temporary binder may prevent the achievement of higher powder volume percentages. Various organic polymeric or resinous binders which are easily volatilized at elevated tempoerature may be used. A preferred material is paraffin which is easily dissolved in an organic solvent. The amount of paraffin relative to the tungsten carbide is about 2 weight percent. The paraffin is easily and completly removed in the processing. It is also desirable to use a lubricant which may be volatilized completely at elevated temperatures in order to facilitate powder movement during the various pressing operations, especially the optional cold isostatic pressing operation. One such material is mineral oil which may also be dissolved with the temporary binder to coat the powder. A typical useable amount is 20 grams of paraffin per 1,000 grams of cast carbide in 0.2 grams of glycerine per 1,000 grams of cast carbide, by way of example.

The powder is dispersed into the solution of the temporary binder and lubricant in hexane (for the paraffin) and the binder and lubricant coat the powder which is then dried and reground into a powder. Other coating procedures may be used as is known in the art.

The next step in the sequence, as indicated at 20, is to arrange the coated TSPCD elements in the desired relationship as needed to form a product. If the product is to contain multiple TSPCD elements it is preferred to use a template or die configured to position the TSPCD elements with respect to each other. The spacing between adjacent TSPCD elements may vary widely, depending upon the configuration and nature of the final product. Where the part includes multiple TSPCD pieces, the side faces of the TSPCD elements may be spaced from each other to provide a gap of from about less than 1 mil to 500 mils and preferably in the range of 6 to about 30 mils (150 to 750 microns), by way of example. Thereafter, the processed powder is placed in the gaps between the adjacent TSPCD pieces and filled in in contact with the surfaces of the TSPCD elements to be bonded to the matrix carrier.

In some instances it is not necessary to form a gap as described since the TSPCD may be assembled with adjacent surface portions in contact with each other. In this instance where liquid state infiltration is used, the binder penetrates between the TSPCD elements and chemically bonds the adjacen coated TSPCD elements together. Such a butting arrangement o of the TSPCD's may be

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used where erosion is not a potential problem, e.g., in bearings, saw blades and wire dies and the like, for example. Where erosion is likely to be a problem, such as exposure to relatively high velocity flow or the use of abrasive materials, the use of a gap in which powder is present is preferred for erosion resistance.

The thus assembled TSPCD-powder temporary assembly is then assembled into a pressure die of suitable configuration which preferably defines the outside contour of the finished part. One manner of carrying this out is to use an open ended die, invert the die and move the temporary assembly of TSPCD elements up into the bottom of the die, re-invert the die right side up so that the assembly is in the bottom of the die and then add the processed powder material to the required volume. The amount of powder added is related to the thickness of the support or backing and the volume percentage of the metal in the final product.

The assembled material is then axially cold compressed in the die, as indicated at 22, at a pressure of between 10,000 psi and 30,000 psi to increase the tungsten carbide packing density to about 50 to 65 volume percent. As a result of this processing, a compacted intermediate is formed which is fragile but still capable of being handled with care. As another example, if the subsequent processing is solid state sintering, pressures around 10,000 psi may be used and the resultant product has a packing density of about 50 volume percent.

An additional step in the processing is the cold isostatic pressing operation, as shown at 24, in which the compacted intermediate is isostatically cold pressed at a pressure of up to about 30,000 psi for five minutes or longer, for example. The isostatic pressing typically achieves a tungsten carbide packing density of about 62 volume percent. In the case of tungsten powder in solid state sintering, the density is about 65 volume percent. During this operation, the tungsten or the carbide powders are moved and compacted uniformly to a more dense product. The step of cold isostatic pressing is optional although in many cases it is preferred particularly for sintered products.

At this point in the processing, two alternate processing routes are available, as indicated in the dotted lines of Figure 1, liquid state infiltration, as seen at 26 or solid state sintering as seen at 28.

In the case of solid state sintering, the product of the isostatic pressing is sintered in a vacuum furnace at 10 to the minus 5 torr. at 1,200 degrees C. for about 1 hour. The result is a sintered product having a density of about 90 volume percent. The finished product indicates a bond between the tungsten material with the tungsten coating on the TSPCD, i.e., a tungsten-tungsten metal bond. The nickel or other activator is used to promote diffusion and metallurgical bonding. The mechanical properties of this bond are quite strong, and the finished product, although somewhat brittle is quite useable.

There are, however, some limitations of solid state sintering. For example, the limitation of sintering at a temperature below 1,200 degrees C. renders it difficult to find a material with high strength and high modulus. Even if the high modulus materials can be sintered below about 1,200 degrees C., as by activation sintering, the sintered product may contain 5% or more porosity which may act as pre-existing cracks. While this may not be a problem in some cases, it is a consideration where the finished part is in a part which is subject to relatively high impact loads, e.g. a drill bit for example.

In those instances in which the bonded TSPCD product is to be mounted to a high modulus backing, the processing may involve two thermal cycles to bond the TSPCD product to a tungsten carbide back-up element. While effective, the processing steps increase the costs.

Even though these problems exist, the advantage of this form of processing is the ability to provide a high strength, low thermal expansion material to bond the TSPCD together. There are known ductile materials which may be added to the powder or the binder in accordance with this invention to decrease the brittleness of the sintered matrix carrier.

It is preferred to use liquid phase infiltration as the last process step. In this processing, the product from the isostatic pressing operation is heated to cause a metal binder to flow through the compacted powder and bind it together and to the TSPCD elements.

Regardless of the type of processing as herein described, the hard ceramic powder in the matrix carrier can be of relatively high volume percentage, e.g., above 50% and up to 90% by volume. The provision of a relatively high density final product, which is formed in situ at relatively low pressures and temperatures and which is temperature stable to about 1,200 degrees C. offers advantages not heretofore obtained.

The metal binder material should be one which in a liquid state can wet the coating on the TSPCD and the hard ceramic powder particles. It is also preerred that the binder metal have good mechanical properties such as ductility and strength. Typical such binders are copper or nickel based brazing alloys, copper-tin-manganese-nickel alloys, the latter being the preferred binder material.

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The processing above described, as already noted may be used to form a wide variety of products which are characterized as having a strong chemical bond between the coating and the TSPCD and between the coating and the supporting structure. It is this chemical bonding which provides the significant strength over that which can be achieved by merely a mechanical gripping of the TSPCD. The advantage of this invention is that the TSPCD elements or element are effectively locked in or on a support structure to provide a TSPCD cutting element as contrasted to the prior temperature sensitive supported TSPCD elements commercially available.

Referring to the drawings which illustrate preferred forms of the present invention, Figure 2 illustrates a TSPCD product 30 which includes six (6) of initially separate TSPCD elements 31a to 31f of generally triangular shape. The TSPCD elements may be bonded together in or on a support structure 32, see also Figure 3 which may be an infiltrated or sintered powdered material. The support structure may be of various dimensions and of various axial lengths, as indicated by the break line 33.

As seen in Figures 2 and 3, the TSPCD elements include at least one side face 34a which may be positioned adjacent to but spaced a small distance from the side face 34b of the adjacent TSPCD element. The distance between adjacent TSPCD elements, referred to as the gap and illustrted as 35 in Figure 3, may be of the dimensions previously indicated.

Referring to Figure 4, for example, the gap 35 is illustrated with reference to its condition after cold isostatic pressing and before further processing. Each of the TSPCD elements 37 and 38 includes the coating 37a and 38a, respectively, the TSPCD elements being spaced from each other by the gap width. Between the coated surfaces is the powder material 40 such that the gap is TSPCD face-coating-powder-coating-TSPCD face. In subsequent processing, a strong chemical bond is formed from the TSPCD face through the coating, through the powder, through the coating of the adjacent TSPCD face and to the adjacent TSPCD.

Again referring to Figures 2 and 3, in the resulting TSPCD product 30, essentially all surfaces of the TSPCD elements, save one, are in contact with bonded support material, i.e., there is material on the bottom face 41 and peripherally around the outer faces, as indicated at 42 and in the gap 35, while one face 44 is exposed. This form provides the optimum bonding of the TSPCD elements together. This product may be assembled to a bit body during infiltration of the bit to form the matrix bit body. It is also possible to braze the product into the bit body, in which event, higher temperature braze alloys may be used than have heretofor been used.

The form or TSPCD product in accordance with this invention shown diagrammatically in Figure 5 illustrates that not all of the faces need be fully in contact and bonded to the support element. Here a triangular TSPCD element 50 includes side faces 50a, 50b and 50c which are only partially beneath the top surfaces 52 of the support structure 53 shown as triangular for purposes of illustration. Due to the strong chemical bonding between the TSPCD and the support structure, it is possible to expose a substantial portion of the large flat face 50d of the TSPCD while the body of the TSPCD is substantially above the support body. Thus, for example it is possible in accordance with this invention to form large bearings from smaller TSPCD elements.

Referring to Figures 6 and 6a, for example, a TSPCD product 60 is illustrated which may be used as a bearing or the like. This form of product also illustrates that TSPCD elements of different geometrical shapes may be used to form a useful TSPCD products. In this form, TSPCD elements 61 and 63 are half circular disks while TSPCD element 64 is square, although it may also be rectangular. The TSPCD elements are bonded to a support 65 of metal powder processed as already described with gaps 66a and 66b between adjacent elements. As illustrated the gaps, however, are not filled with matrix carrier material thus effectively providing channels between the spaced and facing exposed side faces 61f-64f and 64g-63f, the elements 61, 63 and 64 being positioned such that a substantial portion is exposed as noted with reference to Figure 5. When used as a bearing, the channels may provide for flow of cooling or lubricating fluid, if desired. If channels are not needed, the gaps may be substantially filled as illustrated in Figure 3, i.e., the surface of the support is even with the top surface of the TSPCD elements.

Not all of the side faces need be in contact with and bonded to the support material. Thus, for example as illustrated in Figure 7, a single point dressing tool 70 is shown which includes a TSPCD element 72 mounted on and bonded to a support 74 such that one face 72a is fully contacted by the support material which effectively forms a shoulder 76 to the rear of the element 72. Faces 72b and 72c are fully exposed while the bottom surface is bonded to the support. While element 72 is indicated as triangular, it may be other shapes such as square, rectangular, semi-circular or circular, for example.

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The ability to bond a TSPCD element firmly in a support structure permits the fabrication of unique cutting and abrading products. For example, Figures 8 and 8a illustrate an improved saw blade segment 80 composed of a pluarlity of TSPCD elements 81a through 81k, bonded to a support structure 83. In the form illustrated, the TSPCD elements are circular in shape although other geometrical shapes may be used. Circular shapes, however, have the advantage of providing a relatively large surface area for firmly bonding the elements to the support structure. The diameter of the elements may be in the range of one millimeter or larger depending upon the use of the segment. In prior segments, they were either impregnated with diamond dust or used spherical natural diamonds. In the either case as the supporting matrix carrier was worn due to use, the diamond material was lost due to loss of supporting structure. This problem is largely overcome by the present invention since the TSPCD elements are firmly chemically bonded over a comparatively large surface area.

The TSPCD elements are preferably arranged in a redundant pattern such that elements 81e through 81g are to the rear and in the space between the adjacent lead elements 81a-81d, with elements 81h-81k oriented in the spaces between 81e-81g. Thus, for example if the thickness of the elements is equal to or greater than the gap dimension between adjacent side-by-side elements 81a-81d, the entire face of the cut in the workpiece is traversed by at least one cutter. The redundancy may be two or more, that is, additional elements may be arranged to provide added redundancy as may be needed.

As illustrated in Figure 8a, each element 81a-81k includes an exposed arcuate cutting face, for example 81aa, 81ee and 81hh extending above the surface 84 of the support 83, with a substantial portion of each element firmly and chemically bonded to the support. As the segment wears in use, the elements are retained to a much greater degree than the prior diamond cutting segments. While circular elements have been described, one may use a half-circle or quarter-round TSPCD elements, preferably mounted such that the curved peripheral surface is exposed to form the leading cutting edge. Such materials are commercially available or may be cut off a cylindrical TSPCD part to the desired thickness.

The ability to anchor and firmly bond a TSPCD element to a support structure permits the fabrication of a wide variety of cutting and abrading tools. It also permits the fabricatior of products that are other than abrading or cutting rools, such as bearings, as described and, for example, a lead bonding tool. Heretofore, lead bonding tools have been made of a single crystal diamond cut to a precise shape and dimension with a flat working face. Typically these tools are used to bond lead elements to solid state chips and the like by being brought into contact with the chip and bonding the leads in a precise and exact location to the chip through heat and pressure. Normally the temperature is about 500 degrees C. and natural diamonds are able to withstand this temperature. However, it is difficult to support these natural diamonds in a support structure and if they move even slightly relative to the support structure, problems may be encountered in their use since the bonding operation is a precision operation. In accordance with this invention, an improved lead bonding tool is provided which is firmly anchored in a support structure and which is temperature stable.

Referring to Figure 9 and improved lead bonding tool 90 is illustrated and includes a TSPCD element 92 bonded to a support structure 94, the latter being metallic and including an aperture 95 therein for a heater and including a shank 96 for mounting in the lead bonding machine. The support usually includes a cylindrical section 97 having a frusto-conical end 98 with the element 92 mounted at the tip of the end 98. The element 92 includes a working face 99 which projects beyond the end 98 and which is of a precise flatness and face dimension, i.e., length and width. The face contour may be square or rectangular, or any other shape, as may be desired. Heat may be applied to heat the element in a conventional manner normally used to heat the lead bonding tool. In use the tool is subject to vibration and heat which requires that the element be firmly and accurately mounted and maintained in that accurate mounting during use. By the present invention, the TSPCD element 92 may be chemically bonded to the support structure which may be the support 94 or a separate insert to be received in the support. The advantage of this invention is that a TSPCD element may be used which may be relatively easily affixed to a support structure.

Thus, for example, the element 92 may be shaped to the precise required length and width dimensions and in situ bonded to a support structure. If the support structure is the support 94, the face of the TSPCD may be precision ground to the desired flatness such that the plane of the face 99 is referenced to the support structure, an operation which is difficult to achieve with single crystal diamonds. It is also possible to form a lead bonding tool by formation of a TSPCD support structure which is then assembled to the body 94, rather than forming the entire assembly as herein described.

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One aspect of this invention is the ability to form a TSPCD product of virtually any shape or size from smaller TSPCD elements. The TSPCD product illustrated in Figure 10 is an example. There a large TSPCD product 100 is composed of a multiplicity of triangular TSPCD elements 101 in a TSPCD part which is essentially circular in overall shape, although it may be of any shape. In the form illustrated, there is a surrounding portion 105 of tungsten carbide, for example. The tungsten carbide may be of 70 volume percent tungsten carbide By way of example, the part may be 50 mm in diameter and is useful as a cutter for oil and gas drill and core bits.

Figure 11 illustrates another TSPCD product 110 in accordance with this invention composed of a plurality of TSPCD elements 112 illustrated as being triangular pieces which may be for instance 3 per carat or 1 per carat. The elements 112 are bonded together and to a support 115 such as tungsten carbide by any of the methods already described, so as to form a unitary structure in which the previously separate elements are chemically bonded together and to the tungsten carbide and to the tungsten carbide backing 115. It is understood that the backing may be any of the carbide materials already described.

The form of the invention illustrated in Figure 11 illustrates the variety of TSPCD products that may be fabricated in accordance with this invention. This particular structure provides for a plurality of cutting elements 112a and b, 112c and d, and 112e and f, which form pairs which together provides a series of cutting points 116, 117 and 118. In use in a bit, as shown in Figure 11a, the cutting product 110 may be mounted directly into the body matrix during body matrix infiltration or formation. In this form, there is a back support 121 provided which contacts the backing 115, the cutting direction being indicated by the arrow 123. The tungsten carbide backing 115 provides for increased impact strength.

The cutting product 110 is exposed such that at least one top row of elements 112a-112f are essentially fully exposed. In use as the top row of cutters wear, new cutting surfaces are regenerated from the cutter elements below the top row. This product also illustrates the fact that adjacent elements include at least one side surface which is located adjacent to the adjoining piece, the spacing being as already described.

To improve the cutter performance in terms of regenerating cutter edges and points, the amount of matrix carrier between adjacent TSPCD elements may be reduced in cross-sectional thickness in order to provide controlled weakness planes in the cutter structure thereby providing for fracture of the cutter along predetermined planes of fracture. In this way as the loading on a cutter region increases, the cutter is broken out of the support to provide a new cutter element. Since earth boring, in part, relies upon a kerfing type of cutting, the formation of an uneven overall cutting surface generally tends to improve the cutting action in certain types of formations.

As already noted, the products of the present invention are much stronger than products previously described as mechanical mosaic structures. Referring to Figures 12a to 12d, Figure 12a illustrates diagrammatically a three point bending test in which loads are applied to a part 130 in one direction as indicated by the arrows 131 and 132 and a load is applied in another direction as indicated by the arrow 133. The force necessary to bring about fracture through the joint 135 or through the joined parts 136 is measured and expressed in terms of pounds per square inch to failure.

Figure 12b illustrates a TSPCD part 140 in accordance with this invention made up of triangular TSPCD elements 141 joined together as indicated at the joints 142 by the methods already described. The part 140 was processed by sintering tungsten coated 3 per carat TSPCD elements with tungsten powder which had been compressed to a volume percentage of 90%. In the three point test, the failure mode was in the joint between adjacent elements, as indicated at 145. The load to failure was 21,000 psi.

Figure 12c is similar in structure to that of Figure 12b, but the part 150 was formed from tungsten coated 3 per carat TSPCD elements which were liquid state infiltrated with tungsten carbide using a copper binder, as described, and processed as described. In the three point test, the failure mode was through the TSPCD as indicated at 155 and the load to failure was 26,000 psi.

Figure 12d illustrates a mechanical mosaic structure 160 which is essentially the same as 150, but in which the TSPCD elements were not coated and in which the part was processed using conventional infiltration techniques with the same tungsten carbide and binder used to form the part 150. In the three point test, the failure was through the joint, as indicated at 165, and the load to failure was zero psi.

Other test data indicates that the thickness of the carbide forming coating is significant. These data were derived from the use of a matrix material in which the binder included nickel and manganese. In the case of tungsten coated material, it has been observed that nickel and/or manganese tend to adversely affect the coating if the coating is too thin, for example below about 3 microns. However, if the binder for the matrix is copper or tin or cobminations thereof, thinner coatings of one mi-

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cron may be used. Thus if the binder for the matrix is compatible with the coating, thinner coatings of 1 micron may be used. If the binder for the matrix is from the iron group, e.g., nickel or manganese, somewhat thicker coatings are preferred to prevent the binder from penetrating the coating on the diamonds, for example a tungsten coating. It is thus preferred to use binders which are compatible with tungsten, in the preferred form of this invention, in which instance the coating thickness may be 1 micron in thickness.

For example, in a shear test where coated TSPCD is bonded to a matrix carrier, as described, and subject to a lateral pushing force, the results indicate that in the range of 1 to 5 microns, there is improvement in the bond strength to about 5,000 psi over an uncoated product. The failure mode at this range of coating thickness is by failure at the interface of the coating and the matrix carrier. In the range of about 7 to 10 microns thickness, the fracture is mixed in nature, in that the fracture sometimes is at the stated interface and sometimes through the TSPCD. The stated fractures occur at bond strengths in the range of about 5,000 psi and up to about 22,000 psi. In this range of bond strengths, the TSPCD product in accordance with this invention has a wide variety of uses. Above about 10 microns, the fracture mode is through the TSPCD and not through the bond, i.e., this means that the interfaces between the PCD and the coating, the coating and the bond, the coating itself and the bond itself are all stronger than the PCD. These fractures of the TSPCD, rather than at the interface between the support structure and the TSPCD occur typically at strengths in the range of above 22,000 psi. Above about 15 microns of coating thickness, the bond strengths seem to level off at about 27,000 psi, with fracture through the TSPCD rather than the bond interfaces, even though the coating thickness increases to 20 microns or more. For coating thicknesses above about 30 microns, there does not appear to be any increase in bond strength over that achieved in the range of 15 to 30 microns.

by way of further comparison, a titanium carbide coated TSPCD having a thickness of about 5 to 10 microns, typically at 7 microns, and a total coating thickness (including a nickel oxidation protective coating) of about 30 to 50 microns exhibited mixed failures through the bond and through the TSPCD at about 15,000 psi. These data also tend to establish that a tungsten coating, absent any oxidation protective coating, having the thickness dimensions described, is far superior than products with a titanium carbide coating and a nickel protective coating, wherein the titanium coating was about 7 microns and the nickel coating was about 40 microns, since the failure mode of the latter is a mixed mode, either at the bond rather than only through the TSPCD. The achievement of sufficiently high bond strengths to result in the failure of the TSPCD rather than the bond of the latter to the supporting structure offers considerable advantages, especially in the cases of those products which require a strong bond of a cutter-type product in some form of support structure.

The relatively high strength of the bonded joint between the TSPCD and the supporting structure permits wide variation in the types of products in accordance with this invention. One of the advantages is the ability to provide a TSPCD element which is securely bonded to a support structure. Referring to Figure 13, there is illustrated a product 170 which includes a TSPCD element 172 firmly secured to a tungsten carbide support element 174. While the product 170 superficially resembles the appearance of a STRATAPAX brand cutter, it is vastly different.

More specifically, the TSPCD element may be a product available commercially as SYNDAX, TSPCD material in the form of a thin one-piece disc. The dimensions of the disc 172 may vary widely from a diameter of 2 to 3 mm to as much as 50mm or more. The disc 172 is firmly chemically bonded to the support element 174 through the chemical bond formed through the coating applied to the disc 172 which in turn is bonded to the infiltrated or sintered material 175.

The support 174 may be separately formed and the disc 172 and the material 175 may be assembled and processed as described. The result is the chemical bonding of a TSPCD to a preformed support. The advantage is that the length, diameter and shape of the support is not limited by the size of the high pressure high temperature presses normally used to form STRATAPAX types of products. The cost for making a product as shown and described in Figure 13 is less than that for the temperature sensitive product, but the more important advantage is the ability to form the support of essentially any length, as indicated by the break line 176, without requiring larger presses. This form of product has the advantage of being temperature stable up to about 1,200 degrees C. and may thus be infiltrated simultaneously with the formation of a supporting matrix, for example a matrix body for a drill bit. Alternatively, the product may be brazed into the bit body by the use of higher temperature brazing materials than have been heretofore used. It is also understood that the coated diamond may be brazed to a suitable support such as cemented tungsten carbide, and the like, since the braze joint is between the coating on the diamond and the support element. Since the

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diamond is temperature stable, higher melting point brazing alloys may be used as compared to those alloys which are used with diamond product which are not temperature stable, as herein defined.

As illustrated in Figure 13, the side surface 178 of the disc is free or sintered or infiltrated material. In the form illustrated in Figure 13a, the sintered or infiltrated material may cover the sides of the disc 172a, as indicated at 179 for added strength.

Figure 14 illustrates a structure in which one or more TSPCD elements 180 are affixed to a supporting body such that the back side 183 of the elements are in contact with the support body while the side faces are adjacent to each other or include a fully exposed side face, as indicated at 187. In this particular case, the support body may be a saw blade segment or a preformed and preshaped cutter for an earth boring bit. While the configuration of the product illustrated in this figure may appear similar to some of the illustrations of United States Patent 3,938,599 issued to Horn, there are significant differences. Unlike the Horn structure, that of the present invention is chemically bonded to the supporting matrix carrier and is far stronger than a mere mechanical bond as described in the referenced patent, see also the data previously described. This strong bonding allows for the provision of a variety of products.

Thus, for example, Figure 15 illustrates a twist drill 190 having segments 192 and 194 mounted thereon. Segments 192 and 194 may be a TSPCD product in accordance with this invention containding one or more TSPCD elements in a support structure. The drill bit may be a 1/4 inch or larger size.

Figure 16 illustrates a form of the invention similiar to that of Figure 13 wherein the TSPCD elements 200 are square in shape, although rectangular shapes and mixtures of geometrical shapes may be used. The TSPCD elements are bonded to each other through the material 201 and to the base 202, as described. The base may be of a shape other than square and may be of any length as indicated by the break line 205.

Figures 17 and 18 illustrate a drill bit 220 in accordance with the present invention. The bit includes a body 222, preferably of matrix material such as carbide, having a plurality of waterways 225 associated with a plurality of blades 230. It is to be understood that in referring to the bit body as a matrix body, the matrix material of the bit body may be relatively thin coating on a suitable support structure. The bit also includes nozzles 235 for flow of fluid form the interior of the body to the waterways to cool and clean the bit.

As shown in Figure 18, each blade includes a plurality of cutters 240 having a configuration as illustrated in Figure 2, for example. The cutters 240 are mounted in the matrix body during infiltation of the body thus eliminating the need to braze the individual cutters into the bit body. As mentioned. each of the cutters, by virtue of the production thereof is temperature stable to 1,200 degrees C. It is understood that other cutter configuration in accordance with this invention may be used, for example that illustrated in Figure 10 or in Figure 13. for example. It is also possible to provide cutters of selected geometry, e.g., quarter circles, half circles and the like. It is also possible to have temperature stable cutters which are larger in diameter than about 14mm, the usual maximum size for the STRATAPAX brand products.

Drill bit or core bit bodes may be of any of a number of types, as is known in the art. Thus, for example, stepped bit designs may be used with a significant cutter exposure, to mention only one variant. The ability to fabricate cutter to different desired geometries as may be needed for effective cutting action in various formations is now possible in accordance with this invention.

One of the features of the present invention is the fact that a wide variety of shapes and sizes is possible in the provision of a temperature stable PCD assembly through the use of processing steps that do not involve the high temperature and high pressure regime used in the synthesis of PCD materials.

Typical processing of TSPCD elements in accordance with this invention is set forth in the following specific example, by way of illustration.

Triangular temperature stable TSPCD elements of a size of 3 per carat were coated with tungsten metal to a thickness of about 6 microns. The powder used to form the matrix carrier was tungsten carbide powder of 3 to 5 micron particle size. About 1,000 grams of this powder were completely and thoroughly mixed with a solution of 200 ml. of hexane in which 20 grams of paraffin and mineral oil had been dissolved. The resultant mixture was heated to between 80 to 100 degrees C. for 45 minutes to evaporate the hexane completely. The processed powder was then ball milled, as described, for thirty minutes to break up the flocculated powder and then screened through a 200 mesh screen.

The tungsten coated TSPCD elements were arranged in a suitable hexagonal die and 4.5 grams of the processed tungsten carbide powder was placed in the mold to fill the space between the TSPCD elements and to cover them. The resulting assembly was then cold pressed at 20,000 psi to form a hexagonal preform.

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The hexagonal preform was then loaded into a rubber mold which was then evacuated and sealed and then isostatically pressed at 29,000 psi. The resulting product was then ground to specific size.

The isostatically processed hexagonal product was the placed on a crucible with 2.6 grams of a copper based alloy (Cu-Sn-Mn-Ni) on the powder side. The preform was then heated in a vacuum furnace (10 to the minus 5 torr) at the rate of 5 degrees C. per minute up to 400 degrees C. for one hour and then at 10 degrees C. per minute to a temperature of 1160 degrees C. for one hour for infiltration, later followed by cooling.

Heating at a temperature over 1100 degrees C. for one hour is important because it is at this stage that tungsten carbide formation takes place. Typically the tungsten carbide layer thus formed is about 3 microns thick.

If the preform is heated quickly to 1,000 degrees C. and held for 1.5 hours, the formed tungsten carbide layer is about 0.3 microns thick. Heating to the carbide forming temperature at the rate of 10 degree C. per minute may also be used.

After the thermal cycle, the finished product is surface ground to a thickness of about 0.315 of an inch and may be used.

As a variant, cemented tungsten carbide grit (94% by weight of tungsten carbide bonded with 6% by weight of cobalt, a commercially available material) of 400 mesh size was mixed with a solution of 2% by weight paraffin in hexane.

It is within the scope of this invention to form the isostatically pressed part and then process that part so that it is simulataneously bonded to a supportng structure such as a matrix bit body or other support structure while effecting conversion to the carbide layer described. For example, carburized tungsten powder in the nominal size range of 3 to 5 microns was ball milled with 1% by weight of nickel powder (-325 mesh) for one hour. The milled powder mixture was then mixed with a solution of 2% by weight of paraffin wax in hexane.

The mixture was dried by heating and then the processed powders were used with triangular TSPCD elements, coated as already described, to form a much larger assembly, as described. The larger assembly was cold axially pressed and then isostatically pressed as described. The resulting product was a "green" hexagonal cutter as shown in Figure 2. The green assembly was then heated to burn off the organic material and held at a temperature of 1,000 degrees C. for one hour.

Thereafter, the processed green assembly, sufficiently strong to be handled was assembled to a matrix powder material in a mold, e.g. the matrix bit forming operation, and the matrix infiltrated at 1,200 degrees C. During the matrix infiltration, the green assembly was bonded to the matrix and the coating was formed into the carbide layer. In this processing there was a strong bond between the metal binder of the matrix and that in the green assembly and between the coating, powder and matrix supporting structure. Essentially the same processing may be used to form other products already described in or on a matrix carrier support element.

Another form of one step infiltration involves the use of powders processed as follows: As received carburized tungsten carbide powder in a particle size range of from 3 to 5 microns was screened through a mesh screen to break up the agglomerates which tend to form in the fine powder. The screened powders were mixed with 7 weight percent of nickel powder having a particle size in the range of 3 to 7 microns and mixed in a suitable mixer for one hour. A second tungsten carbide powder of a particle size in the range of 3 to 5 microns was screened through a 200 mesh screen to break of the larger agglomerates. The screened material was then ball milled with 3 weight percent of nickel powder of a particle size range of from 3 to 7 microns with 2 weight percent of paraffin in a hexane solution for about eight hours. The ball milled powders were then dried and coated with paraffin.

Six pieces of tungsten coated triangular TSPCD elements, coated as already described, of a size of 3 per carat were arranged in a hexagonal punch and about 0.8 grams of the second powder was placed between the TSPCD elements, spaced as already described. About 4 grams of the first powder was then placed in the die and a hexagon product was formed under pressure of 15, 000 psig. The cold pressed hexagaonal product was then isostatically pressed at 29,000 psig. After isostatic pressing the hexagonal product was infiltrated directly into a matrix, such as a drill bit matrix using a copper-manganese-tin-nickel alloy.

In another example, tungsten carbide powder in the size range of 20 to 30 microns and in the range of 60 to 70 microns was ball milled with 3 weight percent of nickel powder, of the type and size described, with 2 weight percent of paraffin in a hexane solution. The powders were dried, screend through a 200 mesh screen, assembled to TSPCD elements as already described and cold pressed in the fixture.

The cold pressed material with the TSPCD elements was then transferred to a high vacuum furnace, optionally a hydrogen furnace, to burn off the organic components by heating relatively slowly. This was accomplished by heating at a rate of about 5 degrees C. per minute to a temperature of

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800 degres C. The burned off hexagonal shapes were then assembled in a mold, and infiltrated into a matrix to provide a finished part, in this case a drill bit.

It is to be understood that the one-step infiltration process described may be used to form any of a variety of products in accordance with this invention.

In those cases where it is contemplated that the product of the present invention is to be assembled to a matrix material supporting structure, such as a matrix body drill or core bit, it is desirable to coat the product of this invention with a carbide forming material, as already described. Such processing has the advantage of of providing a coating, of the thickness described, which may in turn form a carbide layer for effective bonding to the matrix carrier in which the part is to be mounted. The carbide layer may be formed by a separate preheating operation or by controlled heating during body matrix formation.

The abrasive character of the products in accordance with the present invention may be enhanced somewhat by adding to the powder materials relatively small particles of diamond or TSPCD material in the form of particles having the approximate size of the powders used. The volume percent of such diamond powders may be as high as 40% and the resulting material is processed as already described with the bonding as already described. The starting diamond material is preferably synthetic polycrystalline diamond which is temperature stable through natrual diamond material may also be used in some instances.

It will be apparent to those skilled in the art that there may be variations and alterations, based on the above detailed disclosures, of the various procedures and product here described. It is to be considered that the same may come within the scope of the present invention as set forth in the appended claims.

Claims

Claim 1. A temperature stable diamond product having a temperature stability up to about 1,200 degrees C. comprising:
a metal matrix carrier;
at least one diamond piece of a predetermined geometrical shape and which is temperature stable up to about 1,200 degrees C. having at least one surface contacting at least a portion of said carrier,
each diamond piece being coated with a metal which is a carbide former on at least the portion thereof contacting said metal matrix carrier,
said carbide forming coating being of a thickness of at least about 1 micron and including a relatively thin portion of a carbide material adjacent to said portion thereof contacting said diamond piece, and
said temperature stable diamond product being characterized by a chemical bond between said temperature stable diamond and said coating and said coating and the portion of said matrix carrier which is in contact with said coating.

Claim 2. A temperature stable diamond product as set forth in Claim 1 wherein said diamond piece is a synthetic diamond piece which includes a face, at least a portion of said face being in contact with said matrix carrier, and
said metal matrix carrier being tungsten carbide and extending to the rear of the face a predetermined distance and forming a backing integral with said diamond piece.

Claim 3. A temperature stable diamond product as set forth in Claim 1 wherein said temperature stable diamond includes at least one side face, and said side face being coated with said metal which is a carbide former and being at least partially in contact with said matrix carrier.

Claim 4. A temperature stable diamond product as set forth in claim 1 wherein said product includes a plurality of initially separate temperature stable diamond pieces arranged in a predetermined pattern and including opposed surface portions forming a small gap therebetween, and
matrix carrier being located in said gap and contacting at least a portion of the surface portions of said temperature stable diamond elements.

Claim 5. A temperature stable diamond product as set forth in claim 4 wherein at least some of said temperature stable diamond elements are generally triangular in shape.

Claim 6. A temperature stable diamond product as set forth in claim 1 wherein said product is generally circular in shape and said temperature stable diamond is generally circular in shape.

Claim 7. A temperature stable diamond product as set forth in claim 1 wherein said product is a cutter for an earth boring bit.

Claim 8. A temperature stable diamond product as set forth in claim 7 in which said product includes more than one initially separate temperature stable diamond elements.

Claim 9. A temperature stable diamond product as set forth in claim 4 in which said gap is between 6 and 30 mils.

Claim 10. A temperature stable diamond product as set forth in claim 1 in which said coating has a thickness of up to about 30 microns.

Claim 11. A temperature stable diamond product as set forth in claim 1 in which said matrix carrier includes a carbide and a binder.

Claim 12. A temperature stable diamond product as set forth in claim 1 in which said matrix carrier is a sintered metal.

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Claim 13. A temperature stable diamond product as set forth in claim 1 in which said coating includes at least one metal selected from the metals of Group IVA, VA, VIA, VIIA and alloys and mixtures thereof.

Claim 14. A temperature stable diamond product as set forth in claim 11 in which said carbide is selected from the group consisting of the carbides of tungsten, chromium, niobium, titanium, tantalum, zirconium and molybdenum.

Claim 15. A temperature stable diamond product as set forth in claim 12 in which said sintered metal is selected from the group consisting of tungsten, nickel, tantalum, molybdenum, cobalt and sintered tungsten body infiltrated by a copper based alloy.

Claim 16. A temperature stable diamond product as set forth in claim 1 wherein said diamond piece is composed of at least 60% by volume of diamond aggregates.

Claim 17. A temperature stable diamond product having a temperature stability up to about 1,200 degrees C. comprising:

a metal matrix carrier selected from the group consisting of tungsten metal powder and the carbides of tungsten, titanium, tantalum and molybdenum,

at least one diamond piece of a predetermined geometrical shape and which is temperature stable up to about 1,200 degrees C. at least some of which have at least one surface contacting at least a portion of said carrier,

said diamond being a polycrystalline diamond composed of at least 60% by volume of diamond aggregates,

each diamond piece being coated with a metal which is a carbide former on at least the portion thereof contacting said metal matrix carrier,

said coating on said temperature stable diamond having a thickness of at least about one micron and including a carbide layer which is of a thickness of less than about 20 microns, said carbide former being a metal selected from the group consisting of Groups IVA, VA, VIA and VIIA metals and alloys and mixtures thereof, and

said temperature stable diamond product being characterized by a chemical bond between said temperature stable diamond and said coating and said coating and the portion of said matrix carrier which is in contact with said coating.

Claim 18. A temperature stable diamond product as set forth in claim 17 which includes a plurality of initially separate temperature stable diamond elements arranged in a predetermined relationship and including opposed surface portions forming a gap therebetween,

said gap being in the range of between less than 1 mil and 500 mils, and

said matrix carrier being located in said gap and contacting at least a portion of the surface portions of said temperature stable diamond elements.

Claim 19. A temperature stable diamond product as set forth in claim 17 in which said product is a saw blade segment.

Claim 20. A temperature stable diamond product as set forth in claim 17 in which said product is a bearing element.

Claim 21. A temperature stable diamond product as set forth in claim 17 in which said product is a dressing tool.

Claim 22. A temperature stable diamond product as set forth in claim 17 in which said product is a cutter adapted to be mounted on an earth boring bit.

Claim 23. A temperature stable diamond product as set forth in claim 17 in which said product is a component of a twist drill.

Claim 24. A temperature stable diamond product as set forth in claim 17 in which said product is a lead bonding tool.

Claim 25. A temperature stable diamond product as set forth in claim 17 in which said product is a single point dressing tool.

Claim 26. In an earth boring bit including a body, the improvement comprising:

at least one cutter element supported by said body,

said cutter element including at least one polycrystalline diamond element which is temperature stable to at least about 1,200 degrees C. supported by a carrier matrix, said temperature stable diamond element having a coating thereon at least on that surface thereof which is in contact with said carrier matrix,

said coating including being of a thickness of at least about 1 micron and including a relatively thin carbide layer adjacent to said surface, and

said temperature stable diamond element being bonded to the contacting portion of said matrix carrier by a chemical bond between said temperature stable diamond element and said coating and said coating and the portion of said matrix carrier which is in contact with said coating.

Claim 27. An earth boring bit as set forth in claim 26 wherein said cuter element includes a plurality of polycrystalline diamond elements.

Claim 28. An earth boring bit as set forth in claim 26 wherein said body includes a surface of matrix carrier material.

Claim 29. An earth boring bit as set forth in claim 27 wherein at least some of said polycrystalline diamond elements are triangular in shape.

Claim 30. An earth boring bit as set forth in claim 26 wherein said polycrystalline diamond element is in the form of a facing on said carrier matrix and chemically bonded thereto.

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Claim 31. An earth boring bit as set forth in claim 26 wherein said cutter element is of a diameter greater than 14mm.

Claim 32. An earth boring bit as set forth in claim 26 in which said bit includes a plurality of said cutter elements.

Claim 33. A temperature stable diamond product having a temperature stability up to about 1,200 degrees C. comprising:
a metal matrix carrier including a powdered material and a binder therefor,
a plurality of diamond pieces of a predetermined geometrical shape each of which is temperature stable up to about 1,200 degrees C. and at least some of which have at least one surface contacting at least a portion of said carrier,
at least some of said diamond pieces being in butting relation with an adjacent diamond piece,
each diamond piece being coated with a metal which is a carbide former on at least the portion thereof contacting said metal matrix carrier and on the surface portion which is adjacent to another diamond piece,
the coating on said diamond piece being at least about 3 microns in thickness, and
said temperature stable diamond product being characterized by a chemical bond between said temperature stable diamond and said coating and said coating and the binder for said matrix carrier which is in contact with said coating.

Claim 34. A method of forming a temperature stable diamond product having a temperature stability of up to about 1,200 degrees C. from at least one initially separate temperature stable diamond element of a predetermined geometric shape, comprising the steps of:
coating at least a portion of the surface of said temperature stable diamond element with a metallic carbide former,
said coating being of a thckness of at least about 3 microns,
assembling with said coating temperature stable diamond element a matrix carrier powder such that the powder contacts at least the coated surface of said temperature stable diamond,
cold pressing said assembled owder and said temperature stable diamond to compact said powder to a volume density of more than 40% to form a cold pressed intermediate,
cold isostatic pressing said cold pressed intermediate to compact said powder to a volume density of greater than 50% to provide an isostatic pressed intermediate, and
heating said isostatic pressed intermediate at an elevated temperature and in a controlled atmosphere for a period of time sufficient form of a chemical bond between the coating on the surface of said temperature stable diamond element and said diamond element and between said coating and the matrix carrier material in contact with said coating.

Claim 35. A method as set forth in Claim 34 wherein heating of said isostatic pressed intermediate includes heating at a rate not greater than about 10 degrees C. per minute in the range of between about 900 degrees C. and 1,100 degrees C. to effect conversion of a portion of said carbide forming coating to a carbide.

Claim 36. A method as set forth in Claim 34 wherein said matrix carrier powder is a mixture of a carbide and a binder therefor.

Claim 37. A method as set forth in Claim 34 wherein said assembly step includes the assembly of a plurality of coated temperature stable diamond elements in a predetermined configuration.

Claim 38. A method as set forth in Claim 37 wherein said elements are assembled such that there is a gap between adjacent elements.

Claim 39. A method as set forth in Claim 37 wherein said elements are assembled such that at least some of them are in butting relation.

Claim 40. A method as set forth in Claim 34 wherein said metallic carbide former is a metal selected from the group consisting of the metals of Group IVA, VA, VIA,VII and alloys and mixtures thereof.

Claim 41. A method as set forth in Claim 34 further including the step of assembling said isostatic pressed intermediate to a powdered support material, and
said heating operation including heating the isostatic pressed intermediate and said powdered material to effect the chemical bonding and to effect formation of said powdered material into a support for said temperature stable synthetic diamond element.

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Fig. 1

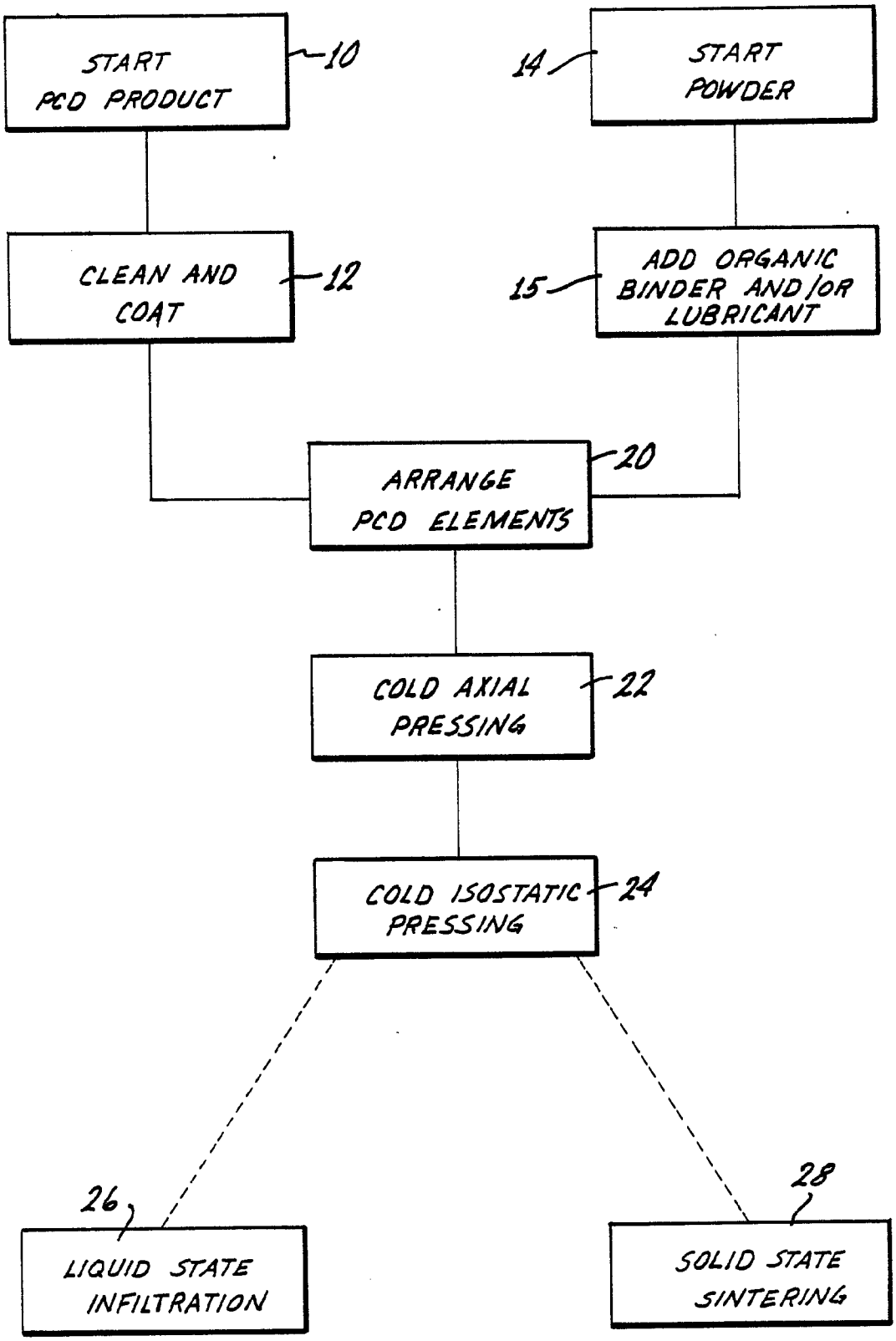

START PCD PRODUCT
10
14
START POWDER
CLEAN AND COAT
12
15
ADD ORGANIC BINDER AND/OR LUBRICANT
ARRANGE PCD ELEMENTS
20
COLD AXIAL PRESSING
22
COLD ISOSTATIC PRESSING
24
26
LIQUID STATE INFILTRATION
28
SOLID STATE SINTERING

Fig. 2

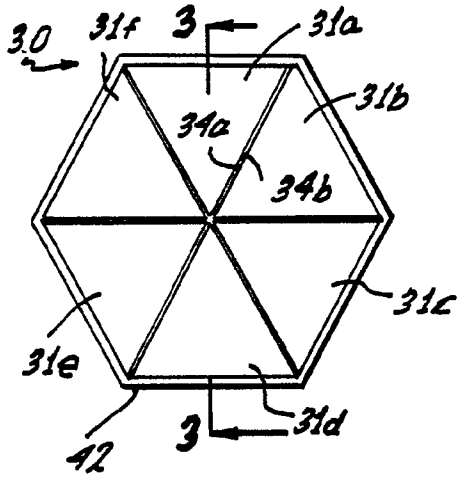
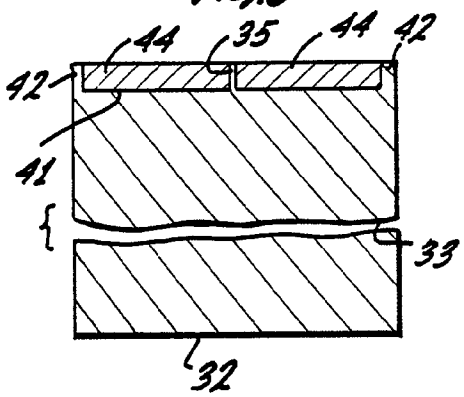


Fig. 3



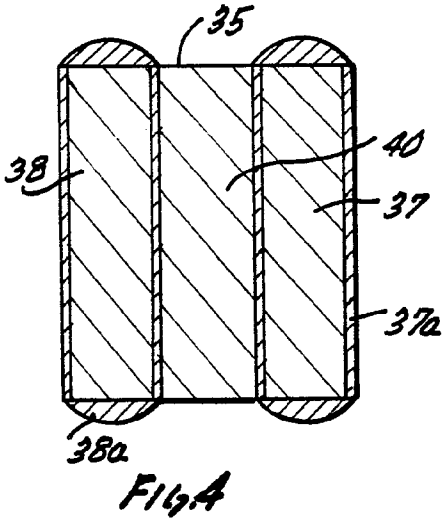


Fig. 4

Fig. 5

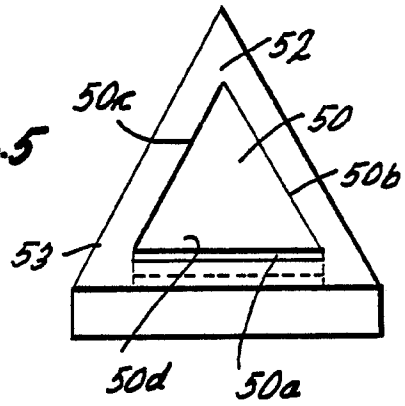
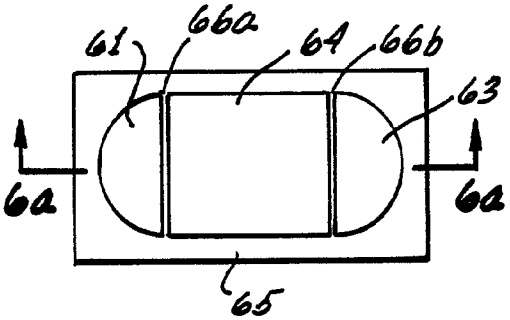


Fig. 6



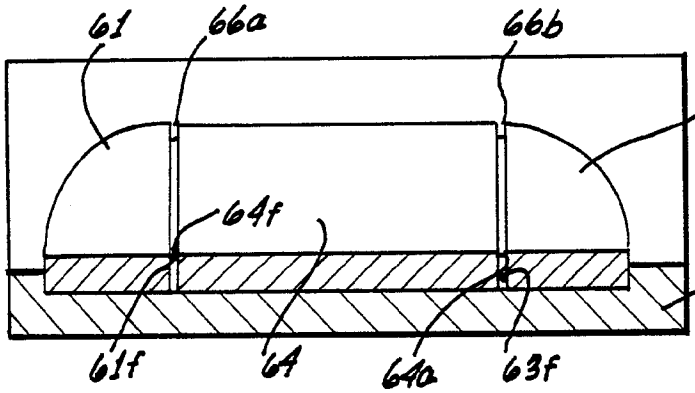
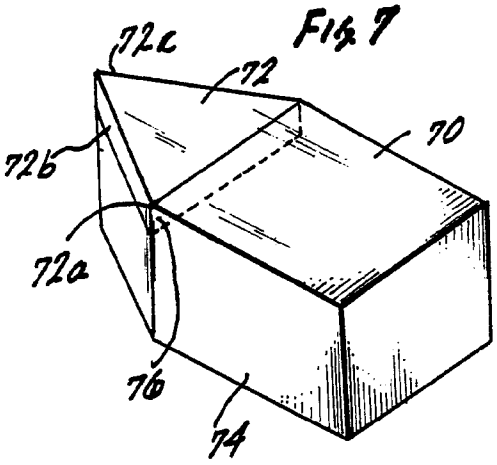


Fig. 6a

BAD ORIGINAL

Fig. 7



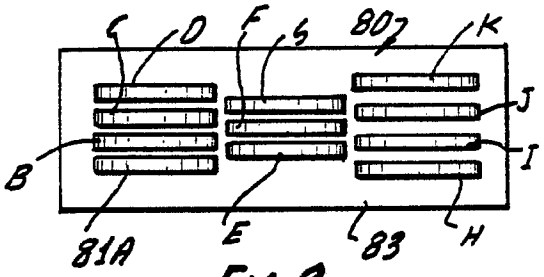


Fig. 8

Fig. 8a

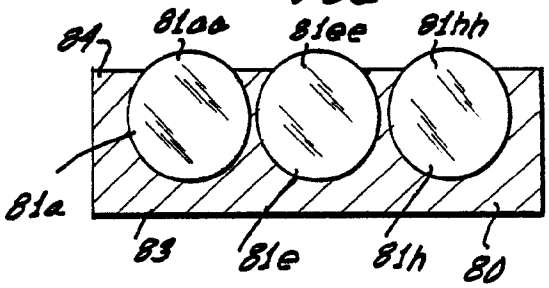


Fig. 9

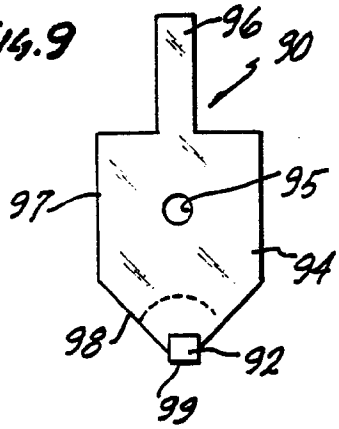
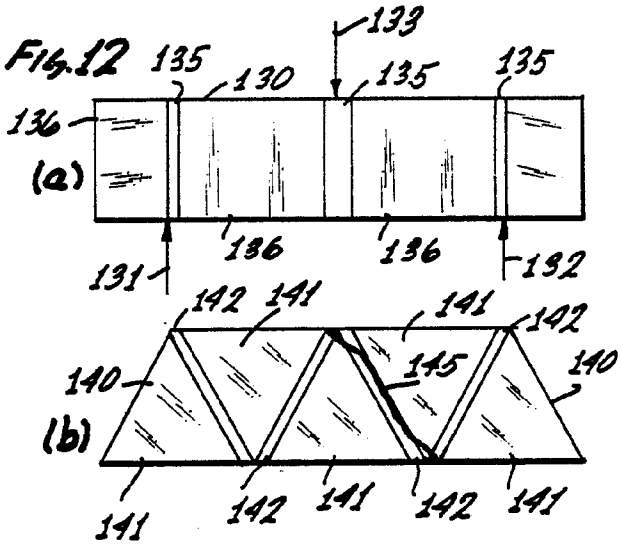


Fig. 12



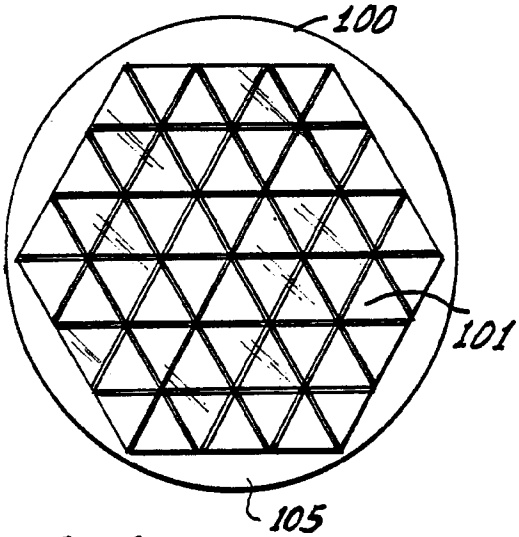
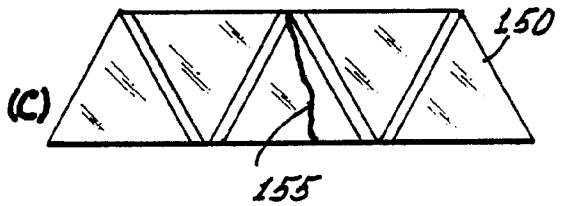
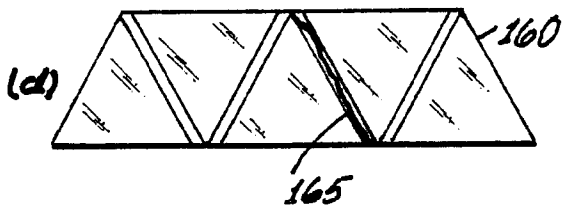


Fig. 10





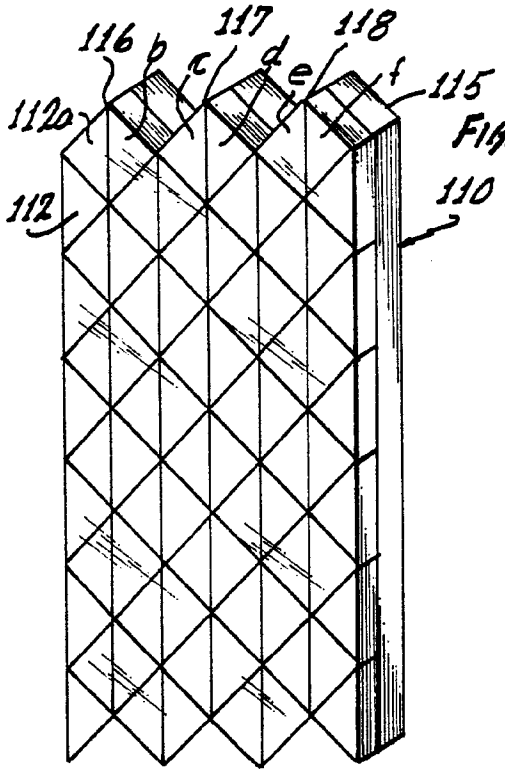


Fig. 11

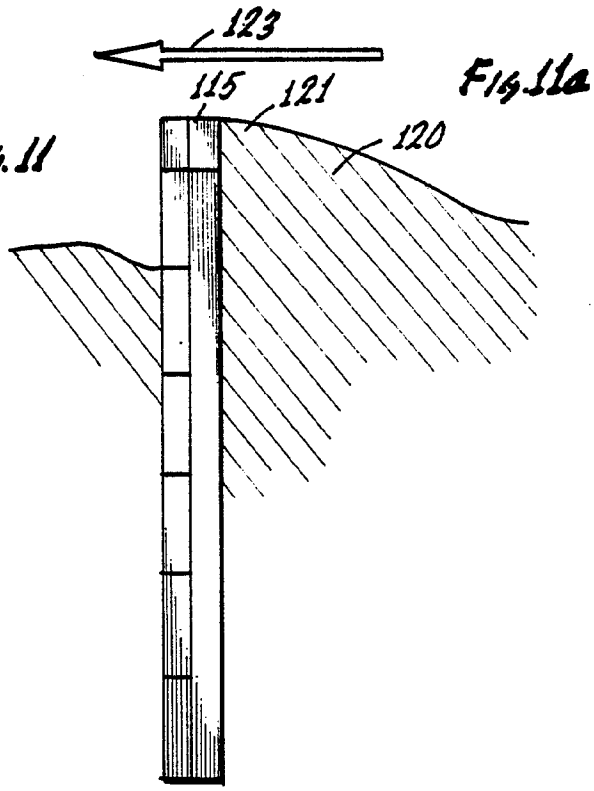


Fig. 11a

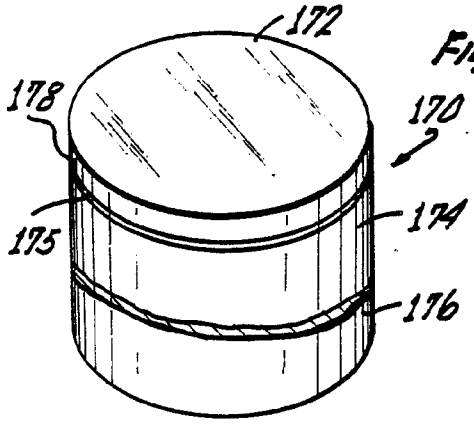


Fig. 13

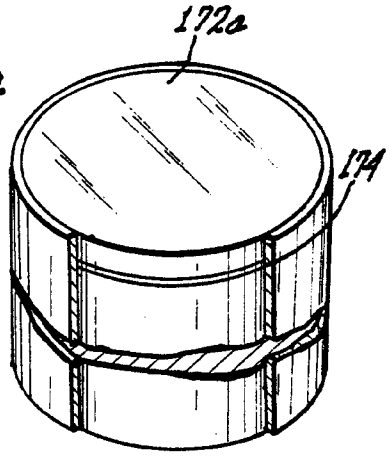


Fig. 13a

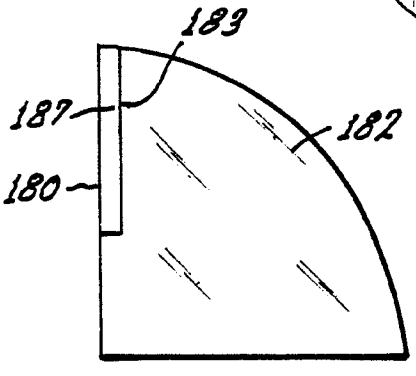


Fig. 14

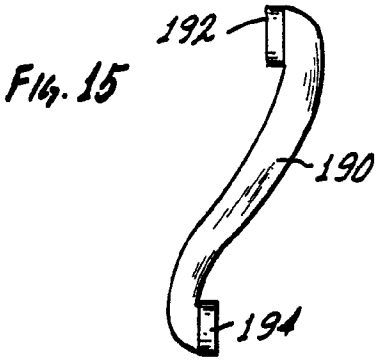


Fig. 15

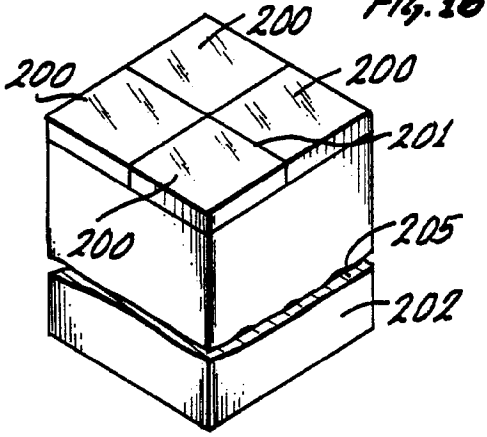


Fig. 16

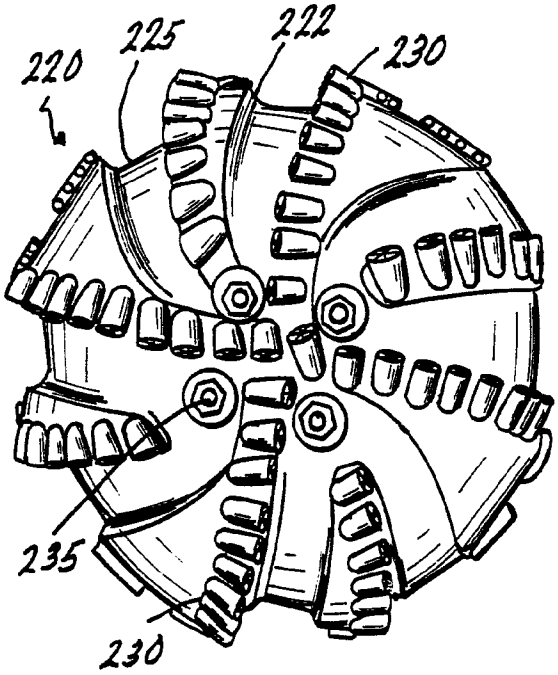


Fig. 17

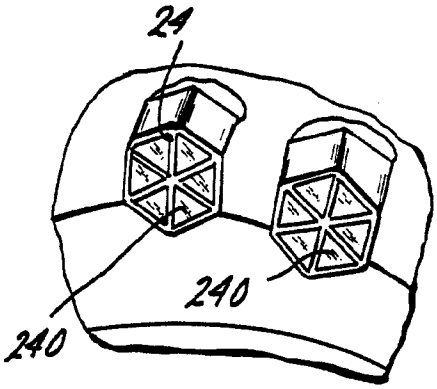


Fig. 18

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A2

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(54) **Flexible abrasives.**

(57) A method of forming an abrasive member comprises fixedly attaching a metal film to one surface of a flexible sheet, applying a mask of plating resistant material to the exposed surface of the metal film, said plating resistant material having a multitude of discrete openings therein, and electrodepositing metal through said discrete openings onto said metal film in the presence of particulate abrasive material so that the material adheres directly to said metal film and the abrasive becomes embedded in the metal deposits.

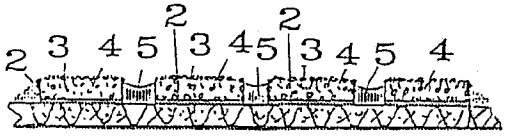


Fig. 1

EP 0 280 657 A2

Description

Flexible abrasives.

This invention relates to a flexible abrasive member particularly suitable for abrading, grinding, smoothing, and finishing operations on stone, glass and other materials in heavy-duty applications.

United States patent no.4,256,467, issued August 17, 1981, to Ian Gorsuch discloses a flexible abrasive member comprising a flexible non-conductive mesh carrying a multitude of nickel deposits in which abrasive material, such as diamond grit, is embedded.

According to the Gorsuch patent, the flexible abrasive member is manufactured by first laying a sheet of flexible non-conductive mesh material onto a smooth electrically conductive surface, suitably masked to expose only those surface portions where electrodeposition is desired, so that the mesh material is in immovable relationship with the conductive surface. Nickel is then electrodeposited onto the exposed portions of the smooth surface through the mesh material in the presence of abrasive material so that the abrasive material becomes embedded in the metal layer and the mesh becomes embedded in the nickel deposits. Finally. the mesh is stripped from the electrically conductive surface and cut into the desired shape.

There are, however, a number of disadvantages associated with the process. The preparation of the cylinder prior to each deposition is expensive and complex. The process is slow and can only operate on a batch basis because a sheet of flexible mesh material of specific size must be attached to the cylinder, applied under tension, and maintained in immovable relationship therewith.

More importantly, the product produced by the Gorsuch process is structurally weak and only suitable for light-duty operations, such as lens grinding. If the product is used in heavier duty applications, such as abrading belts, the mesh has to be bonded to a suitable substrate. The heat generated during the abrading operation makes it difficult to provide a satisfactory bond, and difficulties have been experienced due to the belts breaking, the nickel deposits chipping off the intrinsically weak mesh, and delamination of the belts.

Our co-pending Canadian application no. 518,201, filed on September 15. 1986, describes a method which overcomes the problems relating to the preparation of the conductive cylinder and permits continuous operation of the process. In this method the mask is applied directly to the mesh, which is rendered conductive, instead of to the conductive surface. When a mesh is employed, however, the abrasive member must still be bonded to a strong substrate for heavy-duty applications.

An object of the invention is to provide a process for producing a flexible abrasive member, which is faster and more economical to operate than the one set forth in co-pending Canadian application No. 518. 201, and which lends itself readily to automation. Furthermore, the invention can provide, by such a process, abrasive sheets which can be made into as pads, discs, or belts, capable of operating at higher abrading speeds and presenting a clean surface with clearly defined spaces between the metal deposits. This gives a more efficient abrading action and requires less metal or abrasive material, making the product more economical to manufacture. More significantly, the process can produce directly an abrasive sheet for use in heavy-duty applications without the need for subsequent lamination to a backing material. The abrading member produced by the inventive process dissipates heat efficiently and thus has a longer life.

According to the present invention there is provided a method of making an abrasive member, comprising fixedly attaching a metal film to one surface of a flexible sheet, applying a mask of plating resistant material to the exposed surface of the metal film, said plating resistant material having a multitude of discrete openings therein, and depositing metal directly through said discrete openings onto said metal film in the presence of a particulate abrasive material so that the metal adheres directly to said metal film and the abrasive material becomes embedded in the metal deposits.

The deposition is preferably carried out by electrodeposition although electroless deposition can be employed. The preferred metal for the film is copper and for the metal deposits nickel, although other combinations can be employed.

The abrasive member produced by this process is useful per se. However, in order to reduce the heat buildup in the member during use and thus increase its efficiency and life expectancy, in a preferred embodiment of the present invention , the mask is stripped from the sheet after electrodeposition of the metal to expose the metal film, and the metal film between the discrete metal electrodeposits is etched away to expose the sheet.

The mask can be applied to the metal film by coating with a layer of a photopolymer and exposing the photopolymer to ultra violet light through a screen defining the openings to decompose the polymer. The coating is then developed, preferably by treatment with an alkali, such as sodium hydroxide. The photopolymer can be a dry film photopolymer, such as a dry film photopolymer supplied under the name Riston by Dupont, a laminar dry film resist supplied by Dynachem, or dry film resist supplied by Herculestic, or a liquid film resist supplied by Kodak, GAF, Dynachem, Dupont, or Fuji film. The photopolymer is desirably exposed to ultra-violet light. However, any other type of radiation which degrades the polymer such that it can be developed is suitable.

In a further aspect of the invention there is provided a method of making a flexible abrasive member, comprising applying to an electrically conductive metal surface of a flexible substrate a coating of a photopolymer, exposing the photopolymer to light through a screen having discrete openings to decompose said polymer, developing the coating to provide a mask having a multitude of discrete openings therein, and

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electrodepositing metal directly through said discrete openings onto said metal surface in the presence of a particulate abrasive material so that the metal adheres directly to said metal surface and the abrasive becomes embedded in the metal deposits. As before, in this method it is desirable after electrodeposition of the metal to strip the mask from the substrate sheet to expose the metal surface and etch the metal surface between the deposits to expose the substrate.

Alternatively, the mask may be applied by silk screening, in which case the mask may be made of ultra-violet light curable or thermally curable inks such as infra-red heat curable inks. Such curable plating resists and etching resists may be supplied by McDermid Inc., Dynachem and M&T Chemicals.

The flexible substrate is preferably in the form of a woven fabric, but it may be fibre glass epoxy laminate of the type used for printed circuit board applications, supplied by Westinghouse and GE, when it is desired to make abrasive pads and disks. The sheet may also be formed of a phenolic resin, such as a phenol formaldehyde resin or it may be a polyester fibre glass laminate also supplied for printed circuit board applications. Such sheets suitably have an overall thickness of about 8 to 12 mils.

For forming a flexible abrasive member suitable for use as an abrasive belt, a copper clad, fibre free resin system such as that supplied under the trademark Kapton (by Dupont), which is used for flexible printed circuits may be used. However, in a particularly desirable embodiment of the present invention, the sheet is formed of a strong woven fabric on which the metal film is deposited. A particularly suitable fabric is made of polyaramid yarn, such as p-poly (phenylene) terephthalamide yarn, which is supplied under the trademark Kevlar.

The metal film is fixedly attached to the surface of the sheet and is laminated as a film or deposited by electroless plating, vapour deposition, sputtering, or electrochemical deposition, such as electroplating. The metal may be any electrically conductive metal such as copper, aluminum, nickel, steel, rhodium or gold, but is preferably copper. Suitably the metal film has a thickness from 3/20 to 14 thousanths of an inch preferably 7/10 to 2.8 thousanths of an inch.

The abrasive material is a conventional particulate abrasive such as diamond grit or cubic boron nitride, and preferably industrial diamond. The metal can be any metal which can be deposited from a suitable bath by electrodeposition or electroless deposition and is preferably nickel or copper, more preferably nickel.

In a preferred embodiment, the sheet with the metal film attached thereto is continuously passed through an electrolytic bath to form a cathode, the anodes of which are formed by the metal, whereby the metal is continuously deposited in the discrete openings and during said electrodeposition the particulate abrasive is released into the bath. In order to ensure that the sheet is present in the bath as a cathode, it is connected to a source of negative potential. The sheet is preferably in contact with a smooth non-conductive surface such as a plastic surface, in the bath, which is suitably a nickel sulphamate bath. The mask, which is in the form of a very thin sheet a few thousanths, e.g. 3 to 4 thousanths of an inch thick, defines a lattice with a large number of openings, for example 1/16 of an inch in diameter.

After removal from the bath, the sheet is stripped and etched with alkaline solution. A further very significant feature of the invention is that the Kevlar® sheet bearing the diamond-embedded nickel deposits is coated with a resin, such as a two-part polyurethane resin sold under the trade designation UR 2139X-1 and UR 2139X-1A by Elecbro Inc. After stripping and etching, the Kevlar sheet consists of a multitude of nickel nodules carried by copper segments bonded to the Kevlar fabric. The nodules hold quite well onto the fabric during use, but their tendency to chip off can be dramatically reduced by coating with the polyurethane resin. This fills the interstices between the nodules, thereby reducing the shearing forces as the fabric is moved over the working surface. It has been further found that the use of a filled resin, i.e. a resin filled with a solid particulate material, particularly silicon carbide powder further inhibits the lateral movement of the nodules reducing even further their tendencies to chip off.

In a still further feature of the invention, the nickel nodules are given predetermined characteristic shapes. In one embodiment, the nodules have a crescent-moon shape. This has the effect of minimizing the use of diamond without impairing the abrasive properties. The removal of abraded material can also be assisted by careful design of the shapes of the nodules. The photographic and silk-screen processes described above lend themselves particularly well to the fabrication of shaped nodules.

The invention will now be described in more detail, by way of example only, with reference to the accompanying drawings, in which:

Figure 1 shows in cross-section a short length of Kevlar fabric carrying diamond-bearing nickel deposits;

Figure 2 shows a laminated substrate bearing a surface mask defining a regular pattern of crescent-shaped holes;

Figure 3a shows a detail of one of the shaped holes; and

Figure 3b shows a detail of a group of holes.

Example 1

A copper clad, fibre glass epoxy laminate, sold for printed circuit board applications by Westinghouse or GE, having a thickness of 8 mils to 12 mils had its copper surface mechanically cleaned with a scrubber. A dry film photopolymer supplied by Dynachem was laminated to the copper surface at about 220°F and then exposed to ultra violet light through an apertured screen defining the holes with a Scannex exposure unit. The protective Mylar sheet, which comes with the dry film, was removed and the exposed film developed with

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potassium hydroxide solution.

The product bearing the photographically formed mask was then treated in a commercial electrolytic nickel sulphamate bath, supplied under the trademark SNR 24 by Hansen, operating at 170 amps and 9 volts DC at a temperature of 140-C.

The flexible abrasive member leaving the bath, though suitable for cutting and use without further treatment, was treated with a Chemalex stripper to strip off the dry photofilm and then etched with alkaline-based copper etching solution supplied by Hunt Chemicals, by spray etching.

The abrasive member had a clear translucent aesthetically pleasing appearance with well defined protuberances containing the diamond abrasive and substantially no intermediate diamond-containing metal between the protuberances. This is in contrast to the product obtained according to the process described in our copending Canadian application no. 518.210, which displayed a more untidy appearance and tended to have metal and diamond particles present between the protuberances. The clean appearance of the abrasive member has consumer appeal, particularly in the do-it-yourself market, but it also provides a more efficient abrading member. In addition it makes the product cheaper to manufacture as there is less waste of metal and abrasive material.

The presence of the copper layer has a number of advantages: It provides a smooth surface on which deposition can take place, which is important to prevent break-through of the mask and to permit even distribution of diamond grit. When the mask and copper bridging regions between the nodules are removed, the remaining copper segments under the nodules, by which the nodules are attached to the substrate, form part of the protruberances. To achieve a protuberance of given height, the electrodeposition time can be shortened due to the presence of the underlying metal segments. The metal deposits should stand proud of the substrate by an amount sufficient to permit adequate removal of abraded material and avoid undue wear.

Example 2

A 10 ounce Kevlar fabric 24 × 24 inches in size was subjected to electroless copper plating by passing through the standard electroless copper plating process known under the trademark Ethone System CU 701. Such a process is conventionally used for producing printed circuit boards with a copper coating of a thickness of 80 to 120 microns deposited on both sides.

The copper coated fabric was then subjected to masking and nickel and diamond deposition by the method described in example 1. The copper clad sheets can be treated in a manner similar to the fibre glass epoxy laminate.

Upon removal from the electrolytic bath, and after stripping and etching, the Kevlar sheets were coated with polyurethane resin to fill the interstices between the nickel nodules. The sheets were then cut and formed into belts after the reverse surface was covered with a rubberized epoxy resin system to prevent fraying and cutting of the belt.

Example 3

A Sheet of Barrday F-2160/175 Kevlar 29-1500 denier scoured fabric was impregnated with BO800 LOMOD™ copolyester elastomeric resin. The resin was in liquid form and applied with rollers. A layer of 10oz. copper foil was then applied to the impregnated sheet and the assembly maintained in a press under 250 psi pressure for approximately one hour at room temperature.

Upon removal from the press, the exposed surface of the foil was mechanically scuffed to improve adhesion. A plating-resistant mask with a multitude of openings was then applied to the copper foil in the manner described above, and the laminate placed in an electrolytic deposition bath. Nickel was deposited onto the copper foil through the openings in the mask with diamond particles sprinkled into the tank during the electrodeposition.

The mask was stripped from the foil and the intervening copper etched away to leave upstanding diamond-bearing nickel deposits lying on small copper discs. The interstices between the nickel deposits were then filled with a flexible polyurethane resin, such as Elecbro UR 2139X-1 and UR 2139X-1A, so that the abrasive product presented a continuous surface on the abrasive side. As discussed above, the use of a resin coating has the important advantage that during use the tendency of the deposits to be chipped off the backing fabric is minimized. Other flexible resins can be employed.

The LOMOD™ resin substantially enhances the properties of the fabric. It prevents degradation of the fabric due to fraying and scuffing during heavy industrial use without impairing the flexibility of the belt. It has good physical, mechanical, thermal, electrical and flame-resistant properties.

Of equal significance is the fact that the LOMOD™ has sufficient strength to permit lamination of the copper foil to the fabric and good retention of the residual copper segments after stripping and etching during use.

The advantage of this technique is that unlike the copper spray, the laminated foil has a smooth surface. The uniformity of the abrasive can be accurately controlled and the tendency of the electrolytic deposits to break through the masked portions minimized.

The physical data for these LOMOD™ resins are as follows:

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Property	LOMOD BO800	LOMOD BO852
Specific Gravity	1.23	1.30
Flexural Modulus,psi	85,000	95,000
Tensile Strength,psi	3,350	3,475
Tensile Elongation,% @ Break	250	125
Dielectric Strength	415	405

Belts, discs and other types of abrasive product made with LOMOD℠ impregnated sheets in the manner described have exceptional strength and abrasive properties.

EXAMPLE 4

A sheet of 10 ounce KevlarTM [a trade mark of DuPont for p-poly-(phenylene)terephthalamide yarn] 24 by 24 fabric was bonded under heat and pressure with LomodTM (available from General Electric) resin to a copper sheet having a surface density of one ounce per square foot. The surface of the copper sheet was cleaned and scrubbed with an abrasive brush in a scrubbing machine.

The cleaned laminate was passed through a dry film laminator made by Thiokol/Dynachem Company (Model 30) to apply a Riston (a trade mark of DuPont) photo-resist film (an alternative is Dynachem film).

Laminate with the applied photo-resist film was placed in a Scannex II exposure unit with a screen defining the desired pattern of crescent-shaped holes. The screen can be produced photographically.

After exposure to ultra violet light, the image was developed and the protective Mylar film, applied by the laminator, removed.

The electrodeposition took place in the presence of diamond grit in an electrolytic bath in a similar manner to that described above to form crescent-shaped diamond-embedded nickel pellets. Other abrasive particulate material, such as cubic boron nitride, can be employed,

After electrodeposition, the mask and exposed copper were removed with an alkaline stripping and etching solution.

The product was then roller coated with polyurethane protective resin, having the trade designation UR 2139X-1 and UR 2139X-1A by Elecbro Inc, to fill the interstices between the nickel deposits.

The sheet was then cut into strips and the strips formed into belts ready for use as an abrasive.

Instead of using photo-resist materials to form the mask, the mask can be applied by a silk screening process. In this case, the mask is made of enplate UR 2311B silk screening material which is ultra-violet cured after application in the silk-screening process.

Referring to Figure 1, a length of Kevlar fabric 1 is impregnated with Lomod℠ and has bonded thereto copper discs 2. These discs were applied as a copper foil in the manner described above but are all that remain of the original foil after the stripping and etching operation described above.

The nickel nodules 3 are electrolytically deposited on the copper discs 1 and have diamond particles 4 embedded therein.

The voids between the nodules 3 are filled with polyurethane resin 5 in the manner described above. The resin 5 reduces lateral movement of the nodules 4 and has a profound effect on their tendency to chip off during the abrasion process. The resin has a greater effect than would result merely from its adhesive action due to the way in which it stabilizes the nodules in operation. One of the factors inhibiting widespread use of this type of abrasive product in the past has been the difficulty of retaining the nodules on the substrate in the hostile environment of an industrial abrading machine.

The sheets are cut into strips and formed into belts by making a butt joint and applying a tape on the rear side with Bostik 7070℠ adhesive. To minimize wear, the rear side should be slightly scuffed in the region where the tape is to be located so as to avoid a noticeable bump when the tape is in place. The edges should desirably be cut in a wavy line to reduce lateral movement.

The laminate 11, shown in figure 2, comprises a Kevlar℠ fabric resin bonded to a copper sheet 12 covered

with a surface mask 13 of photo-resist material defining crescent-shaped holes 14 through which electrodeposition occurs. The laminate shown in Figure 2 is subsequently placed in an electrolytic tank to permit deposition of nickel in the presence of diamond grit through the shaped holes 14. This process produces crescent-shaped pellets at the locations of the holes with diamond grit embedded in the nickel.

After removal from the tank, the mask and exposed copper are striped from the Kevlar™ to leave a sheet consisting of a regular pattern of crescent-shaped pellets firmly attached to the Kevlar™ backing. Each pellet consists of an electrodeposit of nickel bearing the diamond grit carried on a crescent-shaped segment of copper bonded to the underlying fabric.

Figure 3a shows in detail the shape of the holes. The crescent-shapes are defined by overlapping circles of slightly different radii. Figure 3b shows how the holes are arranged in a symmetrical arrangement.

The manufactured sheet is subsequently cut into strips, which in turn are formed into belts. The crescent-shaped modules make the belts unidirectional, in that the convex edge has to face the direction of movement a of the belt. This is generally a significant disadvantage.

The use of crescent-shapes permits significant savings in diamond grit, since the surface area of the pellets is less than for circular pellets, without deterioration in the abrasive properties, and furthermore the removal of abraded matter is improved.

The holes can have other shapes. For example, honeycomb shapes provide the belt with greater rigidity.

The spacing and size of the pellets can be varied to fine tune the properties of the abrasive product according to the intended application. A much greater degree of control can be exercised over the abrasive properties than was previously possible. For rough grinding purposes, the pellets are spaced further apart and larger diamonds employed. For smooth grinding applications, the pellets are brought closer together and smaller diamonds used.

Kevlar™ is a particularly useful material for making abrasive belts. For disks on the other hand, the copper foil can be bonded onto fiberglass or other semi-rigid material and the fiberglass then laminated onto a firm backing, for example a polyester backing.

Claims

1. A method of forming an abrasive member, characterized in that a metal film is fixedly attached to one surface of a flexible sheet, a mask of plating resistant material is applied to the exposed surface of the metal film, said plating resistant material having a multitude of discrete openings therein, and metal is electrodeposited through said discrete openings onto said metal film in the presence of particulate abrasive material so that the material adheres directly to said metal film and the abrasive becomes embedded in the metal deposits.

2. A method according to claim 1 characterized in that after electrodeposition of metal, the mask is stripped from the sheet to exposed the metal film and the metal film between the discrete metal electrodeposits is etched away to expose the sheet.

3. A method according to claim 1 or 2 characterized in that the voids between the metal deposits are at least partially filled with resin in particular polyurethane resin, to reduce lateral movement of the deposits.

4. A method according to any of claims 1 to 3 characterized in that the mask is applied to the metal film by coating the film with a layer of photopolymer and the photopolymer is exposed to light through a screen having discrete openings therein to decompose said polymer, said coating then being developed to remove the decomposed polymer and expose the underlying metal film.

5. A method according to claim 1 characterized in that the mask is applied by silk-screening through a mesh.

6. A method according to claim 5 characterized in that the mask is made of an ultra-violet light curable or thermally curable ink.

7. A method according to any of claims 1 to 6 characterized in that the metal film is laminated onto the sheet or is deposited by electroless plating, vapour deposition, sputtering, or electrochemical deposition onto the sheet.

8. A method according to any of claims 1 to 7 characterized in that the sheet is a flexible woven fabric, in particular polyaramid yarn or p-poly (phenylene) terephthalamide yarn.

9. A method according to any of claims 1 to 8 characterized in that the mask defines a multitudinous pattern of holes having a predetermined shape, in particular a crescent shape, whereby said metal deposits form shaped metal pellets.

10. A method according to any of claims 1 to 9 characterized in that said metal film is copper foil, said substrate is a polyaramid fabric resin bonded to sail copper foil, said electrodeposited metal is nickel, and said abrasive particulate material is diamond grit.

11. A method according to any of claims 1 to 10 characterized in that the flexible sheet is coated with a copolyester elastomeric resin.

12. A method according to claim 11 characterized in that the metal film is bonded to the fabric with said copolyester resin under pressure.

13. A method according to claim 3 characterized in that the resin is filled with a particulate solid filler

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material.

14. A method according to claim 3 characterized in that the resin is filled with silicon carbide powder.

15. An abrasive member characterized in that it comprises a flexible sheet having a multitude of discrete metal protuberances fixedly attached to one surface thereof, each of the protuberances comprising a lower thin layer of a first metal fixedly attached to the sheet and an upper electrodeposited layer of a second metal having a particulate abrasive material embedded therein.

16. An abrasive member according to claim 15 characterized in that the first metal is copper, the second metal is nickel, and the particulate abrasive material is diamond grit.

17. A flexible abrasive product characterized in that it comprises a flexible substrate, in particular a polyaramid fabric, having a multitude of metal pellets bearing particulate abrasive material attached thereto, said pellets being arranged in a pattern and having a predetermined shape, said pellets comprising electrodeposited metal on copper segments resin-bonded to said substrate.

18. A flexible abrasive product according to claim 17 characterized in that said segments are bonded to said fabric with copolyester resin.

19. An abrasive product characterized in that it com prises a multitude of discrete metal pellets bearing particulate abrasive material, said pellets being fixedly attached to a flexible substrate and the voids between the pellets being at least partially filled with flexible filler material to reduce the shearing forces on the pellets during use.

20. An abrasive product according to claim 19 characterized in that the filler material is polyurethane resin.

21. An abrasive product according to claim 20 characterized in that the resin is filled with a particulate solid filler material

22. An abrasive product according to claim 20 characterized in that the resin is filled with silicon carbide powder.

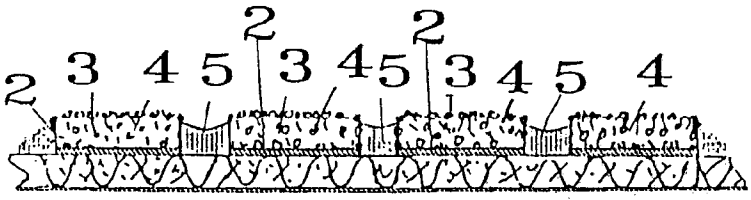


Fig. 1

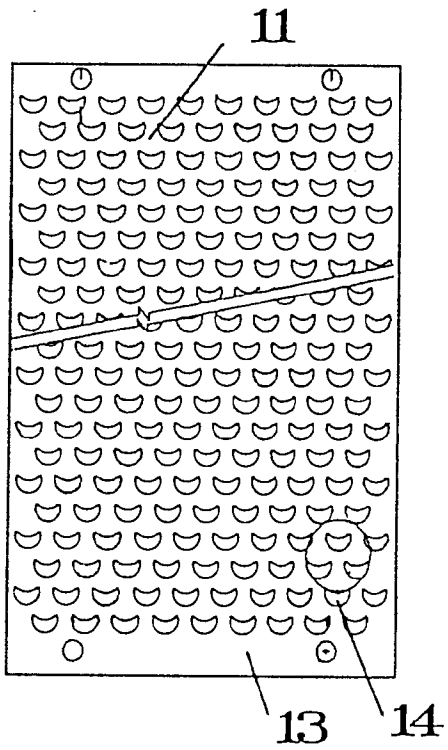


Fig. 2

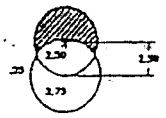


Fig. 3a

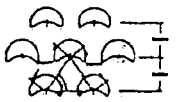


Fig. 3b

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(54) Abrasive sheeting having individually positioned abrasive granules.

(57) Abrasive sheeting can produce fine finishes at surprisingly high cutting rates when its abrasive granules are individually positioned in a predetermined pattern, with an uncoated portion of virtually every granule protruding from the surface of the binder layer. Each of the abrasive granules preferably is a spherical composite of a large number of abrasive grains in a binder. For example, abrasive grains having a mean dimension of about 4 µm can be bonded together to form spherical abrasive granules of virtually identical diameters, preferably within a range of from 25 to 100 µm.

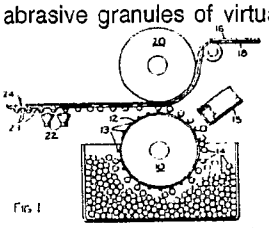


Fig. 1

EP 0 331 344 A2

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ABRASIVE SHEETING HAVING INDIVIDUALLY POSITIONED ABRASIVE GRANULES

Background of the Invention

Field of the Invention

The invention concerns abrasive sheeting or coated abrasives of the type having a backing which usually is flexible and carries abrasive grains or granules embedded in a binder layer and usually is flexible.

Description of the Related Art

At least as early as 1905, as taught in U.S. Patent No.794,495 (Gorton), it was discovered that unbroken "abrading surfaces soon become clogged and gummed by the fine grit and minute particles worn from the abracing surface and from the metal-work (or other work) being held to the abrading-surface" and that these materials can be carried away more effectively by applying the abrasive grit in a dot pattern. In U.S. Patent No. 1,657,784 (Bergstrom), a dot pattern is obtained by applying a binder to a backing, applying abrasive grains or granules to the binder, and then scraping off portions of the binder and adhered abrasive granules. More commonly, an adhesive is applied in a dot pattern so that the abrasive granules adhere only in that pattern. In U.S. Patent No. 4,317,660 (Kramis et al.), the adhesive dot pattern is obtained by applying the adhesive through stencil holes. After attracting a large number of abrasive granules to each dot, the abrasive granules are covered with a size coat.

In abrasive sheeting that has appeared on the market with such a dot pattern, there is a heap or a pile of abrasive granules at each dot, and that heap of granules is covered with a size coat. Because the height of each heap is more or less random, the individual heaps and the individual granules of each heap are loaded differently and hence produce uneven cutting. The size coat interferes with the cutting action of the abrasive granules and also results in uneven cutting due to variations in the extent to which the size coat covers the abrasive granules.

Uneven cutting of prior abrasive sheetings also emanates from irregular sizes and shapes of their abrasive granules. This effect has been minimized by using spherical granules of equal size. Another type of spherical abrasive granule consists of a large number of abrasive grains in either an organic or inorganic matrix. Because of their uniformity, such composite granules renew themselves as they wear away, thus maintaining relatively uniform abrasive cutting action for longer periods of time than has been possible when using abrasive sheeting coated with irregular abrasive granules. Such composite abrasive granules are disclosed in U.S. Pats. No. 3,916,584 (Howard et al.); No. 4,112,631 (Howard); and No. 4,541,842 (Rostoker). U.S. Pat. No. Re. 29,808 (Wagner) shows hollow balls consisting of abrasive grains bonded onto the outer surface of a friable matrix. Even though Fig. 1 of the Wagner patent shows those spheres uniformly positioned in a binder layer, the patent says that the hollow balls "are mixed with a bonding material and brought into the shape of the grinding body, after which the bonding material is allowed to harden out, and during the production of an abrasive belt the hollow bodies are bonded in the usual manner to a base material" (col. 6, lines 43-48). In Example 1, ready-prepared abrasive grain balls are uniformly strewn onto a layer of resin on a cotton twill fabric.

Even when prior abrasive sheetings employ composite spherical granules of equal size, sheetings made at one time tend to have different cutting rates than do those made at other times due to variables in their manufacture. Accordingly, when prior abrasive sheetings have been used under numerical or robotic control, it has been necessary to test the cutting rate of each jumbo roll before putting it to use.

Abrasive sheeting ordinarily is manufactured in great lengths that are wound into rolls for storage and shipment. Eventually, the sheeting is die-cut into desired sizes and shapes. For example, it may be cut to form daisy pads that are used to polish lenses. In doing so, the die contacts the abrasive particles which cause its cutting edge to become dull and to require resharpening within a short period of time.

Other Prior Art

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Abrasive tools are often made by handsetting abrasive granules such as diamonds, but such granules are quite large. It is believed that handsetting has never been employed in abrasive sheeting that has appeared in the market.

U.S. Pat No. 4,536,195 (Ishikawa) concerns a method of making grinding stones, the abrasive grains of which are distributed in a controlled manner so that the load working on each grain is even, making the stone more efficient and of longer life. In a first variation of the Ishikawa method, an electrically conductive pattern is formed on a resinous binder sheet which is then immersed into an electroplating path containing metallic ions mixed with abrasive grains that are attracted to the pattern. The electrically conductive pattern may be formed by photoetching or printing techniques. A number of the abrasive-bearing sheets are placed in layers and molded into a grinding stone by warm or hot pressure molding. Another variation is the same as the first except that the sheet is metallic and a surface is masked so that the abrasive grains are attracted only to the unmasked areas. An example of distribution of abrasive grains on the surface of a grinding stone is shown in Fig. 15 wherein the grains are located in rows and uniformly spaced from adjacent grains.

Summary of the Invention

The invention provides abrasive sheeting or coated abrasive that can produce finer finishes at faster cutting rates than could be attained in the prior art. Furthermore, the novel abrasive sheeting is believed to provide a more predictable cutting rate, thus minimizing the need to test its cutting rate before using it in robotic or numerically controlled machines.

Briefly, the abrasive sheeting of the invention has a backing carrying a binder in which abrasive granules are strongly bonded and lie substantially in a plane and at a predetermined lateral spacing. The granules should be of substantially equal size, i.e., the mean dimension of 90% of the granules should differ by less than 2:1. Each of the abrasive granules should pass a screen with 300 μm openings, because substantially larger granules would not provide the fine finishes desired in uses for which the novel abrasive sheeting is intended.

The granules preferably are in a predetermined pattern (or patterns when using granules of differing sizes or types) that provides spaces between the granules of sufficient width to carry off detritus. In a preferred pattern, single granules are uniformly spaced and aligned in rows extending both longitudinally and transversely (i.e., in the X and Y directions). In another preferred pattern, abrasive sheeting having circular rows of uniformly spaced granules can be cut into discs, the centers of which are concentric with the circular rows.

Preferably the abrasive granules are equiax, and the diameter of substantially every granule is within 10% of the mean diameter so that the granules protrude from the surface of the binder layer to substantially the same extent and so can be loaded equally upon contacting a workpiece, thus providing an extraordinarily uniform finish. By "equiax" is meant that each granule has approximately the same thickness in every direction. An equiax granule can be considered to have a diameter, whether or not it is spherical.

The abrasive granules can have various populations at various areas of the novel abrasive sheeting in order to remove material at differing rates from selected faces of a workpiece. In one technique for determining the populations required to accomplish this, the wear of abrasive sheets of uniform density is studied, and the novel abrasive sheeting is made to have increased granule population at areas showing the most wear. The predetermined granule pattern also can be selected to leave the novel abrasive sheeting free from abrasive granules in areas to be die-cut, thus allowing the die to remain sharp much longer than has heretofore been possible. This also minimizes waste.

The invention also concerns a novel method of making abrasive sheeting by the sequential steps of

1) attracting small abrasive granules only to dots in a predetermined pattern on a carrier,

2) while advancing a backing that carries a tacky binder layer in synchronism with said carrier, transferring the attracted granules into the binder layer in said pattern, and

3) rendering the binder nontacky.

When the carrier is at the surface of a rotating cylinder, this 3-step method can produce abrasive sheeting of almost unlimited length which can be wound up in roll form for convenient storage and shipment. In such a roll, the predetermined pattern of abrasive granules repeats many times. Such a roll can be converted into a variety of articles such as discs, daisies, sheets, and belts.

When the abrasive granules have irregular shapes, the 3-step method causes the major axis of each

granule to lie substantially in a plane parallel to the backing. Hence, when irregular granules are of substantially the same size, they tend to protrude from the binder to substantially the same extent and to abrade uniformly to afford uniform finishes.

Preferably the binder is selected so that subsequent to step 2) is an additional step of softening the binder, usually by being heated, to form a meniscus at each granule, thus enhancing the bonding of each granule to the backing. Doing so should make it unnecessary to overcoat the granules, thus leaving the cutting surface of each granule free from material that could otherwise interfere with its abrasive function. When heat is used to form menisci, the extent to which the abrasive granules protrude from the binder can be controlled by adjusting the time and temperature at which the menisci are formed. When a meniscus is to be formed at each abrasive granule, the pressure applied in step 2) can be very light, just enough to tack the granules to the binder layer.

Instead of, or in addition to, forming a meniscus at each granule, a size coat can be applied over the novel abrasive sheeting to enhance the bonding of the abrasive granules. Usually this is unnecessary, unless the abrasive granules are rather large, e.g., are retained by a screen with 100 μm openings. When the abrasive granules are expensive, e.g., diamonds, a size coat may be desirable to ensure that they are not dislodged and lost.

Although the individual abrasive granules that lie in a predetermined pattern should be of substantially equal size, selected areas of the novel abrasive sheeting can have abrasive granules of one size in one predetermined pattern while other areas have granules of a different size in another predetermined pattern, each to provide a desired rate of cutting and degree of finish at a particular area of a workpiece. For the same reason, the novel abrasive sheeting may employ abrasive granules of two or more different types, each type being individually positioned in a predetermined pattern. In order to make abrasive sheeting having two sizes or two types of abrasive granules, steps 1) and 2) are repeated with the second size or type of granule prior to step 3).

Detailed Description

Each of the abrasive granules of the novel sheeting preferably is an equiax composite of a large number of abrasive grains in an inorganic or organic binder matrix. For example, abrasive grains having a mean dimension of about 4 μm can be bonded together to form spheres of virtually identical diameters, preferably within a range of from 25 to 100 μm. Because of their uniform diameter, each equiax granule can be positioned to protrude to the same extent from the binder layer. By individually positioning the equiax granules to be spaced equally from adjacent granules, the granules each bear the same load and hence wear at substantially identical rates and tend to continue to be equally effective as long as uncoated portions protrude from the binder layer. Consequently, workpieces continue to be polished uniformly, in contrast to the tendency of prior abrasive sheeting to provide uneven polishing upon becoming worn.

Preferably the thickness of the binder layer of the novel abrasive sheeting is from 25 to 150 μm. Thicknesses above that range may be uneconomical, while thicknesses below that range may not bind the abrasive granules as strongly as desired. When the binder layer is coated from solution or emulsion, it may be difficult to obtain uniform layers much greater than 50 μm.

A carrier that can be used in the above-outlined 3-step process is a printing plate marketed by Toray Industries as "Toray Waterless Plate." It has a flexible sheet of aluminum bearing a layer of photosensitive material covered with a layer of silicone rubber. Upon exposure to light through a half-tone screen, the silicone rubber of a positive-acting plate causes the photosensitive material to bind itself firmly to the silicone rubber in areas where the light strikes, after which the silicone rubber in unexposed areas can be brushed off, leaving silicone rubber dots in the predetermined pattern provided by the light exposure. The printing plate is then wrapped onto a cylinder, and the cylinder is rotated through a fluidized bed of abrasive granules. The granules are attracted to the printing plate only where the silicone rubber remains and not to the ink-receptive areas. Upon moving a binder-carrying backing in synchronism with the rotating printing plate, the granules are picked up by and become embedded into the binder layer in the pattern of the printing plate. That pattern repeats many times when the backing is long.

When a "Toray Waterless Plate" is used in the above-outlined 3-step process and the tacky binder layer would stick to the silicone rubber of the printing plate, a transfer roll can be positioned between the binder layer and the printing plate. The surface of the transfer roll should be selected to cause the abrasive granules to transfer from the silicone rubber of the printing plate, while acting as a release surface in relation to the tacky binder.

For most applications of the novel sheet, the breadth of the dots formed in step 1) of the above 3-step

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process should be small enough that only one abrasive granule is attracted to each position, but when each dot is large enough to make it fairly certain that there will be a granule at every dot, it can be expected two or possibly three granules will be deposited side by side at a few positions. When only one abrasive granule per dot is desired, each dot preferably is roughly circular and has a diameter within the range of 30 to 90% of the mean dimension of the abrasive granules. When using spherical abrasive granules 80 μm in diameter, good results have been attained with dots 62 μm in diameter. When the diameter of each dot substantially exceeds the diameter of an abrasive granule, a monolayer of several granules may be attracted to each dot.

The use of a printing plate mounted on a cylinder in the above-outlined 3-step process may result in a seam that may produce discontinuities in the pattern of abrasive granules. Abrasive sheeting of the invention, that has no seam in its pattern, can be made by sequentially coating onto a cylinder formulations that provide a cylindrical printing plate, preferably including a silicone rubber layer. Preferred sequential coating formulations are those of U.S. Pat. No. 3,511,178 (Curtin).

If a seam in the pattern is not objectionable, step 1) of the above-outlined 3-step process for making abrasive sheeting of the invention can use a carrier prepared by the steps of

1) coating one face of a sheet of metal foil with rubber and the other face with a photoresist,
2) exposing the photoresist to light in a predetermined pattern,
3) removing areas of the photoresist corresponding to said pattern, and
4) etching away the metal foil in said areas to expose the rubber in said predetermined pattern.

It is also preferred, particularly if the abrasive granules would be attracted to the remaining photoresist, to include after the etching step the step

5) removing the remaining photoresist.

Among classes of binders that can be used in the novel abrasive sheeting are thermoplastic resins such as ethylene/acrylic acid copolymer, polyethylene, and poly(ethylmethylacrylic) acid, which is available from E.I. duPont Company under the trade designation "Surlyn". Another useful class of binders is acrylic pressure-sensitive adhesives which cure to a nontacky state. Also useful are thermosetting binders which have a tacky state such as epoxy resins, phenolics, and polyurethanes.

The backing of the novel abrasive sheeting can be fabric (e.g., woven or non-woven fabric such as paper) which may be saturated with a filled binder material, a polymer film such as that formed of oriented heat-set polypropylene or poly(ethylene terephthalate) which may be first primed, if needed, with a priming material, or any other conventional backing material.

In the novel abrasive sheeting, the addition of a grinding aid over the surface of the abrasive granules may provide improved grinding performance. Grinding aids may also be added to the size coat or as particulate material. The preferred grinding aid is KBF_4, although other grinding aids are also believed to be useful. Other useful grinding aides include NaCl, sulfur, K_2TiF_6, polyvinyl chloride, polyvinylidene chloride, cryolite and combinations and mixtures thereof. The preferred amount of grinding aid is on the order of 50 to 300 g, preferably 80 to 160 g, per square meter of coated abrasive product.

The Drawing

The invention may be more understandable by reference to the drawing wherein:

Fig. 1 schematically shows a method of printing abrasive granules onto a binder layer carried by a flexible backing, thus providing preferred abrasive sheeting of the invention;

Fig. 2 is an electronmicrograph showing abrasive granules having been attracted to a tackified binder layer using apparatus illustrated in Fig. 1;

Fig. 3 is an electronmicrograph showing a fragment of abrasive sheeting of the invention made by heating the intermediate product of Fig. 2 to form a binder meniscus at each granule; and

Fig. 4 schematically shows a fragment of an abrasive sheeting of the invention after it has been cut to form daisy pads.

In Fig. 1, attached to a rotatable, heated metal cylinder 10 is a printing plate 12, the outer surface of which has been developed to leave roughly circular rubber dots 13. The cylinder is rotated through a fluidized bed of spherical abrasive granules 14, each of uniform diameter somewhat larger than the diameter of the rubber dots. After removing excess granules by suction at 15, substantially one abrasive granule 14 adheres to each of the rubber dots 13. Moving at the same speed as the surface of the cylinder

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10 is a flexible backing 16 carrying a heat-activatable binder layer 18 which is pressed against the printing plate 12 by a heated nip roll 20. Heat from the cylinder 10 and rubber-covered nip roll 20 tackify the binder layer 18 to permit the attracted granules 14 to be adhered superficially to the binder layer 18 in spaced rows extending in the X and Y directions as seen in Fig. 2. In the upper left corner of Fig. 2, a few abrasive granules have fallen out, leaving small craters in the binder layer. The abrasive granules have been deposited in the lower part of Fig. 2 at twice the density of the upper part. At most positions, only one abrasive granule has been deposited, but at a few dots, there are two granules side by side.

Referring again to Fig. 1, the granule-bearing backing 16 is passed across a bank of infrared lamps 22 by which the binder is heated to wet the surfaces of the abrasive granules, thus causing the binder layer to flow and form a meniscus 23 around the base of each granule as shown in the electronmicrograph of Fig. 3. This causes the abrasive granule to become strongly bonded to the flexible backing 16.

The resulting abrasive sheeting 24 of the invention contains abrasive granules 14 individually positioned to permit the sheeting to be die-cut into daisy pads 26 as shown in Fig. 4. The abrasive granules have been positioned in concentric rows such that their density in areas 28 adjacent the outer edges of each petal is twice the density at the central areas 30 of the daisy pad. The abrasive sheeting from which the daisy pads 26 were cut was left free from abrasive granules adjacent the phantom line 32 at the peripheries of the petals along which the sheeting 24 is to be die-cut so that the die does not contact any abrasive granules. By leaving the area 34 between the daisy pads free from abrasive granules, no granules have been wasted.

In the following examples, all parts are given by weight.

Example 1

Used to make abrasive sheeting of this example were:

1) a negative-acting "Toray Waterless Plate" which had been exposed to a half-tone screen to produce roughly circular dots, each about 63 μm in diameter and arranged in rows extending parallel to both the lengthwise and widthwise edges of the plate, 20 rows per inch (7.9 per cm) in both directions;

2) spherical abrasive granules, each 80 μm in diameter and made of 77 parts Al_2O_3 grains having a mean particle size of 4 μm in 23 parts of a matrix based on phenol-formaldehyde resin;

3) a long roll of biaxially oriented poly(ethyleneterephthalate) polyester film 0.05 mm in thickness bearing a 0.05 mm binder layer of ethylene/acrylic acid copolymer.

The dot-containing plate was mounted on the metal cylinder 10 of the apparatus shown in Fig. 1, and spherical abrasive granules 14 were fluidized by a mechanical vibrator and became attached to the silicone dots 13. Excess granules were removed by suction at 15. The binder layer 18 was heated by the rubber-covered nip roll 20 to about 70° C to become tacky so that the abrasive granules transferred to it, with a force of 79 N applied to the nip roll per cm of width. Additional heating by infrared lamps 22 caused the binder to form a meniscus around the base of each of the granules.

The exposed face of the polyester film backing of the resulting abrasive sheeting was laminated with a double-coated pressure-sensitive adhesive tape and this composite was die-cut into daisy pads 7.6 cm in diameter and similar in shape to the daisy pads 26 of Fig. 4 except having six petals. The pads were used as a second fining pad in the polishing of lenses formed of polycarbonate of the type commercially available from PPG under the trade designation CR39. A "Coburn" #506 cylinder machine was used at a load of 20 pounds (89 N) with a water flood on the high speed spindle setting. The test was conducted using two types of lapping tools, a 6.25/8.25 dioptral and a 2.12 dioptral. In both cases the amount of lens removed after two minutes was measured. The results are in Table I.

Examples 2-6

Abrasive sheetings of Examples 2-6 were made as in Example 1 except having different spacings of their rows in both directions as indicated in Table I. Also in Table I are results from using a "Control" daisy pad made with the same spherical abrasive granules coated from slurry in a manner used for current commercial production and having about 870 granules/cm^2. This granule density had been selected based upon extensive experimentation for general purpose use and was intermediate the granule densities of the abrasive sheetings of Examples 3 and 4.

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TABLE I

Ex.	Rows per inch	Rows per cm	mm of lens removed in 2 mins	
			2.12 d. lens	6.25/8.25 d. lens
1	20	7.9	0.001	0.000
2	40	15.7	0.091	0.058
3	65	25.6	0.025	0.078
4	85	33.5	0.026	0.124
5	150	59.0	0.012	0.032
6	200	78.7	0.009	0.025
Control			0.026	0.056

Example 7

A negative-acting "Toray Waterless Plate" was exposed to produce 63 µm silicone rubber dots in rows extending in the X and Y directions at a density of 65 rows per inch (25.6 rows/cm). The plate was covered with the spherical abrasive granules of Example 1, and excess granules were then removed by turning the plate over and tapping it. Examination of the plate showed that there was at least one granule at each of the silicone dots. Against those granules was laid the binder layer of the polyester film backing of Example 1, and the composite was put through the nip of a heated two-roll laminator at about 73° C while a force of 79 N was applied to the nip roll per cm of width. The composite was then placed in an oven at 112° C for 10 minutes to cause the binder to form a meniscus around the base of each granule, resulting in abrasive sheeting of the invention.

Examples 8-11

A round-dot litho contact screen was exposed to form a pattern of spots, each 61 µm in diameter and equally spaced in rows extending in the X and Y directions. The number of rows of spots per unit distance within an inner circle 6.0 cm in diameter differed from the number of rows between that circle and an outer circle 15.24 cm in diameter. In other words, the spot population changed at the junction of the two circles as it does in Fig. 2. Several different combinations of populations were prepared in this manner as shown in Table II.

A negative-acting "Toray Waterless Plate" was exposed using each contact screen and developed in the usual manner. The developed plate was mounted on a metal cylinder and employed in the same way as in Example 1 to transfer spherical abrasive granules 83 µm in diameter from a fluidized bed to create 6-petal daisy pads, the centers of which coincided with the centers of the circles. The daisy pads were tested as in Example 1 with results in Table II in comparison to the same "Control".

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TABLE II

Ex.	Inner Circle Rows/cm	Outer Circle Rows/cm	mm of lens removed	
			212 lens	625/825 lens
8	19.7	33.5	0.034	0.040
9	25.6	19.7	0.108	0.086
10	25.6	33.5	0.058	0.102
11	25.6	39.4	0.070	0.103
Control			0.025	0.056

Example 12

A round-dot litho contact screen was exposed to form an opaque spiral pattern using the standard formula $X = k\phi$ and $X = k\phi + 0.317$ mm, starting from a circle 2.1 cm in diameter and extending to a circle 15.2 cm in diameter. This produced opaque and transparent spiral areas of equal size between the two circles. Then using the developed contact screen as a mask, a laser was used to expose a negative-acting "Toray Waterless Plate" through the transparent areas of the mask to produce a pattern of dots 63 μm in diameter equally spaced in rows extending in the X and Y directions. There were 100 rows of silicone dots per inch (39.4 dots/cm) within a spiral pattern on the developed plate.

The developed plate was used as in Example 7 (except using abrasive granules 83 μm in diameter) to provide abrasive sheeting of the invention which was cut into a disc on which was centered the spiral pattern of abrasive granules in spaced rows.

Example 13

Abrasive sheeting was prepared as in Example 7 except as follows:

a) the abrasive granules were Al_2O_3 grains of irregular shape which had been screened to pass 100 mesh (150 μm openings) and retained on 120 mesh (125 μm openings);

b) there were 65 rows/inch (25.6 rows/cm) of silicone dots;

c) the abrasive sheeting, after being removed from the oven, was overcoated with a size coat of phenolformaldehyde resin which after curing in an oven had a dry weight of 80 g/m^2.

The backing of this abrasive sheeting was laminated with a double-coated pressure-sensitive adhesive tape and then die-cut to 3-inch (7.5 cm) discs. Each disc was adhered by its pressure-sensitive adhesive to a "Coburn" No. 507 cylinder machine using the following settings: spindle stroke set at 7, spindle speed 100%, cross stroke 0, and a load of 30 pounds (133 N). The workpiece was a 1018 mild steel ring 4.45 cm I.D. and 5.4 cm O.D. The ring was abraded in an operation normally called flat lapping after being mounted on a bracket that fixed its axis perpendicular to the abrasive surface as the machine oscillated the abrasive surface in a circular motion. The test was run in one minute cycles at a rate endpoint of 0.3 g/min. The total cut and surface finish at endpoint are given in Table III in comparison to a "Control" made in the same way except that the abrasive granules were coated from slurry to provide a binder layer containing approximately the same mass of granules (i.e., about 0.40g).

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TABLE III

Example	Total Cut	R_a (μm)	R_t (μm)
13	2.94 g	0.30	2.87
Control	1.44 g	0.45	3.45

R_a = average surface roughness
R_t = maximum peak-to-valley height

Claims

1. Abrasive sheeting comprising a backing carrying a binder layer of substantially uniform thickness in which abrasive granules are bonded substantially in a plane and characterized by the abrasive granules lying at a predetermined lateral spacing and being of substantially equal size and passing a screen with 300 μm openings, and a portion of virtually every granule protruding from the surface of the binder layer.

2. Abrasive sheeting as defined in claim 1 further characterized by substantially every granule being equiax and of substantially the same diameter, and each granule protruding from the binder to substantially the same extent.

3. Abrasive sheeting as defined in claim 1 further characterized by single granules being aligned in uniformly spaced rows.

4. Abrasive sheeting as defined in claim 3, further characterized by a great length of which being wound upon itself in roll form, said granules being in a predetermined pattern that repeats a large number of times over the length of the sheet.

5. Abrasive sheeting as defined in claim 4 further characterized by said predetermined pattern leaving areas of the binder layer free from abrasive granules in positions to be contacted by a tool for cutting the sheeting into articles of desired shapes, thus protecting the cutting tool from contacting abrasive granules.

6. Abrasive sheeting as defined in claim 1 further characterized by additional abrasive granules of substantially equal size different from the size of the first-mentioned abrasive granules being individually positioned in a second predetermined pattern and an uncoated portion of virtually every of said additional granules protruding from the surface of the binder layer.

7. Method of making abrasive sheeting of claim 1 by the sequential steps of

1) attracting small abrasive granules only to dots laterally spaced in a predetermined pattern on a carrier,

2) while advancing a backing that carries a tacky binder layer in synchronism with said carrier, transferring the attracted granules into the binder layer in said pattern, and

3) rendering the binder nontacky.

8. Method as defined in claim 7, further characterized in step 2 of which the granules being pressed into the binder layer.

9. Method as defined in claim 7 further characterized by said carrier covering the cylindrical exterior of a rotating drum, and in step 1) the drum being rotated through a fluidized bed of said granules.

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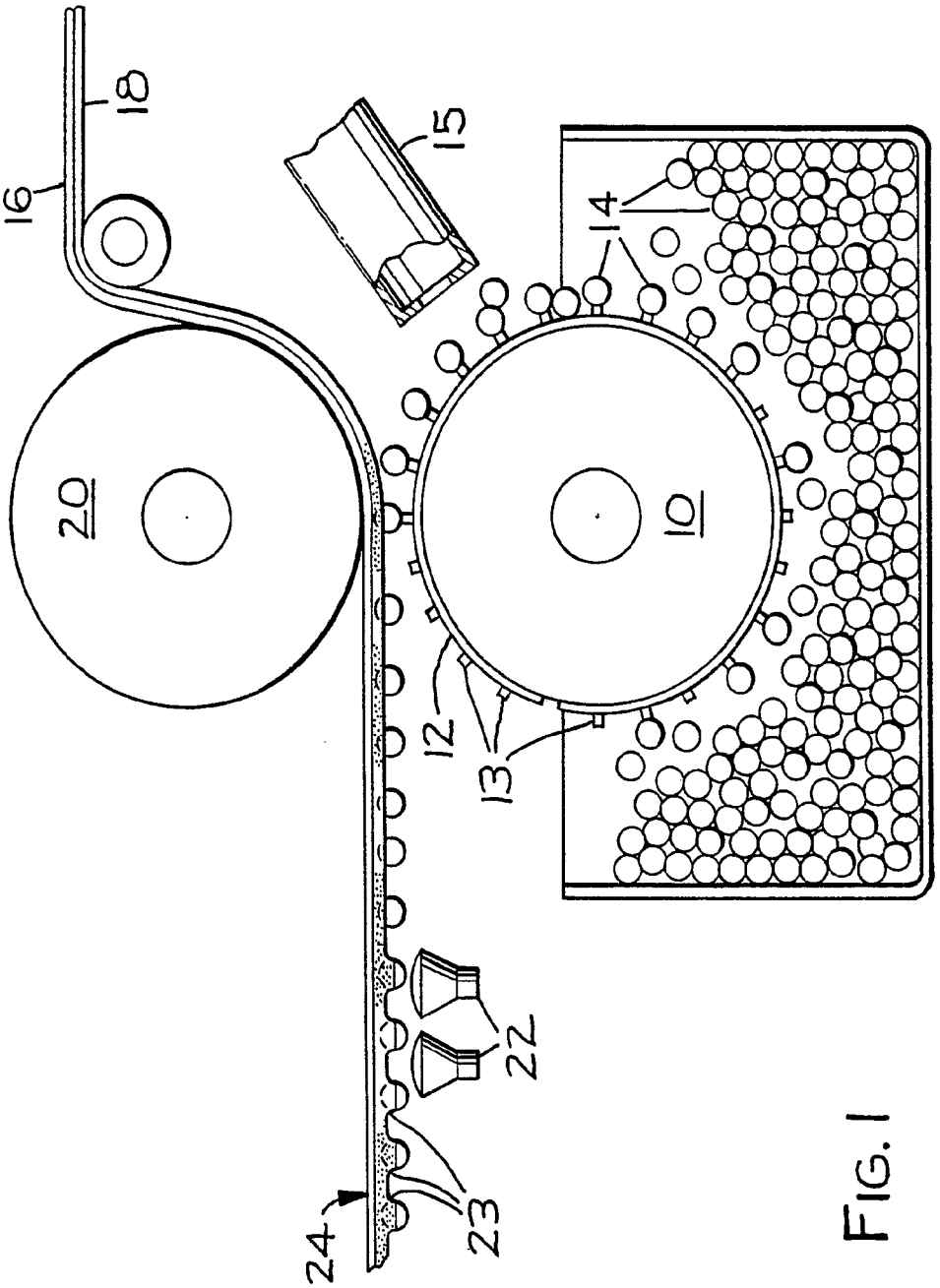


FIG. 1

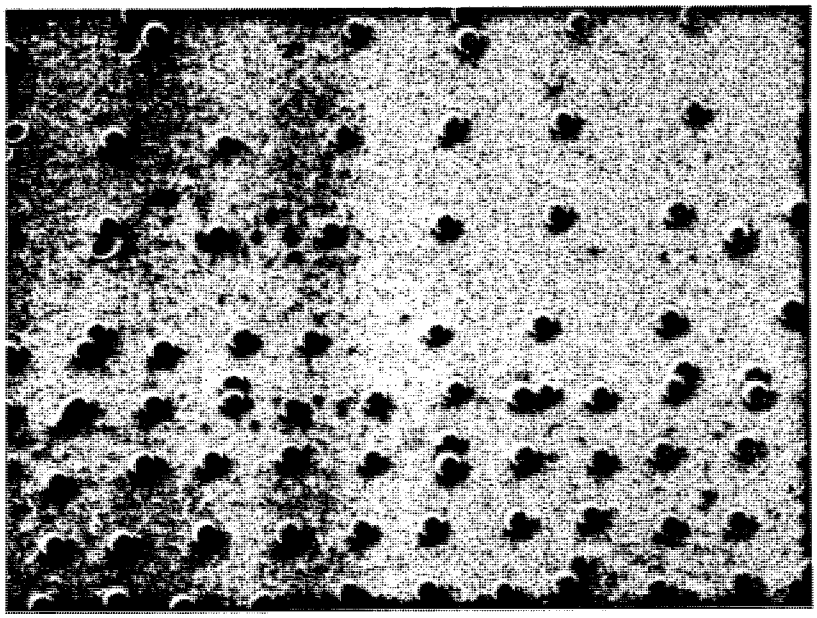


FIG. 2

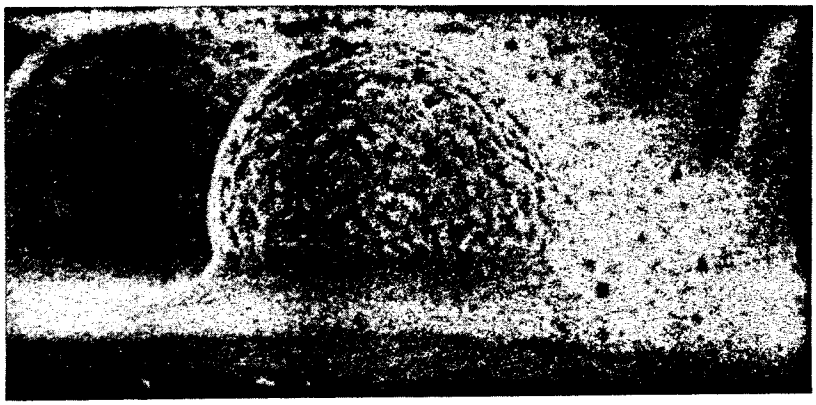


FIG. 3

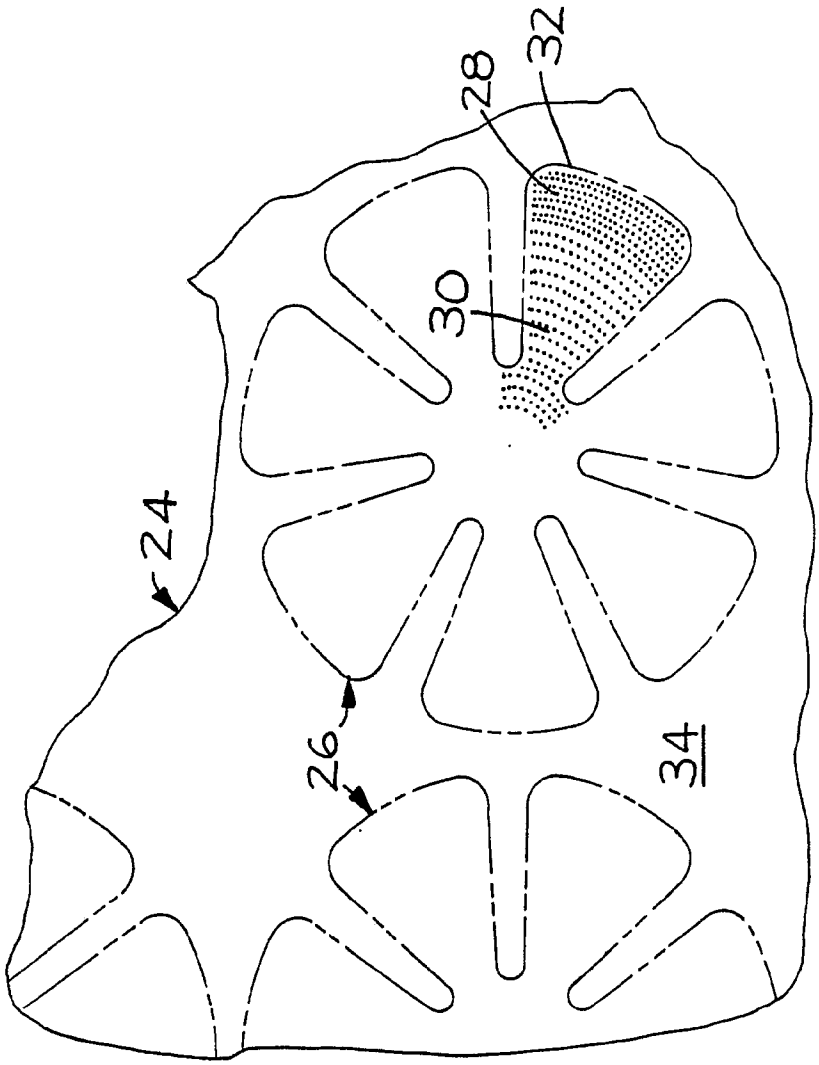


FIG. 4

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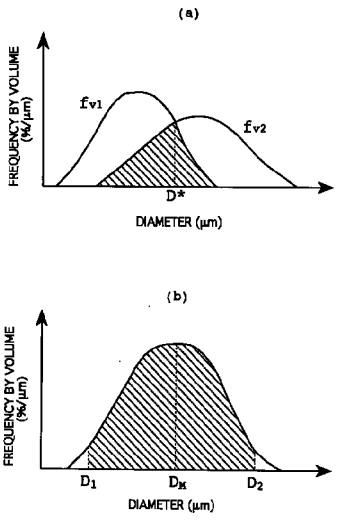
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(54) Diamond sinter, high-pressure phase boron nitride sinter, and processes for producing those sinters

(57)A powder of diamond or high-pressure phase boron nitride core particles is charged into a coating space as it is dispersed to a dispersity that is preset in accordance with the average diameter of those core particles and a precursor of a coat forming substance that is either generated via the vapor phase or in a vapor-phase state is allowed to contact and/or impinge against the particles in said powder of core particles so that their surfaces are covered with the coat forming substance, thereby preparing coated diamond or high-pressure phase boron nitride particles, and these particles or mixtures containing them or mixtures of these particles with bonding materials are sintered under appropriate sintering conditions at a predetermined high temperature and pressure. The thusly produced diamond or high-pressure phase boron nitride sinter is composed of coated core particles of high performance that are superhard, uniform, dense and sintered firmly and which have a controlled microstructure. If sintering is done at pressures less than 2000 MPa, the invention offers the advantage of eliminating the constraint of the need to use equipment capable of creating ultrahigh pressures of at least 2000 MPa. The use of ultrahigh pressure HIP apparatus or other types of HIP apparatus offers the added advantage of enabling the production of shaped sinters, thereby presenting significant benefits to manufacture on an industrial scale.

FIG.1



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Description

BACKGROUND OF THE INVENTION

This invention relates to a diamond sinter produced by sintering a mixture containing at least coated diamond particles having a coat forming substance formed on the surfaces of diamond particles and a high-pressure phase boron nitride sinter produced by sintering a mixture containing at least coated high-pressure phase boron nitride particles having a coat forming substance formed on the surfaces of high-pressure phase boron nitride particles. The invention also relates to processes for producing those sinters.

Diamond, with strong covalent bonding, has many excellent properties. On the other hand, because of this covalent bonding, diamond has such a small self-diffusion coefficient that it is very difficult to sinter. Another problem with diamond is that it is thermodynamically stable only under ultrahigh pressures so that it will experience a phase transition to graphite if the pressure is insufficient under elevated temperatures. Therefore, without addition of bonding materials or sintering aids, strong sinters cannot be produced unless a ultrahigh pressure of about 8500 MPa is applied simultaneously with exposure to a very high temperature of about 2440 K.

High-pressure boron nitrides consist of cubic boron nitride and/or wurtzite boron nitride. Cubic boron nitride (c-BN) has similar characteristics to diamond; on account of strong covalent bonding, it has many excellent properties but, on the other hand, because of this covalent bonding, c-BN has such a small self-diffusion coefficient that it is very difficult to sinter. Further, c-BN is thermodynamically stable only under ultrahigh pressures and it will experience a phase transition to hexagonal boron nitride (h-BN) of a graphitic phase (if the pressure is insufficient under elevated temperatures.) Wurtzite boron nitride (w-BN) has generally the same properties as the cubic boron nitride; it is a difficult-to-sinter substance and it is thermodynamically stable only at ultrahigh pressures and will experience a phase transition to hexagonal boron nitride (h-BN) of a graphitic phase if the pressure is insufficient under elevated temperatures. It should be noted that if the wurtzite boron nitride is sintered under ultrahigh pressures and at elevated temperatures where the cubic boron nitride is thermodynamically stable, a phase transition to the cubic boron nitride occurs depending on the conditions, yielding in this case a sinter containing the cubic boron nitride or a sinter that is solely comprised of the cubic boron nitride. In either case, without addition of bonding materials or sintering aids, strong sinters cannot be produced unless a ultrahigh pressure of about 7000 MPa is applied simultaneously with exposure to a very high temperature of about 2000 K.

However, irrespective of whether diamond or high-pressure phase boron nitride is to be sintered, the sintering conditions set forth in the preceding paragraphs for the case where neither bonding materials nor sintering aids are added are extremely hostile and are not suitable for the purpose of producing diamond or high-pressure phase boron nitride sinters of high density on an industrial scale.

Therefore, in order to produce these high-density sinters, sintering must be done under industrially applicable conditions and to this end the addition of bonding materials and/or sintering aids is essential.

The first thing to be stated in this connection is that in recent years, a particular need exists for enhancing the performance of diamond or high-pressure phase boron nitride sinters of high density and to this end, it is required that diamond or high-pressure phase boron nitride particles such as those not larger than 10 μm be used as the starting material and sintered to produce a diamond or high-pressure phase boron nitride sinter of high density.

Conventionally, diamond or high-pressure phase boron nitride sinters have been produced mainly by a method in which bonding materials and/or sintering aids are added in a powder form. In this case, even if the bonding materials and/or sintering aids are of a fine particulate form, it is extremely difficult to insure ideal uniform addition or uniform dispersion in such a way that they cover all of the individual diamond or high-pressure phase boron nitride particles present. Even if such uniform dispersion is realized, the extent of "uniformity" that can be attained is limited since the bonding materials and/or sintering aids are added on a particle basis. It should particularly be noted that if the bonding materials or sintering aids are added in small quantities, the resulting sinter will inevitably contain those areas where the bonding materials or sintering aids are absent.

In many actual cases, those powder particles or the particles of the bonding material and/or sintering aid agglomerate to either form lumps in the sinter or occur unevenly in the sinter. Hence, particularly in those areas where diamond or high-pressure phase boron nitride particles agglomerate, the structure is essentially the same as what is produced without addition of bonding materials or sintering aids and unsintered portions will locally occur. In those areas where the bonding materials and/or sintering aids agglomerate, the microscopic structure contains portions where diamond or high-pressure phase boron nitride particles are absent from the sinter. Either phenomenon produces imperfections that cause marked deterioration in the performance of the produced diamond or high-pressure phase boron nitride sinter.

Therefore, in order to produce diamond or high-pressure phase boron nitride sinters of high performance that are free from the above-mentioned imperfections, it is necessary that the bonding material and/or sintering aid be positively distributed on individual diamond or high-pressure phase boron nitride particles and, to this end, it is strongly desired to produce diamond or high-pressure phase boron nitride sinters of high performance using coated diamond or high-pressure phase boron nitride particles which are prepared by coating uniformly a bonding material forming substance

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and/or a sintering aid forming substance on the individual particles of diamond or high-pressure phase boron nitride, respectively.

Secondly, as already mentioned, both diamond and high-pressure phase boron nitride are substances that are extremely difficult to sinter and which are stable only under ultrahigh pressures and, hence, in order to prevent the diamond or high-pressure phase boron nitride from experiencing a phase transition to the lower-pressure phase (graphite or h-BN) and to produce a dense sinter of the diamond or high-pressure phase boron nitride, manufacturers have adopted the practice of using bonding materials and/or sintering aids under ultrahigh pressures in excess of 2000 MPa and at elevated temperatures. According to the report of T. Noma et al. (J. Master. Scie., 19 (1984) 2319-2322), diamond is sintered at 6000 MPa (60 kb) and at 1300°C or above. Cubic boron nitride may be sintered at 4000 MPa (40 kb) and at 1200°C or above, as taught in Unexamined Published Japanese Patent Application (kokai) Sho 63-35456. These sintering conditions refer to extreme states and they are both rigorous indeed in that they cannot be created without using a ultrahigh pressure apparatus such as of the girdle or belt type.

This constraint of using a ultrahigh pressure apparatus such as of the girdle or belt type for creating ultrahigh pressures in excess of 2000 MPa has made it difficult to achieve mass production of diamond or high-pressure phase boron nitride sinters and not only has the production cost been high but it has also been impossible to manufacture large shapes.

However, speaking of diamonds, Hall conducted an experiment under ultrahigh pressures and reported that when a diamond was thermodynamically metastable if not stable, it took such a long time for a phase transition to occur that it remained stable for practical purposes; he then drew line ② as shown in Fig. 33a to indicate the upper limit beyond which the diamond would no longer exist in a practically stable manner (H. T. Hall, Science, 169 (1970) 868-869). Hence, according to his report, even under low-pressure and high-temperature conditions that are not stable with respect to thermodynamic equilibrium line ① in Fig. 33a, a diamond will exist practically stable if it is at temperatures that do not exceed line ② in Fig. 33a, say, up to about 1400 K (ca. 1100°C), given a pressure of up to about 35 kb.

Speaking of high-pressure phase boron nitrides, Wakatsuki et al. conducted an experiment on a cubic boron nitride under ultrahigh pressures and reported that when the cubic boron nitride was thermodynamically metastable if not stable, it took such a long time for a phase transition to occur that it remained stable for practical purposes; they then drew line ② as shown in Fig. 33b to indicate the upper limit beyond which the cubic boron nitride would no longer exist in a practically stable manner (Wakatsuki, Ichise, Aoki and Maeda, Abstracts of the Lectures Read at the 14th Symposium on High-Pressure Technology (1972) p. 78). Hence, according to their report, even under low-pressure and high-temperature conditions that are not stable with respect to thermodynamic equilibrium line ① in Fig. 33b, a cubic boron nitride will exist practically stable if it is at temperatures that do not exceed line ② in Fig. 33b, say, not higher than 1200°C.

Based on these facts, one may conclude that if diamond sinters containing diamonds or high-pressure phase boron nitride sinters containing high-pressure phase boron nitrides at least one of which is a cubic boron nitride can be produced under the stable conditions mentioned above, he can effectively use a ultrahigh pressure apparatus such as a piston-cylinder (PC) type ultrahigh pressure apparatus that is capable of creating comparatively moderate ultrahigh pressures less than 2000 MPa, or a ultrahigh pressure HIP apparatus as a known technique capable of pressurization up to 1000 MPa, or hot isostatic press (HI) apparatus excluding the ultrahigh pressure HIP apparatus, or a hot press (HP) apparatus.

Thusly, unlike in the case of ultrahigh pressure apparatus of such types as the aforementioned girdle and belt types that create ultrahigh pressures in excess of 2000 MPa, not only does it become easy to achieve mass production but it also becomes possible to produce sinters of large shapes.

In recent years, it is strongly desired that diamond or high-pressure phase boron nitride sinters of high density and performance that contain comparatively large amounts of diamond or high-pressure phase boron nitride particles such as those not larger than 10 μm should be manufactured in high volumes or in large shapes using a ultrahigh pressure apparatus such as the aforementioned piston-cylinder (PC) type ultrahigh pressure apparatus which is capable of creating comparatively moderate ultrahigh pressures less than 2000 MPa, or the ultrahigh pressure HIP apparatus capable of pressurization up to 1000 MPa, the hot isostatic press (HIP) apparatus excluding the ultrahigh pressure HIP apparatus, or the hot press (HP) apparatus.

In fact, however, it is not easy to assure that diamond or high-pressure phase boron nitride sinters containing fairly large amounts of diamond or high-pressure phase boron nitride, respectively, are effectively densified under those limited pressures.

Stated more specifically, this can be realized only when the bonding material which is added in the form of a feed powder for that material deforms or migrate during sintering to fill the gaps between diamond or high-pressure phase boron nitride particles so that the applied pressure will work effectively for the displacement and loss of pores or the voids which are surrounded by the bonding material and the diamond or high-pressure phase boron nitride particles. To this end, the bonding material and/or the feed powder for that material which reacts with diamond or high-pressure phase boron nitride to generate the bonding material must be present in such a way that they contact and surround the diamond or high-pressure phase boron nitride particles.

It should particularly be noted that under the sintering pressure and temperature conditions where the pressure is less than 2000 MPa and where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, there is little chance for the particles of diamond or high-pressure phase boron nitride to bind directly and, hence,

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those portions of the diamond or high-pressure phase boron nitride particles in the resulting sinter where the feed powder for the bonding material is absent will remain unsintered. As a result, the performance of the sinters produced will deteriorate considerably. If the bonding material is added only in the form of a feed powder for that material, it is extremely difficult to insure ideal uniform addition or uniform dispersion in such a way that the particles of the feed powder cover all of the individual diamond or high-pressure phase boron nitride particles present even if the particles of the feed powder are fine. Even if such uniform dispersion is realized, the extent of "uniformity" that can be attained is limited since the feed powder for the bonding material is added on a particle basis. Thus, a serious problem is presented in the manufacture of diamond or high-pressure phase boron nitride sinters that contain large amounts of diamond or high-pressure phase boron nitride, respectively. Therefore, even in the case of mixing diamond or high-pressure phase boron nitride particles with the feed powder for the bonding material, one may compensate for the insufficiency by using coated diamond or high-pressure phase boron nitride particles which are prepared by coating the surfaces of bare diamond or high-pressure phase boron nitride particles with a bonding material forming substance that is of the same and/or different type from the feed powder for the bonding material; as a consequence, the distribution of the bonding material can be made sufficiently uniform. Hence, the coating method for preparing such coated diamond or high-pressure phase boron nitride particles bears technologically great importance.

Stated more specifically, irrespective of whether the bonding material is added in the form of a feed powder for bonding material forming substance or not, the bonding material and/or a substance that reacts with diamond or high-pressure phase boron nitride to form the bonding material is allowed to be present covering the surfaces of diamond or high-pressure phase boron nitride particles. Only by following this approach, one can assure that diamond or high-pressure phase boron nitride sinters of high density and performance that contain comparatively large amounts of diamond or high-pressure phase boron nitride particles are manufactured in high volumes or large shapes using a ultrahigh pressure apparatus such as the piston-cylinder (PC) type ultrahigh pressure apparatus which is capable of creating comparatively moderate ultrahigh pressures less than 2000 MPa, or the ultrahigh pressure HIP apparatus which is capable of pressurization up to 1000 MPa, or the hot isostatic press (HIP) apparatus excluding the ultrahigh pressure HIP apparatus, or the hot press (HP) apparatus.

While the foregoing description is directed to diamond or high-pressure phase boron nitride sinters that use the respective particles with a particle diameter not greater than 10 μm, it should be noted that if the sinters are to be used in definite applications, it is very effective to intentionally use diamond or high-pressure phase boron nitride particles of comparatively large particle diameters, say, in excess of 10 μm.

Consider, for example, a wear-resistant sinter that takes advantage of the ultrahigh hardness of diamond or high-pressure phase boron nitride. This sinter can be produced by sintering a dispersion of a comparatively large quantity of diamond or high-pressure phase boron nitride particles in excess of 10 μm in diameter and, in this case, using diamond or high-pressure phase boron nitride particles larger than 10 μm in diameter as a starting material is extremely important.

The diamond or high-pressure phase boron nitride sinter which has dispersed therein diamond or high-pressure phase boron nitride particles exceeding 10 μm in diameter is characterized in that the effect of dispersion of the dispersed particles is marked because those dispersed particles are sintered as they are closely bound to the surrounding microstructure without imperfections or pores. However, as already mentioned, both diamond and high-pressure phase boron nitride are extremely difficult to sinter and, therefore, it is essential to use a sintering aid or a bonding material that accelerate the sintering of the diamond or high-pressure phase boron nitride particles larger than 10 μm in diameter together with the surrounding microstructure.

Conventionally, such sintering aids and bonding materials have been added solely by the powder mixing method. However, the incorporation of impurities during mixing is unavoidable in this method; what is more, there is theoretically a limit on the extent to which a uniform structure can be realized. Even if the particles of a sintering aid or a bonding material are extremely fine, it is very difficult to insure ideal uniform mixing or uniform dispersion in such a way that the particles of a sintering aid or bonding material powder cover all of the diamond or high-pressure phase boron nitride particles present. Even if such uniform dispersion is realized, the extent of "uniformity" that can be attained is limited since the particles of the sintering aid or bonding material powder are mixed on a particle basis. Particularly in the case where those particles are used in relatively small amounts, an uneven distribution will occur inevitably.

In many actual cases, the dispersed diamond or high-pressure phase boron nitride particles lump together or the particles of the sintering aid or bonding material powder agglomerate, as a result, the diamond or high-pressure phase boron nitride particles will form lumps in the sinter or they occur unevenly in the diamond or high-pressure phase boron nitride sinter, eventually leading to marked deterioration in the performance of the sinters.

Therefore, it is necessary that the sintering aid or the bonding material be distributed positively to all individual diamond or high-pressure phase boron nitride particles exceeding 10 μm in diameter. Further, in order to assure that the diamond or high-pressure phase boron nitride particles are sintered as they are closely bound to the surrounding microstructure, it is required to provide a highly controlled uniform coating on the surfaces of the diamond or high-pressure phase boron nitride particles; the coating is uniform in that it leaves no surfaces of the individual diamond or high-pressure phase boron nitride particles left uncovered and it is highly controlled in that this uniform coating is applied to all individual diamond or high-pressure phase boron nitride particles. What is more, the greater the size of these

particles, the more uniform this highly controlled coating should be in order to further reduce the uncovered portions of the particles.

Thus, the production of coated diamond or high-pressure phase boron nitride particles of desired diameters in which diamond or high-pressure phase boron nitride particles are covered with uniform coatings that are highly controlled in accordance with the particle diameter, as well as the manufacture of high-performance sinters using those coated particles are strongly desired.

While coat forming substances could be applied by various techniques such as vapor-phase processes and wet plating methods, the vapor-phase approach in which inorganic materials, metallic materials and other coat forming substances are applied to provide coatings as films and various other forms theoretically have major features that are unattainable by other coating techniques, such as: (1) easy control of the atmosphere; (2) the selection of coat forming substances is basically unlimited and various kinds of substances including elemental metallic substances (e.g. active metals), alloys, nitrides, carbides, borides and oxides can be applied; (3) the desired substance can be applied in high purity; and (4) the coating weight of the coat forming substance can be controlled freely.

However, for the reasons to be set forth below, none of the various coating apparatus and methods heretofore proposed as known techniques have been capable of forming the above-described highly controlled uniform coatings.

Particularly in the case of diamond or high-pressure phase boron nitride particles not larger than 10 μm, the diamond or high-pressure phase boron nitride particles to be coated are so fine that they are cohesive enough to have a great tendency to agglomerate together, whereby almost all single particles form agglomerates. Since these agglomerates cannot be disintegrated unless they are subjected to a special action greater than their cohesive force, they cannot be simply coated as such to insure that the surfaces of the individual particles are covered with the coating of a bonding material and/or sintering aid, eventually yielding coated agglomerates in which the surfaces of the agglomerates are covered with the coating of the bonding material and/or sintering aid. This has caused a problem with the individual diamond or high-pressure phase boron nitride particles forming the agglomerates in that the surfaces of the particles located on the surfaces of the agglomerates have large coating weights but suffer from uneven coating whereas the particles located within the agglomerates are not covered at all.

With a view to solving these problems, attempts have already been made to coat the particles in a dispersed state in order to assure the coating of the individual particles in the powder of the core particles to be coated. However, for the reasons stated below, none of the various coating apparatus and methods heretofore proposed as known techniques have been capable of forming the intended uniform coating.

For instance, Unexamined Published Japanese Patent Application (kokai) Sho 58-31076 teaches an apparatus and method, according to which a vessel placed in PVD equipment is charged with the particles in a powder of core particles and vibrated by an electromagnetic means so that the core particles in the vessel are rolled as they are coated by a PVD process. Unexamined Published Japanese Patent Application (kokai) Sho 61-30663 teaches an apparatus, according to which a vessel placed in PVD equipment is charged with the particles in a powder of core particles and vibrated by a mechanical means so that the core particles in the vessel are rolled as they are coated by a PVD process. However, in the actual practice with those apparatus or methods in which the vessel is vibrated so that the particles in the powder of core particles are rolled as they are provided with coatings, the necessary action for disintegrating the agglomerates of diamond or high-pressure phase boron nitride particles with an average diameter not greater than 10 μm by applying a force exceeding their cohesive force cannot be produced and, hence, the agglomerates cannot be disintegrated; to the contrary, a granulating action develops to form agglomerates that are greater in number or size than before the powder of core particles is supplied into the vessel. On the other hand, diamond or high-pressure phase boron nitride particles having an average diameter in excess of 10 μm are simply subjected to a sliding action as they form many layers in superposition and it has been impossible to achieve the desired coating of single separate particles.

Unexamined Published Japanese Patent Application (kokai) Hei 3-153864 teaches an apparatus and method, according to which a rotating vessel having barriers and/or ridges and grooves in the inner surface is charged with core particles and rotated as the surfaces of the particles are coated by an evaporation method. The problem with this apparatus and method is that the necessary action for disintegrating the agglomerates of diamond or high-pressure phase boron nitride particles with an average diameter not greater than 10 μm by applying a force exceeding their cohesive force cannot be produced and, hence, the agglomerates cannot be disintegrated and, what is more, an increased number or size of agglomerates will simply form. On the other hand, diamond or high-pressure phase boron nitride particles having an average diameter in excess of 10 μm are simply subjected to a gentle stirring action as many of them contact one another forming many layers in superposition and it has been impossible to achieve the desired coating of single separate particles.

Unexamined Published Japanese Patent Application (kokai) Sho 58-141375 teaches an apparatus in which the particles of a powder in a reactive gas atmosphere are suspended by the flow of the reactive gas under gravity and in which the surfaces of the particles are coated with the precipitating substance that forms by the chemical reaction involving the reactive gas. Unexamined Published Japanese Patent Application (kokai) Hei 2-43377 teaches a method in which particles placed under vacuum are fluidized as they are subjected to coating by a thermochemical reaction treatment. Unexamined Published Japanese Patent Application (kokai) Sho 64-80437 teaches a method in which the agglom-

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erates of core particles in powder are disintegrated by a sound wave that is a composite of low and high frequency waves, so that the agglomerates are fluidized to improve the coating efficiency. However, these techniques which utilize the fluidized bed of the particles in a powder of core particles which is formed by a gas flow or vibrations have had the problem that with diamond or high-pressure phase boron nitride particles having an average diameter of no more than 10 μm, it is practically impossible to fluidize the separate individual particles, thus failing to disintegrate the agglomerates of these particles. On the other hand, with diamond or high-pressure phase boron nitride particles exceeding 10 μm in average diameter, it is practically impossible to insure that all of these particles are similarly and independently fluidized and suspended as single separate entities and one has been incapable of eliminating uneven coating of the particles which is due to the hiding of one particle by another.

Unexamined Published Japanese Patent Application (kokai) Sho 54-153789 teaches an apparatus in which a powder material is dropped within a vacuum vessel, where the metal vapor is generated to form a metal coating on the particles. Unexamined Published Japanese Patent Application (kokai) Sho 60-47004 teaches a method in which a monomer gas and the particles of a powder are introduced into a high-frequency plasma region in a vacuum vessel, where a coating film of an organic substance is formed by plasma-assisted polymerization. If diamond or high-pressure phase boron nitride particles with an average diameter of no more than 10 μm are simply introduced as in the techniques described above, agglomerates cannot be disintegrated. On the other hand, diamond or high-pressure phase boron nitride particles exceeding 10 μm in average diameter will simply drop while forming agglomerates which are not single separate particles and various problems occur, such as uneven coating due to the hiding of one particle by another, the total failure of the particles within an agglomerate to be coated, and differences in the coating weights of individual particles.

Unexamined Published Japanese Patent Application (kokai) Sho 64-80437 teaches a method in which the agglomerates of core particles in powder are disintegrated by a sound wave consisting of low and high frequency waves so that they are fluidized to improve the coating efficiency. However, this method which imparts vibrations to the fluidized bed has had the problem that with diamond or high-pressure phase boron nitride particles having an average diameter of no more than 10 μm, it is practically impossible to fluidize the separate individual particles, thus failing to disintegrate the agglomerates of these particles. On the other hand, with diamond or high-pressure phase boron nitride particles exceeding 10 μm in average diameter, it is practically impossible to insure that all of these particles are similarly and independently fluidized and suspended as single separate entities and one has been incapable of eliminating uneven coating of the particles which is due to the hiding of one particle by another.

Unexamined Published Japanese Patent Application (kokai) Sho 62-250172 teaches an apparatus and method, according to which a powder that has been preliminarily treated by jet milling is allowed to stay within a chamber for heat treatment under vacuum, where it is subjected to a heat treatment and thence dropped under gravity through a powder feeder into a cylinderal sputtering chamber equipped with a vertical target, whereby the particles in powder are provided with a coating. Unexamined Published Japanese Patent Application (kokai) Hei 2-153068 teaches an apparatus and method, according to which a powder that has been preliminarily treated by jet milling is allowed to stay within a chamber for heat treatment under vacuum, where it is subjected to a heat treatment and thence introduced through a powder feeder into a rotary vessel accommodating a sputter source within a sputtering chamber in the form of a powder (not as single particles), with sputtering being effected as the vessel is rotated. These techniques involve a heating step which is performed before coating so that the jet-milled powder of core particles is allowed to stay for heat treatment and because of this staying of the powder in the heating step, the diamond or high-pressure phase boron nitride particles of any diameter will form agglomerates again which are not single particles and, eventually, such agglomerates will not revert to single particles in the coating step.

Thus, none of the so far proposed techniques have successfully solved the problems associated with the apparatus or method for providing coatings on the core particles in powder which are diamond or high-pressure phase boron nitride particles. In actual cases, diamond or high-pressure phase boron nitride particles having an average diameter of not more than 10 μm form agglomerates which cannot be disintegrated and, hence, no methods or apparatus have been available for producing coated diamond or high-pressure phase boron nitride particles in which said diamond or high-pressure phase boron nitride particles, being dispersed as single particles, are covered on their surfaces with coat forming substances including a bonding material forming substance and/or a sintering aid forming substance.

Speaking of diamond or high-pressure phase boron nitride particles exceeding 10 μm in average diameter, these particles are in actual cases subjected to a coating treatment in the form of agglomerates in which they remain in mutual contact and, hence, those portions which are blocked by other particles remain uncoated. As already mentioned, highly controlled uniform coatings are needed and although even the small cohesive force discussed above has been so much influential as to cause a very serious problem, no methods have been available for producing the satisfactory coated diamond or high-pressure phase boron nitride particles, nor have been apparatus for implementing such methods.

In short, irrespective of the diameter of starting diamond or high-pressure phase boron nitride particles, it has been impossible to prepare coated diamond or high-pressure phase boron nitride particles by providing each of those starting particles with a controlled uniform coat by vapor-phase coating techniques using coat forming substances including bonding material forming substances and/or sintering aid forming substances.

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Hence, it has been impossible to manufacture diamond or high-pressure phase boron nitride sinters of high performance that are uniform, dense and firmly sintered and which have a highly controlled microstructure using small (e.g., ≦ 10 μm) coated diamond or high-pressure phase boron nitride particles. In addition, diamond or high-pressure phase boron nitride sinters of high density and performance that contain comparatively large amounts of diamond or high-pressure phase boron nitride based on those coated particles could not be manufactured in high volumes or large shapes. Further, diamond or high-pressure phase boron nitride sinters of high density and performance that contain comparatively large amounts of diamond or high-pressure phase boron nitride as derived from a mixture of those coated particles and a separately added bonding material could not be manufactured in high volumes or large shapes.

It has also been impossible to manufacture wear-resistant sinters that have dispersed therein comparatively large amounts of coated diamond or high-pressure phase boron nitride particles exceeding, for example, 10 μm in diameter.

BRIEF SUMMARY OF THE INVENTION

Under the circumstances described on the foregoing pages, it is strongly desired to develop and commercialize the following sinters and processes for producing them: a diamond or a high-pressure phase boron nitride sinter of high performance derived from coated diamond or high-pressure phase boron nitride particles in which the particles in a powder of core particles that are diamond or high-pressure phase boron nitride particles to be coated in practice having an average diameter of no more than 10 μm are coated on a single particle basis with a coat forming substance selected from the group consisting of a bonding material forming substance and a sintering aid forming substance, as well as processes for producing such diamond and high-pressure phase boron nitride sinters; a diamond or a high-pressure phase boron nitride sinter of high performance that contains a comparatively large amount of diamond or high-pressure phase boron nitride particles as produced by sintering the coated diamond or high-pressure phase boron nitride particles under pressure and temperature conditions where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, as well as processes for producing such diamond and high-pressure phase boron nitride sinters; a diamond or a high-pressure phase boron nitride sinter of high performance that is produced by sintering a mixture of the coated diamond or high-pressure phase boron nitride particles and a separately added bonding material under pressure and temperature conditions where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, as well as processes for producing such diamond and high-pressure phase boron nitride sinters; the production of coated diamond or high-pressure phase boron nitride particles in which bare diamond or high-pressure phase boron nitride particles in a powder of core particles exceeding 10 μm in average diameter are provided with a highly controlled uniform coating, which is uniform in that it leaves no surfaces of the individual diamond or high-pressure phase boron nitride particles left uncovered and which is highly controlled in that this uniform coating is applied to all individual diamond or high-pressure phase boron nitride particles, said highly controlled uniform coating being further characterized in that the greater the size of those particles, the more uniform it should be in order to further reduce the uncovered portions of the particles, as well as a diamond or a high-pressure phase boron nitride sinter that uses the thus coated diamond or high-pressure phase boron nitride particles, and processes for producing such diamond and high-pressure phase boron nitride sinters.

Thus, an object of the present invention is to provide a diamond or a high-pressure phase boron nitride sinter of high performance that are uniform, dense and firmly sintered and which have a highly controlled microstructure using coated diamond or high-pressure phase boron nitride particles in which diamond or high-pressure phase boron nitride particles that are either the particles in a powder of fine core particles or the particles in a powder of core particles the greater part of which is comprised of fine particles are coated on a single particle basis with a bonding material forming substance and/or a sintering aid forming substance.

Another object of the invention is to provide processes for producing said diameter or high-pressure phase boron nitride sinters of high performance.

A further object of the invention is to provide a diamond or a high-pressure phase boron nitride sinter that contain comparatively a large amount of diamond or high-pressure phase boron nitride particles comprised of high-performance fine particles, which are uniform, dense and firmly sintered and which have a highly controlled microstructure, which sinters are produced by sintering at pressures less than 2000 MPa and at temperatures not exceeding 1850°C those coated diamond or high-pressure phase boron nitride particles in which diamond or high-pressure phase boron nitride particles that are either the particles in a powder of fine core particles or the particles in a powder of core particles the greater part of which is comprised of fine particles are coated on a single particle basis with a coat forming substance selected from between a bonding material forming substance and a sintering aid forming substance, or a mixture containing said coated diamond or high-pressure phase boron nitride particles.

A still further object of the invention is to provide processes for producing said diamond or high-pressure phase boron nitride sinters.

Yet another object of the invention is to provide a diamond or a high-pressure phase boron nitride sinter that contains comparatively a large amount of diamond or high-pressure phase boron nitride particles comprised of high-performance fine particles, which are uniform, dense and firmly sintered and which have a highly controlled microstructure, which

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sinters are produced by sintering, at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable, a mixture of a bonding material and those coated diamond or high-pressure phase boron nitride particles in which diamond or high-pressure phase boron nitride particles that are either the particles in a powder of fine core particles or the particles in a powder of core particles the greater part of which is comprised of fine particles are coated on a single particle basis with coat forming substances comprising not only a bonding material forming substance and/or a sintering aid forming substance but also a surface modifier forming substance capable of controlling grain boundaries.

Still another object of the invention is to provide processes for producing such diamond and high-pressure phase boron nitride sinters.

A further object of the invention is to provide coated quasi-fine diamond or high-pressure phase boron nitride particles in which the particles in a powder of quasi-fine core particles that are quasi-fine diamond or high-pressure phase boron nitride particles or the particles in a powder of core particles the greater part of which is comprised of such quasi-fine particles are provided with a highly controlled uniform coating of a coat forming substance selected from between a bonding material forming substance and a sintering aid forming substance, which coating is uniform in that it leaves no surfaces of the individual diamond or high-pressure phase boron nitride particles left uncovered and which is highly controlled in that this uniform coating is applied to all individual diamond or high-pressure phase boron nitride particles, said highly controlled uniform coating being further characterized in that the greater the size of those particles, the more uniform it should be in order to further reduce the uncovered portions of the particles.

A still further object of the invention is to provide a diamond or a high-pressure phase boron nitride sinter using said coated quasi-fine diamond or high-pressure phase boron nitride particles.

A yet further object of the invention is to provide processes for producing said diamond and high-pressure phase boron nitride sinters.

In order to attain these objects, the present inventors conducted intensive studies and found the following: in order to insure that the particles in a powder of core particles which comprise diamond or high-pressure phase boron nitride particles are coated, on a single particle basis, with coat forming substances including a bonding material and/or a sintering aid, a mixture of a gas with a powder of highly dispersed core particles in which the particles in said powder of core particles are present in a gaseous atmosphere mainly in a single-particle state must be introduced into the coating start region of a coating space while the particles are in a highly dispersed state such that the dispersity β is at least 70%, 80%, 90%, 95%, 97% or 99% depending upon the diameter of the introduced particles and then a coating operation must be started on those particles.

Stated more specifically, the present invention has been accomplished on the basis of the finding of the following two facts: (I) In a mixture of a gas with a powder of highly dispersed core particles in which the particles in said powder of core particles are present in a gaseous atmosphere mainly in a single-particle state, those dispersed particles have a tendency to reagglomerate with the passage of time, chiefly due to turbulent agglomeration, even if they are not allowed to stay within a certain area and once they have formed reagglomerates, it is difficult to disintegrate the latter to a highly dispersed state, namely, to redisperse the agglomerated particles to separate single particles unless they are dispersed by a dispersing means having especially high dispersing performance (the situation is the same as with the agglomerates that formed before the treatment conducted to prepare the highly dispersed core particles) and, to this end, those particles have to be introduced into the coating start region of a coating space while the particles are in a highly dispersed state such that the dispersity β is at least 70%, 80%, 90%, 95%, 97% or 99% depending on the diameter of the introduced particles; and to this end, (II) it is necessary to employ one or more dispersing means that have especially high dispersing performance such that the agglomerates composed of the powder of those core particles can be disintegrated and dispersed in a gaseous atmosphere to provide a very high dispersity in accordance with the specific diameter of the particles under treatment.

The present inventors also found that the coated diamond or high-pressure phase boron nitride particles described above behaved during sintering as if they were the particles of the aforementioned coat forming substances. Consequently, they found that such coated diamond or high-pressure phase boron nitride particles could be sintered in the presence of an added fibrous substance comprising at least one metal or compound that was capable of reinforcing diamond or high-pressure phase boron nitride sinters, which had a width of no more than 500 μm and which was of such a shape that the length to width ratio was at least two. The present invention has been accomplished on the basis of these findings.

According to the present invention, there is provided a process for producing a diamond or high-pressure phase boron nitride sinter comprising the step of preparing coated diamond or high-pressure phase boron nitride particles and sintering said coated diamond or high-pressure phase boron nitride particles or mixtures containing such particles or mixtures of coated diamond or high-pressure phase boron nitride particles with bonding material,

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures no less than 2000 MPa and at elevated temperatures; or

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures of less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure

and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable; or

sintering said mixtures of coated diamond or high-pressure phase boron nitride particles with a bonding material in a volume ratio of (1 - 90):(99 - 10), said bonding material being sintrable to a density of at least 85% at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such conditions that diamond and/or high-pressure phase boron nitride particles are thermodynamically metastable, at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond and/or high-pressure phase boron nitride is thermodynamically metastable if not stable.

wherein said coated diamond or high-pressure phase boron nitride particles are prepared by a method comprising the steps of charging a powder of diamond or high-pressure phase boron nitride core particles into a coating space and then permitting a precursor of a coat forming substance which is generated via the vapor phase and/or a precursor of a coat forming substance in a vapor-phase state to contact and/or impinge against the particles in said powder of core particles so that their surfaces are coated with the coat forming substance and

said coated diamond or high-pressure phase boron nitride particles are prepared by coating means comprising:

(A) a dispersing step in which the particles in the powder of core particles are dispersed by a group of means for high dispersion treatment of particles in a gaseous atmosphere to form a mixture of a gas and the particles in a powder of highly dispersed particles, the final treating means in said group of means for high dispersion treatment of particles being selected from between:

(a) dispersing means for dispersing the particles in the powder of core particles in a gaseous atmosphere; and
(b) means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles which comprises:

(b-1) means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles that separates a portion of the powder that is composed of less highly dispersed particles from the mixture of a gas and the particles in the powder of core particles in which the particles in the powder of core particles are dispersed in a gaseous atmosphere, thereby selecting a mixture of a gas and the particles in a powder of highly dispersed core particles in which the particles in the powder of core particles are present in the gaseous atmosphere mainly in a single-particle state; and
(b-2) feedback means by which the portion of the powder that is composed of less highly dispersed particles and which has been separated by said means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles is transported to the final dispersing means among the dispersing means in the group of means for high dispersion treatment of particles and/or treating means upstream of the final dispersing means; and

(B) a coating step in which the particles in the powder of core particles that have been dispersed in the dispersing step (A) start to be coated by being allowed to contact and/or impinge against the precursor of the coat forming substance in the coating start region of the coating space as they are dispersed to satisfy the following conditions:

the dispersity β should be at least 70% if those particles have an average diameter of no more than 10 μm in the frequency distribution by volume;

the dispersity β should be at least 80% if those particles have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume;

the dispersity β should be at least 90% if those particles have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume;

the dispersity β should be at least 95% if those particles have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume;

the dispersity β should be at least 97% if those particles have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume; and

the dispersity β should be at least 99% if those particles have an average diameter in excess of 800 μm in the frequency distribution by volume, and wherein said sintering step is performed by

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures no less than 2000 MPa and at elevated temperatures; or

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures of less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable; or

sintering said mixtures of coated diamond or high-pressure phase boron nitride particles with a bonding material in a volume ratio of (1 - 90):(99 - 10), said bonding material being sintrable to a density of at least 85% at

pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such conditions that diamond and/or high-pressure phase boron nitride particles are thermodynamically metastable, at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond and/or high-pressure phase boron nitride is thermodynamically metastable if not stable.

Preferably, said coated diamond or high-pressure phase boron nitride particles are prepared through the following additional step(s):

a step of disagglomeration or otherwise size reduction in which lumps of the coated diamond and/or high-pressure phase boron nitride particles that form as a result of association of several particles that contact one another via the coat forming substance on the coated particles are disagglomerated and/or otherwise reduced in size; and/or

a step of selective separation in which the associating lumps of the coated diamond or high-pressure phase boron nitride particles are selectively separated from the coated diamond or high-pressure phase boron nitride particles on a primary particle basis.

Preferably, the particles in the powder of diamond and/or high-pressure phase boron nitride core particles to be coated with the coat forming substance are coated by a dip method using a molten salt bath with one or more layers of the coat forming substance that derives from the dip method.

Preferably, the dispersing step is performed by:

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%; and

said coated diamond or high-pressure phase boron nitride particles being prepared by:

a method in which the mixture of a gas and the particles in the powder of highly dispersed core particles as formed by one of the means in said group of means for high dispersion treatment of particles is either discharged directly to the coating step or transported thereto via at least one member indispensable to transport that is selected from the group consisting of a hollow member, an intermediate member composed of a member that forms a hollow portion, and a pipe and which is provided between the dispersing and coating steps, as the mixture emerges from a discharge section that discharges said mixture of a gas and the particles; and/or

a method in which the mixture of a gas and the particles in the powder of highly dispersed core particles as formed by one of the means in said group of means for high dispersion treatment of particles is transported to the coating step via at least one means selected from the group consisting of means for maintaining the dispersion in a gaseous atmosphere of the highly dispersed core particles in the mixture of a gas with the core particles which have been dispersed in the gaseous atmosphere to attain one of the dispersities set forth above, means for enhancing the dispersion in a

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gaseous atmosphere of the highly dispersed core particles in the mixture of a gas with the core particles which have been dispersed in the gaseous atmosphere to attain one of the dispersities set forth above, and means for separating a mixture of a gas and the particles in a powder of less highly dispersed core particles from said gas-particle mixture so as to select a mixture of a gas and the particles in a powder of highly dispersed core particles in which the core particles are present in the gaseous atmosphere mainly in a single-particle state.

Preferably, the dispersing step is performed by:

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%; and

said coated diamond or high-pressure phase boron nitride particles being prepared by performing at least one part of the dispersing step in such a way that it shares one or more parts of the space with at least one part of the coating step.

Preferably, said coated diamond or high-pressure phase boron nitride particles are prepared with the coating start region of the coating space being located in either one of the following space regions that includes planes through which all particles in the powder of highly dispersed core particles as mixed with a gas will pass:

a space region in which a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a space region in which a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a space region in which a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a space region in which a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the

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group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

a space region in which a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

a space region in which a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%, or wherein

said coated diamond or high-pressure phase boron nitride particles are prepared with the coating start region of the coating space being located in either one of the following space regions that includes planes through which all particles to be recovered into the recovery section of the recovery means will pass:

a space region in which a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a space region in which a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a space region in which a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a space region in which a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

a space region in which a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

a space region in which a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%.

Preferably, the particles in the powder of core particles to be used have a size distribution of ($[D_M/5, 5D_M]$, ≧ 90%) in terms of frequency distribution by volume, where D_M represents the average particle diameter.

According to another aspect of the present invention, there is provided a diamond or high-pressure phase boron nitride sinter that are produced by the processes for producing a diamond or high-pressure phase boron nitride sinter as recited above.

Thus, in accordance with the present invention, diamond or high-pressure phase boron nitride sinters are produced by one of the following methods: the particles in a powder of core particles that are diamond or high-pressure phase boron nitride particles and the surfaces of which are coated with a coat forming substance or mixtures containing such particles are sintered at a pressure of 2000 MPa or higher and at an elevated temperature; or those particles or mixtures containing them are sintered at a pressure less than 2000 MPa and at a temperature not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable; or a mixture of the coated diamond or high-pressure phase boron nitride particles and a bonding material in a volume ratio of (1 - 90):(99 - 10), which bonding material is sinterable to a density of at least 85% at a

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pressure of less than 2000 MPa and at a temperature not exceeding 1850°C under such conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable, is sintered at a pressure of less than 2000 MPa and at a temperature not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable. In the practice of this invention, the diamond or high-pressure phase boron nitride particles the surfaces of which are coated with the coat forming substance are prepared by the following method: a precursor for the coat forming substance that has just formed via the vapor phase by a vapor-phase process and/or a precursor for the coat forming substance in a vapor-phase state and a mixture of a gas with a powder of highly dispersed core particles that have been dispersed in a gaseous atmosphere by the final treating means in a group of means for high dispersion treatment of particles are allowed to combine with each other in the coating start region of a coating space while the particles in the mixture of a gas and the powder of highly dispersed core particles are in a dispersed state with their dispersity being adjusted to one of the values set forth in preceding paragraphs depending upon their diameter, whereupon the precursor and the mixture are allowed to contact and/or impinge against each other so that the surfaces of the diamond or high-pressure phase boron nitride particles are coated with the coat forming substance. By so doing, one can produce a heretofore unattainable diamond or high-pressure phase boron nitride sinter of high performance that has no surfaces of diamond or high-pressure phase boron nitride particles left unsintered, that is uniform, dense and firmly sintered and which has a highly controlled microstructure. The precursor for the coat forming substance which is to be used in preparing the coated core particles is in a vapor-phase state as comprised of atoms, molecules, ions, clusters, atomic clusters, molecular clusters, cluster ions, etc. or it has just formed via the vapor phase; having started to contact and/or impinge against the diamond or high-pressure phase boron nitride particles in the already-discussed highly dispersed state, the coat forming substance binds firmly to the surfaces of the individual core particles in the state of primary particles, thereby yielding coated diamond or high-pressure phase boron nitride particles in which those core particles in powder form are covered with the coat forming substance on a single particle basis.

As will be understood from the above description, when the coated diamond or high-pressure phase boron nitride particles are sintered at a pressure of 2000 MPa or above and at an elevated temperature under such sintering conditions that diamond or high-pressure phase boron nitride is thermodynamically stable, the coats on the diamond or high-pressure phase boron nitride particles are bursted by the pushing force from inside and any two contiguous diamond or high-pressure phase boron nitride particles will bind directly to each other, thereby yielding an extremely uniform and dense sinter.

The invention also contemplates the case where the coated diamond or high-pressure phase boron nitride particles, either taken alone or in combination with a bonding material, are sintered at a pressure less than 2000 MPa and at a temperature not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable. In this case, the diamond or high-pressure phase boron nitride particles may contact each other but will not bind directly to each other; nevertheless, except in areas where the coated diamond or high-pressure phase boron nitride particles are in direct contact with each other, the coating substance which is to form a bonding material or a sintering aid is sure to surround those diamond or high-pressure phase boron nitride particles, and the resulting sinter has no part left unsintered, is uniform, dense and firmly sintered, and has an extremely highly controlled microstructure.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1a is a diagram showing the dispersity β of particles in a powder;

Fig. 1b is a diagram showing the frequency by volume vs diameter relationship of a powder 90% of the volume of which is occupied by particles with sizes in the range from D_1 - D_2;

Figs. 2a, 2b and 2c are block diagrams showing three basic arrangements of means for high dispersion treatment of particles;

Figs. 3a - 3g are block diagrams showing in greater detail the arrangements of means for high dispersion treatment of particles;

Figs. 4a - 4e are diagrams showing how the coating operation is started on core particles in powder;

Figs. 5a - 5g are block diagrams showing the compositions of various apparatus for producing coated diamond or high-pressure phase boron nitride particles;

Fig. 6 is a diagram showing the apparatus used in Example 1;

Fig. 7 is a partial enlarged view of the apparatus used in Example 1;

Fig. 8 is a scanning electron micrograph showing one of the coated diamond particles produced in Example 1;

Fig. 9 is an electron micrograph showing a polished surface of the sinter produced in Example 1;

Fig. 10 is an electron micrograph showing a polished surface of a commercial sintered diamond tool;

Fig. 11 is a diagram showing the apparatus used in Example 2;

Fig. 12 is a partial enlarged view of the apparatus used in Example 2;

Fig. 13 is a diagram showing the apparatus used in Example 3;

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Fig. 14 is a partial enlarged view of the apparatus used in Example 3;

Fig. 15 is a scanning electron micrograph showing one of the coated cubic boron nitride particles produced in Example 5-1;

Fig. 16 is a graph showing Vickers microhardness of the cubic boron nitride sinters;

Fig. 17 is an electron micrograph showing a polished surface of the sinter produced in Example 5-1;

Fig. 18 is an electron micrograph showing a polished surface of a commercial sintered cubic boron nitride tool;

Fig. 19 is a scanning electron micrograph showing one of the coated diamond particles produced in Example 6-1;

Fig. 20 is an electron micrograph showing a polished surface of the sinter produced in Example 6-1;

Fig. 21 is an electron micrograph showing a polished surface of a sinter comprising uncoated diamond particles;

Fig. 22 is a scanning electron micrograph showing one of the coated cubic boron nitride particles produced in Example 7-1;

Fig. 23 is an electron micrograph showing a polished surface of the sinter produced in Example 7-1;

Fig. 24 is an electron micrograph showing a polished surface of a sinter comprising uncoated cubic boron nitride particles;

Fig. 25 is a scanning electron micrograph showing one of the coated diamond particles produced in Example 8-1;

Fig. 26 is an electron micrograph showing a polished surface of the sinter produced in Example 8-1;

Fig. 27 is a scanning electron micrograph showing one of the coated cubic boron nitride particles produced in Example 9-1;

Fig. 28 is an electron micrograph showing a polished surface of the sinter produced in Example 9-1;

Fig. 29 is a scanning electron micrograph showing one of the coated diamond particles produced in Example 10-1;

Fig. 30 is an electron micrograph showing a polished surface of the sinter produced in Example 10-1;

Fig. 31 is a scanning electron micrograph showing one of the coated cubic boron nitride particles produced in Example 11-1;

Fig. 32 is an electron micrograph showing a polished surface of the sinter produced in Example 11-1;

Fig. 33a is a pressure-temperature diagram showing the region where diamond is stable; and

Fig. 33b is a pressure-temperature diagram showing the region where high-pressure phase boron nitride is stable.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is described below in detail. Before going into details of the invention, let us define the various terms, phrases and expressions that are used herein, and describe, if necessary, the specific implications of those terms, phrases and expressions, and then proceed to the description of the technical means for preparing diamond or high-pressure phase boron nitride particles coated with coat forming substances.

Coated Diamond or High-Pressure Boron Nitride Particles

The term "coated diamond particles" refers to the diamond particles to be described below which are provided with coats. The term "coated high-pressure phase boron nitride particles" refers to the high-pressure phase boron nitride particles to be described below which are provided with coats. To give one specific example, the terms refer to those coated particles in which diamond or high-pressure phase boron nitride core particles are provided with the coats of coat forming substances in the form of at least one type selected from among ultrafine particles, islands, continuous phase, uniform membranes, projections, etc.

Feed Powder Particles for Diamond or High-Pressure Boron Nitride Sinters

Natural and/or synthetic diamond powder particles are used as feed powder particles for diamond sinters in the present invention. On the other hand, cubic and/or wurtzite boron nitride particles are used as feed powder particles for high-pressure phase boron nitride sinters in the present invention.

To produce diamond or high-pressure phase boron nitride sinters of high performance which suit the purposes of the present invention, diamond or high-pressure phase boron nitride particles with diameters of no more than 10 μm are advantageously used as feed powders. However, in the case where wear resistance is of particular importance, particles exceeding 10 μm in average diameter are advantageous. Stated specifically, the particle diameter can be expressed in terms of frequency distribution by volume such that the average particle diameter D_M satisfies the relation ($[D_M/5, 5D_M]$, ≧ 90%). However, depending on use, diamond or high-pressure phase boron nitride particles of a comparatively narrow distribution which, when expressed in terms of frequency distribution by volume, satisfies the relation ($(D_M/3, 3D_M]$, ≧ 90%) can preferably be selected. More advantageously, one may select diamond or high-pressure phase boron nitride particles that have been controlled, by sieve classification or other techniques, in the diameter of diamond or high-pressure phase boron nitride particles to satisfy the relation ($[D_M/2, 3D_M/2]$, ≧ 90%) in terms of frequency distribution by volume.

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If diamond or high-pressure phase boron nitride particles having such distributions are used as feed powder particles and, by sintering those diamond or high-pressure phase boron nitride particles or mixtures containing those coated diamond or high-pressure phase boron nitride particles, one can manufacture diamond or high-pressure phase boron nitride sinters of high performance that are uniform, dense and firmly sintered and which have an extremely highly controlled microstructure, those sinters being characterized in that the diamond or high-pressure phase boron nitride particles are sure to be surrounded by a bonding material and/or a sintering aid and/or a surface modifier except in areas where the coat forming substance is bursted by the pushing force from inside and any two contiguous diamond or high-pressure phase boron nitride particles bind directly to each other and also characterized in that no part of the surfaces of the diamond or high-pressure phase boron nitride particles in the coated diamond or high-pressure phase boron nitride sinters is left unsintered.

It should be particularly noted when sintering is done under sintering pressure and temperature conditions where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, the diamond or high-pressure phase boron nitride is advantageously of as high purity as to inhibit a phase transition to the low-pressure phase (graphite or hBN). As for diamond, grades of ultrahigh purity can be selected from natural products; however, high-pressure phase boron nitride does not occur naturally. Hence, with synthetic products of diamond or high-pressure phase boron nitride, any substance that has a catalytic action and which is used during synthesis is advantageously removed thereafter as much as possible. Most advantageously, one can select, for example, a diamond or cubic boron nitride of ultrahigh purity that has been synthesized via the vapor phase by a suitable technique such as a physical vapor deposition (PVD) process or a chemical vapor deposition (CVD) process. When the synthesized product is in the form of a thin film, it is used after being reduced in size with care being taken to avoid contamination with impurities. If the synthesized product is in a particulate or powder form, it may be used as such. Another example of high-purity product that can be selected is a high-purity single-crystal one which has been grown over time. Alternatively, diamond or cubic boron nitride particles that have been positively freed of impurities may be selected.

Vapor-Phase Coating Method

The term "vapor-phase coating method" means a method in which coating is applied with the feed of a coat forming substance being passed at least once through a vapor-phase state that consists of at least one member selected from among a molecular stream, an ionic stream, a plasma, a gas, a vapor and an aerosol; alternatively, the term refers to a method in which coating is applied from the feed of a coat forming substance in either one of the vapor-phase states mentioned above.

Core Particles

The term "core particles" refers to those particles which are to be provided with coatings. Such particles may sometimes be referred to as "base particles", "seed particles" or "particles to be coated".

The core particles are diamond or high-pressure phase boron nitride particles and the high-pressure phase boron nitride particles consist specifically of cubic boron nitride particles and/or wurtzite boron nitride particles.

Powder of Core Particles

The term "powder of core particles" means a powder consisting of core particles. The phrase "the particles in a powder of core particles" refers to those particles which compose the powder of core particles. The particles in the powder of core particles to be coated which are used in the present invention range from fine particles the average diameter of which is not more than 10 μm in terms of frequency distribution by volume to those particles the average diameter of which exceeds 800 μm in terms of frequency distribution by volume.

Preferred particles are those which have such a particle size distribution that the average diameter D_M satisfies the relation ($[D_M/5, 5D_M]$, $\geqq$ 90%) in terms of frequency distribution by volume.

With powders having such comparatively narrow distributions, their dispersion or cohesion characteristics are characterized by average particle diameter and the powders can be dispersed by operating a group of means for high dispersion treatment of particles under conditions that suit the specific value of D_M.

With a powder of core particles the particle size distribution of which is either broad or has a plurality of separate spaced peaks, a suitable selective separation treatment, say, classification may advantageously be performed and the individual classified powder portions are subjected to the coating treatment according to the invention. By so doing, coating can be started on the individual classified powder portions under the above-stated conditions in the coating start region of the coating space with the dispersity β adjusted to at least 70%, 80%, 90%, 95%, 97% or 99% depending on the average particle diameter, whereupon the individual particles in the powder of core particles can be provided with coatings.

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Coat Forming Substance

The term "coat forming substance" means a substance that forms a coat on the particles to be coated. This may specifically be exemplified by those substances which provide the particles in the powder of core particles with coatings in the form of at least one kind selected from among ultrafine particles, islands, continuous phase, uniform membranes, projections, etc.

Particularly in the case where the coat forming substance assumes the form of ultrafine particles, their diameter may range from 0.005 μm to 0.5 μm.

The coat forming substance may form a coating by itself or, alternatively, it reacts with the diamond or high-pressure phase boron nitride in the core particles and/or dissolves in the diamond or high-pressure phase boron nitride particles to form a solid solution and/or two or more coat forming substances may be reacted and/or alloyed with each other and/or dissolved in each other to form coatings. To this end, the coat forming substance is selected from among elemental substances and/or compounds that generate one or more of the desired inorganic compounds, alloys, intermetallic compounds, etc. to form such coatings, thereby serving as sintering aids and/or bonding materials which promote the sintering of the coated diamond or high-pressure phase boron nitride particles and/or as surface modifiers for the diamond or high-pressure phase boron nitride particles.

When sintering is done under sintering pressure and temperature conditions where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, the diamond or high-pressure phase boron nitride particles are to be coated with a coat forming substance that is selected from among those which will not promote the phase transition of diamond or high-pressure phase boron nitride to the lower-pressure phase (graphite or hBN). The coat forming substance is also selectable as a surface modifier which controls the grain boundaries of the diamond or high-pressure phase boron nitride particles. Various modifications may be performed as required and they include, for example: enhancing the chemical bonding between the diamond or high-pressure phase boron nitride particles and said sintering aid and/or bonding material; isolating the individual diamond or, high-pressure phase boron nitride particles from a certain substance, thereby inhibiting the phase transition of diamond or high-pressure phase boron nitride to the lower-pressure phase (graphite or hBN); or inhibiting the reaction between diamond or high-pressure phase boron nitride with a certain substance. These methods contribute to an outstanding increase in the latitude in the selection of the coat forming substance as a sintering aid and/or bonding material, which certainly is a definite advantage for the purposes of the invention.

These coat forming substances can be those which contain at least one member selected from among metals, semiconductors, metalloids, rare earth metals and nonmetals of groups 1a, 2a, 3a, 4a, 5a, 6a, 7a, 1b, 2b, 3b, 4b, 5b, 6b, 7b and 8 of the periodic table, as well as oxides, nitrides, carbides, oxynitrides, oxycarbides, carbonitrides, oxycarbonitrides, borides and silicides thereof, as exemplified by the following: Al, B, Si, Fe, Ni, Co, Ti, Nb, V, Zr, Hf, Ta, W, Re, Cr, Cu, Mo, Y, La, TiAl, Ti_3Al, $TiAl_3$, TiNi, NiAl, Ni_3Al, SiC, TiC, ZrC, B_4C, WC, W_2C, HfC, VC, TaC, Ta_2C, NbC, Mo_2C, Cr_3C_2, Si_3N_4, TiN, ZrN, Si_2N_2O, AlN, HfN, VxN (x = 1 ~ 3), NbN, TaN, Ta_2N, TiB, TiB_2, ZrB_2, VB, V_3B_2, VB_2, NbB, NbB_2, TaB, TaB_2, MoB, MoB_2, MoB_4, Mo_2B, WB, W_2B, W_2B_5, LaB_6, $B_{13}P_2$, $MoSi_2$, BP, Al_2O_3, ZrO_2, $MgAl_2O_4$ (spinel) and Al_2SiO_5 (mullite).

The amounts in which the coat forming substances are added to form the coats on the surfaces of the coated diamond or high-pressure phase boron nitride particles are not limited in any particular way and suitable values can be selected that suit specific uses; advantageously, any desired values are selected as long as they are capable of densifying the diamond or high-pressure phase boron nitride sinters.

Uniform Coating

In the case where the coat forming substance takes the form of a uniform membrane, the term "uniform coating" means that the coating film is uniform in every portion of a single particle. In the case where the coat forming substance takes the form of an ultrafine particle, an island or a projection, the term "uniform coating" means that the coat forming substance in the form of an ultrafine particle, an island or a projection provides a coating of uniform distribution. It should be understood that any unevenness that is unavoidable in the process of generation of the coat forming substance will be embraced within the category of "uniformity".

Definition of "Charging into the Coating Space"

The phrase "charging into the coating space" means introducing the powder of core particles into the coating space by a certain method of falling such as free fall. In the case of charging by means of a carrier gas, the phrase means introducing the powder of core particles as it is carried in the direction of a mixture of a gas and the particles in the powder of core particles, or carried by a gas in the direction of its flow, or carried by a gas to change the direction of flow. Alternatively, the phrase means introduction under the action of a carrier gas, for example, through the wave motion, specifically, a nonlinear wave motion, of the carrier gas. Alternatively, the phrase means introduction into the coating

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space by sound waves, ultrasonic waves, magnetic fields, electron beams, etc. in the gas. The phrase also means introduction in an applied field such as an electric field, a magnetic field or electron beams. Specifically, the powder particles may be charged or magnetized in an electric field, a magnetic field, by electron beams, etc. and introduced into the coating space by attractive or repulsive forces. Also contemplated by the phrase is introduction by aspiration under the back pressure of the gas or in vacuo.

Coating Space

The term "coating space" refers to a space in which the precursor of the coat forming substance which is generated from the feed of the coat forming substance via the vapor phase and/or the precursor of the coat forming substance in a vapor-phase state contacts and/or impinges against the particles in the powder of core particles. Alternatively, the term refers to a space region in which the surfaces of the particles in the powder of core particles are coated with the coat forming substance.

Coating Chamber

The term "coating chamber" means a compartment having the coating space in at least one part. More specifically, the coating chamber is a partitioned or generally partitioned (generally closed or semi-closed) compartment including the coating space and it is a compartment including the coating space in at least one part.

Within Gaseous Atmosphere

The expression "within a gaseous atmosphere" means within a space under vacuum or in a vapor-phase state. The term "vapor-phase state" as used herein means various states such as a molecular stream, an ionic stream, a plasma, a gas and a vapor. Technically speaking, the term "vacuum" refers to a state under reduced pressure. Strictly speaking, gases, molecules, atoms, ions, etc. are contained at any values of reduced pressure.

Precursor of the Coat Forming Substance

The term "precursor of the coat forming substance" means a precursor for the coat forming substance. More specifically, it refers to the feed per se of the coat forming substance in a vapor-phase state or, alternatively, it means a substance that is formed and/or synthesized from the feed of the coat forming substance via the vapor phase and which exists until just before it forms a coating on the core particles to be coated. The precursor of the coat forming substance is not limited to any state as long as it is formed and/or synthesized from the feed of the coat forming substance via the vapor phase. If the feed of the coat forming substance is in the vapor phase, the feed itself can be used as the precursor of the coat forming substance. The precursor of the coat forming substance may itself be in the vapor phase. If the precursor of the coat forming substance is a reactive substance, it may be prior to, or during or after the reaction. Specific examples of the precursor of the coat forming substance include ions, atoms, molecules, clusters, atomic clusters, molecular clusters, cluster ions, superfine particles, gases, vapors, aerosols, etc.

Feed of the Coat Forming Substance

The term "feed of the coat forming substance" refers to a feed material that passes through the vapor phase to become a coat forming substance. Specific examples of the state in which the feed of the coat forming substance may exist include solid lumps, powder particles, gases, liquids, etc.

Dispersity β

Dispersity β was proposed by Masuda, Gotoh et al. as an index for evaluating the dispersing performance of powder dispersing equipment [see KAGAKU KOGAKU, Summaries of Speeches and Lectures Delivered at the 22th Autumn Conference, p. 349 (1989)] and is defined as the proportion of the weight of particles in the state of apparent primary particles relative to the total weight of the particles present. The term "particles in the state of apparent primary particles" as used herein refers to the proportion of the overlap between the frequency distribution by mass of powder particles in a given state of dispersion f_{m2} and the frequency distribution by mass of completely dispersed powder particles f_{m1} and is expressed by β according to the following equation:

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$$\beta = \int_0^{D_m^*} f_{m2}(D)dD + \int_{D_m^*}^{\infty} f_{m1}(D)dD$$

where

D: particle diameter (μm);
D_m^*: the particle diameter (μm) for the point of crossing between f_{m1} and f_{m2};
f_{m1}: the frequency distribution by mass (%/μm) representing the particle size distribution for complete dispersion;
f_{m2}: the frequency distribution by mass (%/μm) representing the particle size distribution of particles in a given state of dispersion; and
β: dispersity (%).

In the equation set forth above, the unit of measurement (μm) of the particle diameter is not limited to any particular value.

This equation evaluates dispersity on the basis of the particle size distribution as expressed by mass; however, dispersity should in principle be evaluated on the basis of the particle size distribution expressed by volume. But given the same density of powder particles, the particle size distribution as expressed by mass is equal to the particle size distribution expressed by volume. Therefore, in practice, the particle size distribution by mass which is easy to measure is determined and used as an equivalent of the particle size distribution by volume. Therefore, the dispersity β in the true sense of the term is expressed by the following equation and the area of the hatched portion shown in Fig. 1a:

$$\beta = \int_0^{D_v^*} f_{v2}(D)dD + \int_{D_v^*}^{\infty} f_{v1}(D)dD$$

where

D: particle diameter (μm);
D_v^*: the particle diameter (μm) for the point of crossing between f_{v1} and f_{v2};
f_{v1}: the frequency distribution by volume (%/μm) representing the particle size distribution for complete dispersion;
f_{v2}: the frequency distribution by volume (%/μm) representing the particle size distribution of particles in a given state of dispersion; and
β: dispersity (%).

In the equation set forth above, the unit of measurement (μm) of the particle diameter is not limited to any particular value.

In the following description, the distribution of the particles in the powder of core particles and their average diameter should, in principle, be based on volume unless otherwise noted.

Frequency Distribution by Volume

The frequency distribution by volume represents the distribution of particle diameter in terms of the relative volume of particles in a certain range of diameters.

Definition of ([D1,D2], ≧ 90%)

A ([D1,D2], ≧ 90%) distribution represents one in which particles from D1 to D2 (D1 and D2 each represent the particle diameter, provided that D1 < D2) account for at least 90% of the total volume of the particles present; a powder having this distribution is shown graphically in Fig. 1b, in which the hatched portion accounts for at least 90% of the area under the curve.

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Definition of Frequency Distribution by Volume ([D_M/5, 5D_M], ≧ 90%)

A particle size distribution that is expressed by ([D_M/5, 5D_M], ≧ 90%) in terms of frequency distribution by volume represents one in which particles ranging in diameter from one fifth of D_M to five times D_M (D_M is the average particle diameter by volume) account for at least 90% of the total volume of the particles present. Consider, for example, particles having an average diameter D_M of 10 μm on a volume basis; a particle size distribution that is expressed by ([D_M/5, 5D_M], ≧ 90%) in terms of frequency distribution by volume represents one in which particles ranging in diameter from 2 μm to 50 μm account for at least 90% of the total volume of the particles present. The average particle diameter D_M on a volume basis is expressed by:

$$D_M = \frac{\int_0^\infty Df(D)dD}{\int_0^\infty f(D)dD}$$

where f(D) is the frequency distribution by volume. Or D_M is technically expressed by:

$$DM = \Sigma(V_i D_i)/\Sigma V_i$$

where Vi is the volume of a group of particles within a given interval of diameters $D_i \pm \Delta D_i/2$ (ΔD_i is the width of interval).

Coating Start Region

The region where coating is first started after the final treatment by the group of means for high dispersion treatment of particles is called the "coating start region". Therefore, prior to the final treatment by the group of means for high dispersion treatment of particles, no region is called the "coating start region" according to this definition even if coating is first started there.

Dispersity β in the Coating Start Region

In the present invention, the coating chamber is provided in such a way that the coating start region of the coating space is located in a region that satisfies one of the following conditions:

(1) a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 70%;
(2) a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 80%;
(3) a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 90%;
(4) a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 95%;
(5) a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group

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of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 97%; and

(6) a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 99%.

Given one of those dispersities in the coating start region of the coating space, one can disperse the particles in the powder of core particles to such a state that they are substantially single particles in a gaseous atmosphere, so that the precursor of the coat forming substance will uniformly contact and/or impinge against the surfaces of all particles in the powder of core particles that pass through the coating start region of the coating space, whereby the coat forming substance can be deposited on single particles in equal amounts.

In the present invention, dispersity β varies continuously with the average diameter of the particles in the powder of core particles but because of the difficulty involved in expressing it, the convenient stepwise expression is adopted.

Advantageously, the coating chamber is provided in such a way that the coating start region of the coating space is located in a space region that satisfies one of the following conditions:

(1) a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 80%;

(2) a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 90%;

(3) a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity of the particles in said powder of core particles should be adjusted to 95%;

(4) a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to 97%; and

(5) a powder of core particles that have an average diameter in excess of 300 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 99%. Given the coating chamber in which the coating start region of the coating space is located in such a way as to satisfy those conditions, the particles in the powder of core particles are at least free from areas that are substantially closed by two adjacent core particles and it is possible to assure that the precursor of the coat forming substance is allowed to contact and/or impinge against the surfaces of individual particles from every direction, whereby coating with the coat forming substance can be accomplished more uniformly on a single particle basis and, accordingly, coating can be done to provide more uniform coating weights for the individual core particles.

The particles in a powder of core particles that have an average diameter exceeding 10 μm in the frequency distribution by volume are subjected to a cohesive action in a gaseous atmosphere, although not as intense as in the case of the particles in a powder of core particles that have an average diameter no more than 10 μm, and they contact and/or impinge against one another, causing unevenness in the distribution of the particles in the powder of highly dispersed core particles which form a mixture with a gas. However, if the coating of the particles in the powder of core particles is started as they are dispersed to provide one of the above-specified dispersities in accordance with their diameter, the particles in the powder of core particles or the particles in a powder that consists chiefly of the core particles can be coated with the coat forming substance more uniformly on a single particle basis and, accordingly, the individual particles can be coated with the coat forming substance in more uniform weights.

More advantageously, in the coating start region of the coating space,

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(1) a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final dispersing treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 90%, or

(2) a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final dispersing treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 95%, or

(3) a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final dispersing treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 97%, or

(4) a powder of core particles that have an average diameter in excess of 50 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final dispersing treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 99%.

If one of these dispersities is attained in the coating start region of the coating space, the core particles are practically free from agglomeration and practically uniform coating can be performed on all surfaces of the individual particles.

If, in a particular case, high-quality coating is desired at the sacrifice of the efficiency of treatment, the dispersity is preferably at least 95%. In this case, the throughput of the treatment of the particles in the powder of core particles may be reduced to a very small level, namely, the concentration by number of the particles in the powder of core particles in the gaseous atmosphere may be reduced so that the particles in the powder of core particles are dispersed completely, whereby uniform coating can thoroughly be accomplished on the entire surfaces of the individual particles.

Group of Means for High Dispersion Treatment of Particles

The group of means for high dispersion treatment of particles which is to be used in the present invention is such that: (A) it has at least one dispersing means; and (B) it has, as the final treating means,

(a) dispersing means for dispersing the particles in a powder of core particles in a gaseous atmosphere or
(b) means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles which comprises

(b-1) means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles that separates a portion of the powder that is composed of less highly dispersed particles from the mixture of a gas and the particles in the powder of core particles in which the particles in the powder of core particles are dispersed in a gaseous atmosphere, thereby selecting a mixture of a gas and the particles in a powder of highly dispersed core particles in which the particles in the powder of core particles are present in the gaseous atmosphere mainly in a single-particle state and

(b-2) feedback means by which the portion of the powder that is composed of less highly dispersed particles and which has been separated by the means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles is transported to the final dispersing means among the dispersing means in the group of means for high dispersion treatment of particles and/or treating means upstream of the final dispersing means.

Advantageously, the group of means for high dispersion treatment of particles has such dispersing performance that one of the following conditions is satisfied:

(1) a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 70%;

(2) a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder

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of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 80%;

(3) a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 90%;

(4) a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 95%;

(5) a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 97%; and

(6) a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume should be dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and the dispersity β of the particles in said powder of core particles should be adjusted to at least 99%.

By insuring that the group of means for high dispersion treatment of particles have dispersing capabilities comparable to or better than the various dispersities to be attained in the above-described coating start region and by providing them in correspondence to those dispersities, high-quality coating can be applied in the coating start region to comply with the respective dispersities.

Final Treating Means

If the final treating means in the group of means for high dispersion treatment of particles is a dispersing means, said dispersing means is referred to as the final treatment means in the group of means for high dispersion treatment of particles. If the final treating means in the group of means for high dispersion treatment of particles is a means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles which is equipped with a feedback means by which the portion that has been separated selectively on account of less highly dispersed state during the step of treatment for selecting the mixture of a gas and the particles in the powder of highly dispersed core particles is to be transported to the final dispersing means at the last stage of the means for high dispersion treatment of particles, or if said final treating means is a means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles which is equipped with a feedback means by which the portion that has been separated selectively on account of less highly dispersed state during the step of treatment for selecting the mixture of a gas and the particles in the powder of highly dispersed core particles is to be transported to a treating means upstream of the final dispersing means, said means for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles is referred to as the final treating means in the group of means for high dispersion treatment of particles.

It should be noted here that any means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles that is provided upstream of the means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles that is equipped with a feedback means and which is the final treating means in the group of means for high dispersion treatment of particles ("upstream" may typically mean between the means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles that is equipped with a feedback means and the final dispersing means, or upstream of the final dispersing means) is a constituent element of the group of means for high dispersion treatment of particles and this is true irrespective of whether the feedback means is used or not.

Dispersing Means

The means used to disperse particles is named a dispersing means. Any mechanism that has even a small or slight dispersing effect is usable as a dispersing means and it is used as a dispersing means in the invention. Consider, for example, a rotary feeder and an injection feeder for pneumatic conveying which are commonly used as supply means ["Funtai Kogaku Binran (A Handbook of Particle Technology)", Ed. by Funtai Kogakukai (Society of Particle Technology), published by Nikkan Kogyo Shinbunsha in 1986, pp. 568 and 571]. These apparatus also have a dispersing effect and, hence, they are dispersing means if used as means to achieve dispersion. The dispersion maintaining and promoting means which are to be discussed later are also dispersing means if they are used to achieve dispersion (for increasing

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β). Such dispersing means may be a single apparatus or machine or it may be a complex of apparatus and machines; to cover all of these cases, the dispersing means is collectively referred to as the "group of means for high dispersion treatment of particles".

The group of means for high dispersion treatment of particles is such that it operates on at least one selected mechanism of dispersion, such as dispersing the particles in a powder of core particles by a gas stream which accelerates and/or places them in a velocity gradient, dispersing the particles in a powder of core particles by impingement against a static obstacle and/or an obstacle composed of a rotating body, and dispersing the particles in a powder of core particles by mechanical disagglomeration which consists of a fluidized bed and/or pulsation and/or a rotary drum and/or vibrations and/or scraping.

Specifically, the group of means for high dispersion treatment of particles is equipped with at least one selected dispersing means, such as an ejector-type disperser, a Venturi-type disperser, a disperser using a capillary, an agitator, and an obstacle in a gas stream, a disperser using a jet blow, a disperser using a spiral tube and rotating blades, a disperser using rotating pins (Kady mill), a fluidized bed-type disperser, a disperser using pulsation, a disperser using a rotary drum, a disperser using vibrations, a disperser using a vibrating screen and the scraping action of a scraper, an SAEI Gonnel-type disperser, a Chujo-type disperser, a Roller-type disperser, an office-type disperser, a B.M. type disperser, a Timbrell-type disperser, and a Wright-type disperser ["Funtai Kogaku Binran (A Handbook of Particle Technology)", Ed. by Funtai Kogakukai (Society of Particle Technology), published by Nikkan Kogyo Shinbunsha in 1986, p. 430].

Also usable are the dispersers described in official gazettes and exemplified blow: the disperser using agitating blades which is described in Unexamined Published Japanese Patent Application (kokai) Sho 56-1336; the disperser using a high-speed gas stream and dispersing nozzles which is described in Unexamined Published Japanese Patent Application (kokai) Sho 58-163454; the disperser using the dispersing action of rotating blades and the dispersing action of plasma ions which is described in Unexamined Published Japanese Patent Application (kokai) Sho 59-199027; the disperser using the dispersing action of plasma ions which is described in Unexamined Published Japanese Patent Application (kokai) Sho 59-207319; the disperser using an ejector and the dispersing action of plasma ions which is described in Unexamined Published Japanese Patent Application (kokai) Sho 59-216616; the disperser using an ejector and the dispersing action of ion streams which is described in Unexamined Published Japanese Patent Application (kokai) Sho 59-225728; the disperser using the dispersing action of plasma ions which is described in Unexamined Published Japanese Patent Application (kokai) Sho 59-183845; the disperser using the dispersing action of dispersing blades and a pressure gas which is described in Unexamined Published Japanese Patent Application (kokai) Sho 63-166421; the disperser using lineal or annular slit jet ports which is described in Unexamined Published Japanese Patent Application (kokai) Sho 62-176527; the disperser using mesh blades which is described in Unexamined Published Japanese Patent Application (kokai) Sho 63-221829; the disperser using the dispersing action of high-speed gas streams issuing from jet nozzles which is described in Unexamined Published Japanese Patent Application (kokai) Sho 63-1629; the disperser using many small holes which is described in Unexamined Published Utility Model Application (kokai) Sho 63-9218; the ejector-type disperser which is described in Unexamined Published Japanese Utility Model Application (kokai) Sho 62-156854; and the disperser using small holes and orifices which is described in Unexamined Published Japanese Utility Model Application (kokai) Sho 63-6034.

Dispersing means advantageous for use in the group of means for high dispersion treatment of particles include the apparatus that are described in Japanese Patent Application Sho 63-311358, Japanese Patent Application Hei 1-71071, Japanese Patent Application Hei 2-218537, etc.

Means for Selecting a Mixture of a Gas and the Particles in a Powder of Highly Dispersed Core Particles

The means for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles is a means that separates a mixture of a gas and the particles in a powder of less highly dispersed core particles from the mixture of a gas and the particles in the powder of core particles so as to select a mixture of a gas and the particles in a powder of highly dispersed core particles that is chiefly composed of those particles which are in a single-particle state. Agglomerating particles which are association of primary particles have a greater apparent diameter than the primary particles and, hence, they can be separated by a suitable means such as dry classifying means. An example of the means for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles is at least one dry classifying means selected from among the following: classifying means using gravity, classifying means using inertia force, classifying means using centrifugal force, classifying means using static electricity, classifying means using a fluidized bed, etc.

Specific examples of the means for selecting the mixture of a gas and the particles in a powder of highly dispersed core particles include: a gravity classifier, an inertia classifier, a centrifugal classifier, a cyclone, an air separator, a micron separator, a microplex, a multiplex, a zigzag classifier, an acu-cut, a conical separator, a turbo classifier, a super separator, a dispersion separator, an elbow jet, a fluidized bed classifier, a virtual impactor, an O-Sepa, a sieve, a vibrating

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screen, a sifter ["Funtai Kogaku Binran (A Handbook of Particle Technology)", Ed. by Funtai Kogakukai (Society of Particle Technology), published by Nikkan Kogyo Shinbunsha in 1986, p. 514].

Mixture of a Gas and the Particles in a Powder of Core Particles

The mixture of a gas and the particles in a powder of core particles refers to (a) a homogeneous flow characterized in that the particles in a powder of core particles are suspended uniformly in a gaseous atmosphere (which may be called a "uniform suspension flow"), (b) a heterogeneous flow characterized in that the particles in a powder of core particles show a nonuniform distribution in certain regions of a gaseous atmosphere (which may be called an "inhomogeneous suspension flow"), (c) a flow involving a sliding layer of the particles in a powder of core particles (which may be called a "sliding flow"), or (d) a flow involving a stationary layer of the particles in a powder of core particles.

Mixture of a Gas and the Particles in a Powder of Less Highly Dispersed Core Particles

The mixture of a gas and the particles in a powder of less highly dispersed core particles refers to that portion of a mixture of a gas and the particles in a powder of core particles in which the powder particles are present in a gaseous atmosphere mainly in states other than the single-particle state.

Mixture of a Gas and the Particles in a Powder of Highly Dispersed Core Particles

The mixture of a gas and the particles in a powder of highly dispersed particles refers to a mixture of a gas and the particles in a powder of core particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state. No matter how much high the degree of dispersion is, the mixture of a gas and the particles in a powder of highly dispersed core particles contains agglomerating particles in practice. The mixture of a gas and the particles in a powder of less highly dispersed particles contains non-agglomerating single particles in practice and can be selectively separated into a mixture of a gas and the particles in a powder of less highly dispersed particles and a mixture of a gas and the particles in a powder of highly dispersed particles. The mixture of a gas and the particles in a powder of less highly dispersed particles is converted to a mixture of a gas and the particles in a powder of highly dispersed particles by selective separation and/or redispersion of the agglomerating particles.

Recovery Means

The recovery means is a means for picking up the coated particles that have been prepared in the coating space. The part of the recovery means in which the recovery treatment is performed is called the "recovery section". The coated particles the coating on which has been provided by passage through the coating start region of the coating space are recovered by direct pickup from the gaseous atmosphere or after temporary storage following pickup from the gaseous atmosphere or together with a gas.

Usable as the recovery section of the recovery means is one of the following members: the recovery section of the recovery means that uses barriers (obstacles), the recovery section of the recovery means that uses gravity, the recovery section of the recovery means that uses inertia forces, the recovery section of the recovery means that uses centrifugal forces, the recovery section of the recovery means that uses coulombic attractive forces; the recovery section of the recovery means that uses thermophoretic forces, the recovery section of the recovery means that uses Brownian diffusion, the recovery section of the recovery means that uses the pulling force of the back pressure, evacuation, etc.

Advantageous examples of the recovery section of the recovery means include a gravity dust collector, an inertia dust collector, a centrifugal dust collector, a filtration dust collector, an electrostatic precipitator, a scrubbing dust collector, a particle packed layer, a cyclone, a bag filter, a ceramic filter, a scrubber, etc.

Bonding Material

The bonding material to be used to manufacture diamond or high-pressure phase boron nitride sinters in accordance with the invention is selected from among those bonding materials which can be sintered densely to a density of at least 85% by sintering at pressures less than 2000 MPa and at temperatures not exceeding 1850°C. Advantageously, those bonding materials are selected which will not promote the phase transition of diamond or high-pressure phase boron nitride to the lower-pressure phase (graphite or hBN). Alternatively, those bonding materials are selected which, when sintered at pressures less than 2000 MPa and at temperatures not exceeding 1850°C, will react with diamond or boron nitride to yield dense reaction products that have densities of at least 85%. More preferably, those substances are selected which, when sintered at pressures less than 2000 MPa and at temperatures not exceeding 1850°C, will produce bonding materials that are dense (density ≧ 90%) and/or of high hardness (Vickers hardness ≧ 600). Feed powders which, when sintered at pressures less than 2000 MPa and at temperatures not exceeding 1850°C, will yield dense

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bonding materials having densities of at least 85% are selected from powders or particles that contain at least one of the metals, semiconductors, metalloids and rare earth metals of groups 1a, 2a, 3a, 4a, 5a, 6a, 7a, 1b, 2b, 3b, 4b, 5b, 6b, 7b and 8 of the periodic table and/or at least one compound containing at least one of those metals, semiconductors, metalloids and rare earth metals. More specifically, such powders or particles can be those of at least one member which is selected from among B, Ti, Zr, Hf, Ta, Nb, V, SiC, TiC, ZrC, B_4C, WC, HfC, TaC, NbC, Si_3N_4, TiN, ZrN, AlN, HfN, TaN, TiB, TiB_2, ZrB_2, HfB, HfB_2, LaB_6 $MoSi_2$, BP, Al_2O_3, Al_2SiO_5 (mullite), ZrO_2 (PSZ: partially stabilized zirconia with Y_2O_8, MgO or CaO, or TZP: tetragonal zirconia polycrystalline compound), and $MgAl_2O_4$ (spinel). To take alumina as an example, a suitable example is a high-purity, easily sintrable fine feed, such as the alumina described in Unexamined Published Japanese Patent Application (kokai) Sho 63-151616 which is produced by pyrolysis of an ammonium aluminum carbonate and this is preferred since it can be densified at a temperature of about 1400°C even by normal sintering at atmospheric pressure. Another suitable example is a fine, high-purity alumina powder that contains up to 10% by volume of magnesia (MgO) and/or titania (TiO_x, x = 1 - 2) which are effective in promoting the sintering of alumina and if this condition is met, high-purity aluminas other than the alumina described in Unexamined Published Japanese Patent Application (kokai) Sho 63-151616, supra may be used, as exemplified by high-purity (≧ 99%) and easily sintrable aluminas that are composed of fine (≦ 1 μm) particles and which are typically produced by the Bayer process, hydrolysis of organic aluminum, pyrolysis of aluminum alum, the ethylene chlorohydrin process, submerged arc discharge, etc.

Besides the aluminas mentioned above, zirconium oxides may also be selected and advantageous examples include the easily sintrable yttria partially stabilized zirconia (2-4 mol% Y_2O_3-ZrO_2) powder which is produced by coprecipitation, and an alumina-zirconia base powder [FC Report, 1(5) (1983) 13-17]. Also selectable is a titanium oxide or titania powder [TiO_2; Summaries of Lectures Read at the 15th Symposium on High-Pressure Technology (1973) p. 174].

Another example that can be selected is titanium nitride [TiN; Yamada et al., Yogyo Kyokaishi (Journal of The Ceramic Society of Japan, 89, (1981) 621-625].

In the next place, the group of means for high dispersion treatment of particles which is adopted to prepare the coated diamond or high-pressure phase boron nitride particles is described below with reference to accompanying drawings.

Description of the Drawings of the Group of Means for High Dispersion Treatment of Particles

Fig. 2a is a block diagram showing an example of the basic composition of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles. The group is composed of a final dispersing means A for dispersing the particles in a powder of core particles and a constituent element d of the group of means for dispersion treatment which is upstream of the final dispersing means. Shown by ε is a mixture of a gas and the particles in a powder of highly dispersed core particles which are part of the particles in the powder of core particles and which are present in a gaseous atmosphere mainly in a single-particle state. Constituent element d may be any treating means such as dispersing means, supply means, and means for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles, which may be used either individually or in combination. Constituent element d is optional and may be omitted. The group of means for high dispersion treatment of particles is advantageously of such a design that after treatment by the final treating means A, one of the following values of dispersity β can be realized: (1) at least 70% for a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume; (2) at least 80% for a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume; (3) at least 90% for a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume; (4) at least 95% for a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume; (5) at least 97% for a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume; and (6) at least 99% for a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume.

Fig. 2b is a block diagram showing a second example of the basic composition of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles. The group is composed of a final dispersing means A for dispersing the particles in a powder of core particles, final means B for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles at the last stage which is equipped with feedback means C by which a mixture of a gas and the particles in a powder of less highly dispersed core particles η as separated from a mixture of a gas and the particles in a powder of highly dispersed core particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state is fed back to the final dispersing means A, a constituent element d of the group of means for dispersion treatment which is upstream of the final dispersing means, and a constituent element e of the group of means for high dispersion treatment of particles which is provided between the final dispersing means and the final selecting means. As for the mixture ε and the constituent element d, the explanation made in connection with Fig. 2a will apply and, hence, no detailed description is made. Constituent element e may be any treating means other than the dispersing means, such as supply means and

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selecting means, which may be used either individually or in combination. Constituent elements d and e are optional and may be omitted. The group of means for high dispersion treatment of particles is advantageously of such a design that after treatment by selecting means B which is the final treating means, the above-mentioned values of dispersity can be realized for powders of core particles having the above-mentioned average diameters.

Fig. 2c is a block diagram showing a third example of the basic composition of the group for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles. The group is composed of a final dispersing means A for dispersing the particles in a powder of core particles, final means B for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles at the last stage which is equipped with feedback means C by which a mixture of a gas and the particles in a powder of less highly dispersed core particles η as separated from a mixture of a gas and the particles in a powder of highly dispersed core particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state is fed back to a treating means upstream of the final dispersing means A, a constituent element d of the group of means for high dispersion treatment of particles which is upstream of the final dispersing means, and a constituent element e of the group of means for high dispersion treatment of particles which is provided between the final dispersing means and the final selecting means. As for the mixture ε, constituent elements d and e, and the group of means for high dispersion treatment of particles, the foregoing explanation will apply and no detailed description is made.

Having the construction described above, the group of means for high dispersion treatment of particles under discussion may include powder supply sources such as a supply vessel and core particle generating means. To take the case of Fig. 2c as an example, the group of means for high dispersion treatment of particles may of course adopt such a composition that the mixture η is fed back to a supply vessel by the feedback means C. It also goes without saying that the step of dispersion by the group of means for high dispersion treatment of particles may be preceded by a disintegrating step in which the particles in the powder of core particles are disintegrated and/or otherwise reduced in size.

Typical specific examples of these basic compositions of the group of means for high dispersion treatment of particles are described below in greater detail with reference to more detailed block diagrams.

Design 1

Fig. 3a is a block diagram illustrating a first specific design of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles and the drawing corresponds to Fig. 2a. The group shown in Fig. 3a is composed of a supply vessel 100 for supplying the powder of core particles to be coated, and the final dispersing means A for dispersing the powder of core particles to be coated.

Design 2

Fig. 3b is a block diagram illustrating a second specific design of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles and the drawing corresponds to Fig. 2a. The group shown in Fig. 3b is composed of a supply vessel 100 for supplying the powder of core particles to be coated, dispersing means a for dispersing the powder of core particles to be coated, and the final dispersing means A for dispersing the powder of core particles to be coated.

Design 3

Fig. 3c is a block diagram illustrating a third specific design of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles and the drawing corresponds to Fig. 2a. The group shown in Fig. 3c is composed of a supply vessel 100 for supplying the powder of core particles to be coated, dispersing means a for dispersing the powder of core particles to be coated, feedback means C by which a mixture of a gas and the particles in a powder of less highly dispersed core particles η as separated from a mixture of a gas and the particles in a powder of highly dispersed core particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state is fed back from the mixture of a gas and the particles in the powder of core particles (which have been dispersed by the dispersing means a) to the dispersing means a, means b for selecting the mixture of a gas and the particles in a powder of highly dispersed particles, by which the mixture of a gas and the particles in a powder chiefly composed of highly dispersed core particles is introduced into the final dispersing means A, and the final dispersing means A for dispersing the powder of core particles to be coated.

Design 4

Fig. 3d is a block diagram illustrating a fourth specific design of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles and the drawing in Fig. 3d corresponds to Fig. 2b. The group shown in Fig. 3d is composed of a supply vessel 100 for supplying the powder

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of core particles to be coated, a final dispersing means A for dispersing the powder of core particles to be coated, feedback means C by which a mixture of a gas and the particles in a powder of less highly dispersed core particles η as separated from a mixture of a gas and the particles in a powder of highly dispersed particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state is fed back from the mixture of a gas and the particles in the powder of core particles (which have been dispersed by the final dispersing means A) to the dispersing means A, and final means B for selecting the mixture of a gas and the particles in the powder of highly dispersed core particles at the final stage and which discharges the mixture of a gas and the particles in the powder of highly dispersed core particles.

Design 5

Fig. 3e is a block diagram illustrating a fifth specific design of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles and the drawing corresponds to Fig. 2b. The group shown in Fig. 3e is composed of a supply vessel 100 for supplying the powder of core particles to be coated, dispersing means a for dispersing the powder of core particles to be coated, a final dispersing means A for dispersing the powder of core particles to be coated, feedback means C by which a mixture of a gas and the particles in a powder of less highly dispersed core particles η as separated from a mixture of a gas and the particles in a powder of highly dispersed particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state is fed back from the mixture of a gas and the particles in the powder of core particles (which have been dispersed by the final dispersing means A) to the dispersing means A, and final means B for selecting the mixture of a gas and the particles in the powder of highly dispersed core particles at the final stage and which discharges the mixture of a gas and the particles in the powder of highly dispersed core particles.

Design 6

Fig. 3f is a block diagram illustrating a sixth specific design of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles and the drawing corresponds to Fig. 2b. The group shown in Fig. 3f is composed of a supply vessel 100 for supplying the powder of core particles to be coated, means b for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles, which rejects a mixture of a gas and the particles in a powder chiefly composed of less highly dispersed core particles from the mixture of a gas and the particles in the powder of core particles and which introduces into dispersing means A the mixture of a gas and the particles in a powder chiefly composed of highly dispersed core particles, final dispersing means A for dispersing the particles in the selectively separated powder of core particles, feedback means C by which a mixture of a gas and the particles in a powder of less highly dispersed core particles as separated from a mixture of a gas and the particles in a powder of highly dispersed particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state is fed back from the mixture of a gas and the particles in the powder of core particles (which have been dispersed by the final dispersing means A) to the dispersing means A, and final means B for selecting the mixture of a gas and the particles in the powder of highly dispersed core particles at the final stage and which discharges the mixture of a gas and the particles in the powder of highly dispersed core particles.

Design 7

Fig. 3g is a block diagram illustrating a seventh specific design of the group of means for high dispersion treatment of particles as it is used to prepare coated diamond or high-pressure phase boron nitride particles and the drawing corresponds to Fig. 2c. The group shown in Fig. 3g is composed of a supply vessel 100 for supplying the powder of core particles to be coated, dispersing means a for dispersing the powder of core particles to be coated, a final dispersing means A for dispersing the powder of core particles to be coated, feedback means C by which a mixture of a gas and the particles in a powder of less highly dispersed core particles as separated from a mixture of a gas and the particles in a powder of highly dispersed particles in which the powder particles are present in a gaseous atmosphere mainly in a single-particle state is fed back from the mixture of a gas and the particles in the powder of core particles (which have been dispersed by the final dispersing means A) to the dispersing means A, and final means B for selecting the mixture of a gas and the particles in the powder of highly dispersed core particles at the final stage and which discharges the mixture of a gas and the particles in the powder of highly dispersed core particles.

To maintain the thus achieved high dispersive state of the particles, means for maintaining dispersion in a gaseous atmosphere may be added to the group of means for high dispersion treatment of particles. The term "means for maintaining dispersion in a gaseous atmosphere" as used herein refers to means that maintains a desired value of dispersity β by preventing reagglomeration of the particles in the powder of core particles that have been carried dispersively in a gaseous atmosphere. To promote the thus achieved high dispersive state of the core particles, means for promoting dispersion in a gaseous atmosphere may be added between the group of means for high dispersion treatment of particles

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and the coating chamber. The term "means for promoting dispersion in a gaseous atmosphere" as used herein refers to means which is primarily intended to promote the redispersion of that part of the particles in the powder of core particles carried dispersively in a gaseous atmosphere which have agglomerated again, thereby retarding the drop in the dispersive state of the powder; the term also refers to means that promotes redispersion in such a way that the state of dispersion that has dropped once can be restored to the initial high dispersive state.

Advantageous examples of said means for maintaining dispersion in a gaseous atmosphere or promoting dispersion in a gaseous atmosphere include a pipe vibrator, a pipe heater, a plasma generator, an electric charger, etc.

The pipe vibrator is means in which a pipe equipped with an oscillator is vibrated to provide the particles dispersed in a gaseous atmosphere with vibrations uncomparable to those imparted by dispersers, whereby reagglomeration is suppressed to maintain the high dispersive state or the dispersion of reagglomerating particles is promoted.

The pipe heater is means in which a heated pipe imparts heat to a carrier gas from outside, thereby expanding the carrier gas so that its flow velocity is accelerated to a level that is too fast to be comparable to that achieved by dispersers, whereby reagglomeration of the particles is suppressed while promoting the dispersion of reagglomerating particles.

The plasma generator is means in which a plasma is generated in the gaseous atmosphere which dispersively caries the powder of core particles, with the resulting plasma ions being allowed to impinge against the core particles, whereby reagglomeration is suppressed to maintain the high dispersive state or the dispersion of reagglomerating particles is promoted.

The electric charger is means in which corona discharge, electron beams, radiations or some other method is used to generate monopolar ions in the gaseous atmosphere which dispersively carries the powder of core particles, which are subsequently passed through the monopolar ion atmosphere to be charged to a single polarity, whereupon electrostatic repulsive forces either suppress reagglomeration to maintain the high dispersive state or promote the dispersion of reagglomerating particles.

The powder of core particles which have been rendered to assume a highly dispersive state in the manner described on the foregoing pages is sent to the coating chamber so that the surfaces of the particles are coated with the coat forming substance. The coating compartment is provided with the coating space including the coating start region.

The group of means for high dispersion treatment of particles is desirably coupled directly to the coating chamber. If necessary, they may be connected together by means of a hollow member and/or a pipe that are indispensable to transport. In this case, too, it is essential that the dispersity β in the coating start region be adjusted to one of the values within the ranges set forth hereinabove.

If the group of means for high dispersion treatment of particles is coupled to the coating chamber located separately, the powder of core particles suffices to be introduced into the coating chamber as it maintains the state of dispersion that has been achieved by said group of means for high dispersion treatment of particles. To this end, means for maintaining dispersion in a gaseous atmosphere (which is a device for maintaining the state of dispersion of the powder of core particles) and/or means for promoting dispersion in a gaseous atmosphere (which is a device for enhancing the state of dispersion) and/or means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles (which separates the powder portion of less highly dispersed core particles from the mixture of a gas and the particles in the powder of core particles, thereby selecting a mixture of a gas and the particles in a powder of highly dispersed core particles, the major part of which comprises particles in a single-particle state) may be provided between the group of means for high dispersion treatment of particles and the coating chamber.

The invention also contemplates that when used to prepare coated diamond or high-pressure phase boron nitride particles, the group of means for high dispersion treatment of particles may share one or more portions of the space with (1) the coating chamber, (2) the coating space or (3) the coating start region.

For example, the group of means for high dispersion treatment of particles may share its dispersing space with the coating chamber, or with the coating space having the coating start region, or with the coating start region.

The term "coating start region" as used herein refers to the region where the precursor of the coat forming substance that has been generated via the vapor phase and/or the precursor of the coat forming substance in a vapor-phase state contacts and/or impinges against the powder of highly dispersed core particles which has been transported in the state of dispersion that has one of the following values of dispersity β, whereupon coating of the individual particles is started: (1) at least 70% for a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume; (2) at least 80% for a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume; (3) at least 90% for a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume; (4) at least 95% for a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume; (5) at least 97% for a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume; and (6) at least 99% for a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume. Five typical embodiments of the coating start region are shown schematically in Figs. 4a - 4e.

In Figs. 4a - 4e, the coating start region is indicated by numeral 2.

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In the case shown in Fig. 4a, the coating start region 2 of the coating space in which the coating of core particles is started as they are dispersed to one of the above-listed values of dispersity β in accordance with the average diameter of those core particles is provided in such a way that it surrounds the group of means for high dispersion treatment of particles or its discharge section 1.

In the case shown in Fig. 4b, the coating start region 2 of said coating space is provided in such a way that it is passed by all the particles 4 in the powder of core particles as they are discharged from the group of means for high dispersion treatment or its discharge section 1.

By adopting these arrangements, the particles in all powders of core particles can start to be coated as they are dispersed to the above-listed values of dispersity β.

In the case shown in Fig. 4c, the coating start region 2 of said coating space is provided in such a way that it is passed in all cases by those particles 4 in the powder of core particles which are discharged from the group of means for high dispersion treatment of particles or its discharge section 1 to enter the recovery section 5.

In the case shown in Fig. 4d, the coating start region 2 of said coating space is provided in such a way that it surrounds the recovery section 5.

In the case shown in Fig. 4e, the recovery section 5 is provided in a position that can be reached solely by the particles in the mixture of a gas and the particles in the powder of highly dispersed core particles. Hence, the region indicated by 6 in Fig. 4e is selection means using gravity. The coating start region 2 of said coating space is provided in the hatched area of Fig. 4e so that it is passed in all cases by those particles in the mixture of a gas and the particles in the powder of highly dispersed core particles which enter the recovery section. This arrangement insures that only the core particles that started to be coated as they were dispersed to the above-listed values of dispersity β can be recovered and there is no chance that the core particles that did not pass through the coating start region will intermingle with the coated particles which emerge from the coating start region.

As one can understand from the foregoing description, the apparatus for implementing the present invention are composed of the group of means for high dispersion treatment of particles and the coating chamber or, alternatively, the group of means for high dispersion treatment of particles, the coating chamber and the recovery means. The constituent elements of the apparatus can be combined in various manners and several designs of these apparatus are described below with reference to drawings.

Apparatus Design 1

Fig. 5a is a block diagram showing the construction of a first apparatus for producing coated diamond or high-pressure phase boron nitride particles. As shown, the apparatus is composed of the main body of the production equipment 2-A (coating apparatus), coating chamber 2-B1, coating space 2-B2, coating start region 2-B3, the group of means for high dispersion treatment of particles 2-C1, and recovery means 2-D. The group of means for high dispersion treatment of particles 2-C1 is coupled directly to the coating chamber 2-B1.

Apparatus Design 2

Fig. 5b is a block diagram showing the construction of a second apparatus for producing coated diamond or high-pressure phase boron nitride particles. As shown, the apparatus is composed of the main body of the production equipment 2-A (coating apparatus), coating chamber 2-B1, coating space 2-B2, coating start region 2-B3, the group of means for high dispersion treatment of particles 2-C1, indispensable hollow member 2-C2, and recovery means 2-D. The group of means for high dispersion treatment of particles 2-C1 is connected to the coating chamber 2-B1 via the indispensable hollow member 2-C2.

Apparatus Design 3

Fig. 5c is a block diagram showing the construction of a third apparatus for producing coated diamond or high-pressure phase boron nitride particles. As shown, the apparatus is composed of the main body of the production equipment 2-A (coating apparatus), coating chamber 2-B1, coating space 2-B2, coating start region 2-B3, the group of means for high dispersion treatment of particles 2-C1, means for maintaining dispersion in gaseous atmosphere 2-C3, and recovery means 2-D. The group of means for high dispersion treatment of particles 2-C1 is connected to the coating chamber 2-B1 via the means for maintaining dispersion in gaseous atmosphere 2-C3.

Apparatus Design 4

Fig. 5d is a block diagram showing the construction of a fourth apparatus for producing coated diamond or high-pressure phase boron nitride particles. As shown, the apparatus is composed of the main body of the production equipment 2-A (coating apparatus), coating chamber 2-B1, coating space 2-B2, coating start region 2-B3, the group of means

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for high dispersion treatment of particles 2-C1, and recovery means 2-D. The group of means for high dispersion treatment of particles 2-C1 shares space with the coating chamber 2-B1.

Apparatus Design 5

Fig. 5e is a block diagram showing the construction of a fifth apparatus for producing coated diamond or high-pressure phase boron nitride particles. As shown, the apparatus is composed of the main body of the production equipment 2-A (coating apparatus), coating chamber 2-B1, coating space 2-B2, coating start region 2-B3, the group of means for high dispersion treatment of particles 2-C1, and recovery means 2-D. The group of means for high dispersion treatment of particles 2-C1 is provided within the coating chamber 2-B1.

Apparatus Design 6

Fig. 5f is a block diagram showing the construction of a sixth apparatus for producing coated diamond or high-pressure phase boron nitride particles. As shown, the apparatus is composed of the main body of the production equipment 2-A (coating apparatus), coating chamber 2-B1, coating space 2-B2, coating start region 2-B3, the group of means for high dispersion treatment of particles 2-C1, and recovery means 2-D. The coating chamber 2-B1 is provided within the dispersing space of the group of means for high dispersion treatment of particles 2-C1.

Apparatus Design 7

Fig. 5g is a block diagram showing the construction of a seventh apparatus for producing coated diamond or high-pressure phase boron nitride particles. As shown, the apparatus is composed of the main body of the production equipment 2-A (coating apparatus), coating chamber 2-B1, coating space 2-B2, coating start region 2-B3, the group of means for high dispersion treatment of particles 2-C1, recovery means 2-D, and recoating supply means 2-E. The coated particles issuing from the recovery means 2-D can be transported by the recoating supply means 2-E to the group of means for high dispersion treatment of particles 2-C1 for performing repeated coating treatments.

Either one of the apparatuses of these designs can produce coated diamond or high-pressure phase boron nitride particles.

The coated particles in which the powder of core particles (diamond or high-pressure phase boron nitride particles) has its surface coated with the coat forming substance may be coated again with the coat forming substance or subjected to repeated recoating operations. In these cases, the coated particles are sent to the recoating supply means. The term "recoating supply means" as used herein refers to means for transporting the coated particles to the group of means for high dispersion treatment of particles to perform recoating. Specifically, the recoating supply means is furnished with (a) means for recovering the coated particles and (b) means for transporting said coated particles from the recovery means (a) to the group of means for high dispersion treatment of particles. Alternatively, the recoating supply means is furnished with (a) means for recovering the coated particles, (b) means for transporting said coated particles from the recovery means (a) to the group of means for high dispersion treatment of particles, and (c) means for classifying the coated particles. Given large coating weights, the particle size distribution of the coated particles will vary from that of the particles in the powder of uncoated core particles. Under these conditions, it is effective to perform the recoating operation after the particle size distribution of the coated particles is adjusted by the classifying means (c).

The recoating operation may be repeated depending on the need and the coating weight of the coat forming substance can be set to a desired level. If necessary, the coating operation may be repeated with the type of the coat forming substance varied and, thus, a substance of more than one component can be coated in multiple layers as the coat forming substance.

The equipment for producing coated particles that is to be used in the present invention is in no way limited as long as it is capable of applying the coat forming substance over the surfaces of the particles in the powder of core particles by vapor-phase processes involving transition through the vapor phase. For example, chemical vapor deposition (CVD) equipment can be used, as exemplified by a thermal CVD apparatus, a plasma-assisted CVD apparatus, apparatus for CVD utilizing electromagnetic waves (i.e., visible light CVD, laser CVD, ultraviolet CVD, infrared CVD and far-infrared CVD) and a MOCVD apparatus. Alternatively, physical vapor deposition (PVD) equipment can be used, as exemplified by a vacuum evaporation apparatus, an ion sputtering apparatus and an ion plating apparatus. Stated more specifically, a suitable apparatus for producing coated particles is described in the official gazette of Unexamined Published Japanese Patent Application (kokai) Hei 3-75302, entitled "Particles Coated with Superfine Grains on the Surfaces and A Process for Producing Such Coated Particles".

As described on the foregoing pages, the process of the present invention for producing coated diamond or high-pressure phase boron nitride comprises the steps of charging into the coating space the particles in the powder of core particles which are diamond or high-pressure phase boron nitride particles and then permitting the precursor of the coat forming substance which is generated via the vapor phase and/or the precursor of the coat forming substance in a vapor-

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phase state to contact and/or impinge against the particles in said powder of core particles so that their surfaces are coated with the coat forming substance. Five basic processes for coating the core particles with the coat forming substance are summarized below.

I. A coating method comprising:

(A) a dispersing step in which the particles in the powder of core particles are dispersed in a gaseous atmosphere by the group of means for high dispersion treatment of particles so as to make a mixture of a gas and the particles in a powder of highly dispersed core particles; and
(B) a coating step in which the core particles in said gas-particle mixture, as they have been dispersed with the dispersity β adjusted to the values within the ranges set forth above, are allowed to contact and/or impinge against the coat forming substance in the coating start region of the coating space, thereby starting the coating operation.

II. A coating method comprising:

(A) a dispersing step in which the particles in the powder of core particles are dispersed in a gaseous atmosphere by the group of means for high dispersion treatment of particles which realize the adjustment of dispersity β to the values within the ranges set forth above, thereby making a mixture of a gas and the particles in a powder of highly dispersed core particles; and
(B) a coating step in which the core particles in said gas-particle mixture, as they have been dispersed with the dispersity β adjusted to the values within the ranges set forth above, are allowed to contact and/or impinge against the coat forming substance in the coating start region of the coating space, thereby starting the coating operation.

III. A coating method comprising:

(A) a dispersing step in which the particles in the powder of core particles are dispersed in a gaseous atmosphere by the group of means for high dispersion treatment of particles which realize the adjustment of dispersity β to the values within the ranges set forth above, thereby making a mixture of a gas and the particles in a powder of highly dispersed core particles;
(B) a transport step in which the highly dispersed core particles in said gas-particle mixture are transported directly to a subsequent coating step; and
(C) the coating step in which the transported core particles in said gas-particle mixture, as they have been dispersed with the dispersity β adjusted to the values within the ranges set forth above, are allowed to contact and/or impinge against the coat forming substance in the coating start region of the coating space, thereby starting the coating operation.

IV. A coating method comprising:

(A) a dispersing step in which the particles in the powder of core particles are dispersed in a gaseous atmosphere by the group of means for high dispersion treatment of particles which realize the adjustment of dispersity β to the values within the ranges set forth above, thereby making a mixture of a gas and the particles in a powder of highly dispersed core particles;
(B) a transport step in which the highly dispersed core particles in said gas-particle mixture are transported via at least one member indispensable to transport that is selected from the group consisting of a hollow member, an intermediate member composed of a member that forms a hollow portion, and a pipe; and
(C) a coating step in which the transported core particles in said gas-particle mixture, as they have been dispersed with the dispersity β adjusted to the values within the ranges set forth above, are allowed to contact and/or impinge against the coat forming substance in the coating start region of the coating space, thereby starting the coating operation.

V. A coating method comprising:

(A) a dispersing step in which the particles in the powder of core particles are dispersed in a gaseous atmosphere by the group of means for high dispersion treatment of particles which realize the adjustment of dispersity β to the values within the ranges set forth above, thereby making a mixture of a gas and the particles in a powder of highly dispersed core particles;
(B) a transport step in which the highly dispersed core particles in said gas-particle mixture are transported to a subsequent coating step via at least one means selected from the group consisting of means for maintaining the dispersion in a gaseous atmosphere of the highly dispersed core particles in said gas-particle mixture, means for

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enhancing the dispersion in a gaseous atmosphere of the highly dispersed core particles in said gas-particle mixture, and means for separating a mixture of a gas and the particles in a powder of less highly dispersed core particles from said gas-particle mixture so as to select a mixture of a gas and the particles in a powder of highly dispersed core particles in which the core particles are present in the gaseous atmosphere mainly in a single-particle state; and

(C) the coating step in which the transported particles in said mixture of a gas and the powder of highly dispersed core particles, as they have been dispersed with the dispersity β adjusted to the values within the ranges set forth above, are allowed to contact and/or impinge against the coat forming substance in the coating start region of the coating space, thereby starting the coating operation.

In each of the coating methods I - V, it is preferred that the coating start region of the coating space is located in either one of the following portions of the space region in which the dispersity β of the particles in the powder of highly dispersed core particles as mixed with a gas and which have been dispersed by the group of means for high dispersion treatment of particles is adjusted to the values within the ranges set forth above:

the space region that includes planes through which all particles in the powder of highly dispersed core particles as mixed with a gas will pass; or

the space region that includes planes through which all particles to be recovered into the recovery section of the recovery means will pass.

Alternatively, in each of the coating methods I and II, it is preferred that at least one part of the dispersing step, in which the particles in the powder of core particles are dispersed in a gaseous atmosphere by the group of means for high dispersion treatment of particles which realize the adjustment of dispersity β to the values within the ranges set forth above, thereby making a mixture of a gas and the particles in a powder of highly dispersed core particles, is performed sharing one or more parts of the space with at least one part of the coating step.

It should be noted here that the coated diamond or high-pressure phase boron nitride particles occasionally form lumps as a result of association of several particles that contact one another via the coat forming substance on the coated particles. Thus, the powder of the coated diamond or high-pressure phase boron nitride particles consists of coated particles in a single-particle state, lumps formed by the association of from several to several tens of such discrete coated particles as a result of contacting one another, and larger lumps formed by the association of more of such discrete coated particles as a result of contacting one another, and the shapes and sizes of the particles and lumps are nonuniform and irregular. The lumps which are the associations of the discrete coated particles are preferably disagglomerated and/or otherwise reduced in size before they are subjected to the shaping (molding) or sintering process. To disagglomerate and/or otherwise reduce in size the associating lumps of the coated diamond or high-pressure phase boron nitride particles, various disagglomerating means may be utilized, as exemplified by ball mills, vibrating ball mills, mortars and jet mills, etc. Alternatively, the discrete coated particles may be selectively separated from the associating lumps of such discrete coated particles, so that only the discrete coated particles can be subjected to the shaping or sintering process.

In accordance with the present invention, the thus coated diamond or high-pressure phase boron nitride particles or mixtures containing such particles are then sintered at pressures no less than 2000 MPa and at elevated temperatures, or at pressures of less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable.

Alternatively, the coated diamond or high-pressure phase boron nitride particles are mixed with a bonding material in volume ratios of (1 - 90):(99 - 10) that is sintrable to a density of at least 85% at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable, and the mixture is then sintered at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable.

If an auxiliary agent, or a substance that develops another function, is to be added, the substance may be in a powder, plate or particulate form. More specifically, the substance may be selected from among powders and/or particles, etc. that are composed of at least one member selected from the group consisting of metals, semiconductors, metalloids, and rare earth metals of groups 1a, 2a, 3a, 4a, 5a, 6a, 7a, 1b, 2b, 3b, 4b, 5b, 6b, 7b and 8 of the periodic table, as well as oxides, nitrides, carbides, oxynitrides, oxycarbides, carbonitrides, oxycarbonitrides, borides and silicides of these elements, as exemplified below:

Al, B, Si, Fe, Ni, Co, Ti, Nb, V, Zr, Hf, Ta, W, Re, Cr, Cu, Mo, TiAl, Ti_3Al, $TiAl_3$, TiNi, NiAl, Ni_3Al, SiC, B_4C, Cr_3C_2, TiC, ZrC, WC, W_2C, HfC, TaC, Ta_2C, NbC, VC, Mo_2C, Si_3N_4, TiN, ZrN, Si_2N_2O, AlN, HfN, VxN (x = 1 ~ 3), NbN, TaN, Ta_2N, TiB, TiB_2, ZrB_2, VB, V_3B_2, VB_2, NbB, NbB_2, TaB, TaB_2, MoB, MoB_2, MoB_4, Mo_2B, WB, W_2B, W_2B5, LaB_6, BP, $B_{13}P_2$, $MoSi_2$, Al_2O_3, ZrO_2 (PSZ: partially stabilized zirconia with the addition of Y_2O_3, MgO or CaO; or TZP: tetragonal zirconia polycrystalline compound), $MgAl_2O_4$ (spinel) and Al_2SiO_5 (mullite).

The auxiliary agent may be a fibrous substance. The fibrous substance to be mixed with the coated diamond or high-pressure phase boron nitride particles is composed of at least one of elemental metals and compounds and has such a morphology that the width is no more than 500 μm, with the length to width ratio being at least 2. The fibrous

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substance comprises bar- or rod-like substances having widths of no more than 500 μm, with the length to width ratio being at least 2, and/or filaments which are continuous fibers formed by melt spinning and/or short fibers produced by crystals themselves to give shape and/or whiskers produced by unidirectional crystal growth into a fibrous form. The whiskers comprise intrinsic whiskers which, according to the definition, are formed without experiencing any phase transition or any phenomenon such as chemical reactions that affect the overall volume and/or whiskers in the broad sense of the term which refer to single crystals that are formed as long needles by the growth of only one crystal face of the crystal that is created by a phase transition or a chemical change that affects the overall volume and/or other whiskers that are single crystals having cross-sectional areas of no more than 8×10^{-5} in^2, with the length being at least 10 times the average diameter.

The fibrous substance to be used may be those which contain at least one compound containing at least one member of the group consisting of metals, semiconductors, metalloids, rare earth metals and nonmetals of groups 1a, 2a, 3a, 4a, 5a, 6a, 7a, 1b, 2b, 3b, 4b, 5b, 6b, 7b and 8 of the periodic table and which have widths of no more than 500 μm, with the length to width ratio being at least 2. More specifically, the fibrous substances to be used are those which are composed of at least one member selected from the group consisting of metals, semiconductors, metalloids, and rare earth metals of groups 1a, 2a, 3a, 4a, 5a, 6a, 7a, 1b, 2b, 3b, 4b and 8 of the periodic table, as well as oxides, nitrides, carbides, oxynitrides, oxycarbides, carbonitrides, oxycarbonitrides, borides and silicides and which have widths of no more than 500 μm, with the length to width ratio being at least 2. Preferably, the following fibrous substances may be selected: those which are composed of at least member one selected from the group consisting of Al, B, Si, Fe, Ni, Co, Ti, Nb, V, Zr, Hf, Ta, W, Re, Cr, Cu, Mo, TiAl, Ti_3Al, $TiAl_3$, TiNi, NiAl, Ni_3Al, SiC, B_4C, Cr_3C_2, TiC, ZrC, WC, W_2C, HfC, TaC, Ta_2C, NbC, VC, Mo_2C, Si_3N_4, TiN, ZrN, Si_2N_2O, AlN, HfN, VxN ($x = 1 \sim 3$), NbN, TaN, Ta_2N, TiB, TiB_2, ZrB_2, VB, V_3B_2, VB_2, NbB, NbB_2, TaB, TaB_2, MoB, MoB_2, MoB_4, Mo_2B, WB, W_2B, W_2B5, LaB_6, BP, $B_{13}P_2$, $MoSi_2$, Al_2O_3, ZrO_2 (PSZ: partially stabilized zirconia with the addition of Y_2O_3, MgO or CaO; or TZP: tetragonal zirconia polycrystalline compound), $MgAl_2O_4$ (spinel), Al_2SiO_5 (mullite), etc., and which have widths of no more than 500 μm, with the length to width ratio being at least 2.

As described above, the coated diamond or high-pressure phase boron nitride particles to be used in the present invention have their surfaces coated with the coat forming substance by vapor-phase processes and, hence, the coat forming substance that can be used is basically unlimited. While materials design of diamond or high-pressure phase boron nitride sinters can be made in any suitable manners depending on their use, the coating of diamond or high-pressure phase boron nitride particles with the coat forming substance may be preceded by preliminary coating of the surfaces of those surfaces with a similar and/or dissimilar coat forming substance by a similar and/or dissimilar coating technique.

Take, for example, the case where the surfaces of diamond or high-pressure phase boron nitride particles are to be eventually provided with coats formed of a desired metal carbide; in this case, those particles may be preliminarily coated with carbon. While the preliminary coating technique is not limited in any particular way, suitable examples include not only the molten salt dip method which is described in Unexamined Published Japanese Patent Application (kokai) Hei 2-252660 and the molten salt disproportionation method which is described in Unexamined Published Japanese Patent Application (kokai) Hei 1-207380 but also electroplating, electroless plating, cladding, physical vapor deposition processes (e.g., sputtering and ion plating) and chemical vapor deposition processes. The metals in the metal components to be eventually coated are not limited to any particular types as long as they are within the class of substances that can be applied as bonding materials and/or sintering aids for the purpose of the invention.

The coating films formed by the molten salt dip method are composed of dense substances having high hardness and melting point and, having typically the capability of isolating diamond or high-pressure phase boron nitride particles from other substances, these films offer the advantage of markedly increasing the latitude in the choice of binders. The diamond or high-pressure phase boron nitride particles provided with coating films by the molten salt dip method are difficult to sinter densely by the conventional process for producing diamond or high-pressure phase boron nitride sinters at pressures less than 2000 MPa under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable. However, if diamond or high-pressure phase boron nitride particles that are coated with the films of high-hardness and high-melting substances which have been formed by the molten salt dip method are coated by the vapor-phase coating techniques of the invention with one or more layers in suitable amounts of substances that can be applied as bonding materials that are sintrable to assure satisfactory density and high hardness, favorable results are attained that are advantageous for the purpose of promoting sintering.

In accordance with the present invention, coated diamond or high-pressure phase boron nitride particles which have the coat forming substance applied to the surfaces of bare diamond or high-pressure phase boron nitride particles by vapor-phase processes may be mixed with a bonding material or, alternatively, the mixture of the coated diamond or high-pressure phase boron nitride particles and the bonding material may be mixed with the aforementioned auxiliary substance in a powder, plate or particulate form and/or the fibrous substance also mentioned above which has a width of no more than 500 μm, with the length to width ratio being at least 2, and either mixture may be sintered in a powder form or after being shaped into a compact.

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Diamond or high-pressure phase boron nitride is thermodynamically stable only at ultrahigh pressures and if the pressure is inadequate under elevated temperatures, they will experience a phase transition to the lower-pressure phase (graphite or hexagonal boron nitride (hBN)).

Therefore, in order to prevent the phase transition of diamond or high-pressure phase boron nitride to the lower-pressure phase (graphite or hBN) and to insure sintering to high density, the sinters containing diamond or high-pressure phase boron nitride are produced at ultrahigh pressures exceeding 2000 MPa and at elevated temperatures under such conditions that diamond or high-pressure phase boron nitride is thermodynamically stable.

Therefore, if one selects those sintering pressure and temperature conditions where the pressure is at least 2000 MPa and where diamond or high-pressure phase boron nitride is thermodynamically stable, the temperature is limited by pressure in accordance with the thermodynamic equilibrium line in the phase diagram of diamond or high-pressure phase boron nitride. However, if one selects those sintering pressure and temperature conditions where the pressure is at least 2000 MPa and where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, temperatures will suffice if they deviate slightly from the region that is limited by pressure in accordance with the thermodynamic equilibrium line in the phase diagram of diamond or high-pressure phase boron nitride.

On the other hand, if one selects those sintering pressure and temperature conditions where the pressure is less than 2000 MPa and where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, one should note that there is a pressure-dependent temperature in the region where diamond or high-pressure phase boron nitride is thermodynamically metastable.

Stated more specifically, in the case of selecting those sintering pressure and temperature conditions where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, the upper limit of the sintering temperature will vary with the quality of the diamond or high-pressure phase boron nitride particles to be sintered.

Take, for example, the case of diamonds; Hall conducted an experiment under ultrahigh pressures and reported that when a diamond was thermodynamically metastable if not stable, it took such a long time for a phase transition to occur that it remained stable for practical purposes; he then indicated the temperature 1100°C as the upper limit beyond which the diamond would no longer exist in a practically stable manner (see H.T. Hall, Science, 169 (1970) 868-869, as well as Fig. 15a). Speaking of high-pressure phase boron nitrides, Wakatsuki et al. conducted an experiment on a cubic boron nitride under ultrahigh pressures and reported that when the cubic boron nitride was thermodynamically metastable if not stable, it took such a long time for a phase transition to occur that it remained stable for practical purposes; they then indicated the temperature 1200°C as the upper limit beyond which the cubic boron nitride would no longer exist in a practically stable manner (see Wakatsuki, Ichise, Aoki and Maeda, Abstracts of the Lectures Read at the 14th Symposium on High-Pressure Technology (1972) p. 78, as well as Fig. 33b).

Therefore, if high-purity diamonds (e.g. natural products of high quality synthetic diamonds produced via the vapor phase by means of PVD or CVD processes, or diamonds synthesized by application of ultrahigh pressures over a long time) are especially selected and if they are sintered either by HIP, optionally under ultrahigh pressures, as they are confined within a degassed, pressure-transmitting capsule or by PC or HP under vacuum or in an inert gas, diamonds will actually exist up to 1850°C which is much higher than 1100°C, or the temperature reported by Hall, even if they are not in a thermodynamically stable state. However, if the temperature exceeds 1850°C, the diamonds will turn to the graphite phase in a short time. Generally speaking, synthesis catalysts or the like will sometimes remain as impurities in synthetic diamonds. However, if synthetic diamonds are such that impurities have been removed positively to achieve high purity, the diamond will exist up to 1700°C by application of similar sintering techniques and this is the same as in the case of natural diamonds. Alternatively, with known diamonds that do not contain fine grains smaller than 1 μm, preferably those which are at least 3 μm and whose size is within the class contemplated by the present invention, the diamond will exist up to 1600°C irrespective of whether they are natural or synthetic products. It should also be noted that in the case of known diamonds of comparatively high purity, both natural and synthetic products will exist up to 1500°C. However, with commonly known types of synthetic diamonds, the suitable temperature is up to 1400°C. Therefore, the upper limit of sintering temperatures is 1850°C.

Speaking of high-pressure phase boron nitrides, if those of high purity (e.g. cubic boron nitrides of ultrahigh purity that are produced via the vapor phase by means of PVD or CVD processes, or cubic boron nitrides of ultrahigh purity that are synthesized by application of ultrahigh pressures over a long time) are especially selected and if they are sintered either by HIP (hot isostatic pressing), optionally under ultrahigh pressures, as they are confined within a degassed, pressure-transmitting capsule or by PC (piston-cylinder) or HP (hot pressing) under vacuum or in an inert gas, cubic boron nitrides will actually exist up to 1850°C which is much higher than 1200°C, or the temperature reported by Wakatsuki et al., even if they are not in a thermodynamically stable state. However, if the temperature exceeds 1850°C, the cubic boron nitrides will turn to a graphitic phase in a short time. If conventionally known cubic boron nitrides are used after impurities have been removed positively to achieve high purity, the cubic boron nitride will exist up to 1700°C by application of similar sintering techniques. Alternatively, with known cubic boron nitrides that do not contain fine grains, preferably those which are at least 3 μm in size, the cubic boron nitride will exist up to 1600°C by application of similar sintering techniques. It should also be noted that in the case of known cubic boron nitrides of comparatively high purity, the cubic boron nitride will exist up to 1500°C by application of similar sintering techniques. However, in the case where

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commonly known types of cubic boron nitrides or wurtzitic boron nitrides are contained, the suitable temperature is up to 1400°C.

Consequently, if one selects those sintering pressure and temperature conditions where the pressure is less than 2000 MPa and where diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, the upper limit of sintering temperatures is 1850°C. It should be remembered that the temperature at which the diamond or high-pressure phase boron nitride is not in a thermodynamically stable state but exists stably for practical purposes varies with the quality of the diamond or high-pressure phase boron nitride to be used and that, therefore, the sintering temperature must be set in accordance with the quality of the feed of diamond or high-pressure phase boron nitride. If it is necessary that the sintering temperature be set to a value that is close to the right temperature which matches the quality of the feed of diamond or high-pressure phase boron nitride, said sintering temperature must be controlled with close tolerance.

The diamond or high-pressure phase boron nitride sinters of the present invention are produced by sintering processes that adopt two kinds of conditions with different pressures. To produce diamond or high-pressure phase boron nitride sinters by performing sintering for a suitable period of time at ultrahigh pressures of 2000 MPa or above and at elevated temperatures, any conventional equipment that produces ultrahigh pressures can be applied without particular limitations, as exemplified by the cubic, tetragonal, girdle, and belt type ultrahigh pressure apparatus.

Known apparatus and methods may be applied without any particular limitations to produce dynamic ultrahigh pressures (≧ 2000 MPa) and elevated temperatures and they include: an explosive charge lens (planar explosion generator)_, a cylindrical explosion generator, a method involving collision with a flying object, a magnetic implosion method, a Mach explosion method, an excessive explosion method, a conical implosion method, a single-action shock gun, a double-action light gas gun, etc. According to these apparatus and methods which generate dynamic ultrahigh pressures and elevated temperatures, the pressure that can be produced is at least 10 GPa (10,000 MPa), preferably at least 40 GPa and, therefore, they can be selected as preferred examples in cases where particularly high pressures need be exerted for short periods of time.

Depending on the object, for example, in the case where samples need be pressurized while giving results with good reproducibility, the above-mentioned cubic apparatus and various other types of equipment that are capable of generating ultrahigh temperatures in a static manner may be used to produce pressures of 2000 MPa and above. The sintering temperature condition may deviate slightly from the region where diamond or high-pressure phase boron nitride is thermodynamically stable.

But, more preferably, one may select those sintering pressure and temperature conditions where the pressure is at least 2000 MPa and where diamond or high-pressure phase boron nitride is thermodynamically stable.

To produce diamond or high-pressure phase boron nitride sinters by performing sintering for a suitable period of time at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, any conventional equipment can be applied without particular limitations, as exemplified by PC (piston-cylinder) type ultrahigh pressure apparatus, ultrahigh pressure HIP (hot isostatic pressing) apparatus, HIP apparatus and HP (hot pressing) apparatus.

If the PC type ultrahigh pressure apparatus is to be used, pressures less than 2000 MPa may be applied but, considering the durability of this apparatus, the pressure does not preferably exceed 1500 MPa. Conventionally known technologies concerning the production of pressures include ultrahigh pressure HIP apparatus which is capable of operating at HIP pressures up to 1000 MPa, as well as HIP apparatus (excluding the ultrahigh pressure HIP apparatus) and HP apparatus which are each capable of operating at pressures up to 200 MPa.

The diamond or high-pressure phase boron nitride sinters produced by the methods described above have high performance with highly controlled microstructures. While their most common use is as machine parts, it is possible to manufacture diamond or high-pressure phase boron nitride sinters that are superhard, with the Vickers hardness (Hv) being preferably at least 600, and which are dense, with the density being at least 85%. Preferably, it is possible to manufacture diamond or high-pressure phase boron nitride sinters that are superhard, with the Vickers hardness (Hv) being preferably at least 800, and/or which are dense, with the density being at least 90%. More preferably, considering the application to highly wear-resistant machine parts, superhard (Hv ≧ 1000) diamond or high-pressure phase boron nitride sinters can be manufactured by both increasing the relative content of diamond or high-pressure phase boron nitride and sintering to high density. For use in tools and other applications that require even higher levels of wear resistance, diamond or high-pressure phase boron nitride sinters having Vickers hardness values of at least 2000 can be manufactured by further increasing the content of diamond or high-pressure phase boron nitride while sintering to high density.

In a typical case, a diamond sinter may be produced from a diamond powder feed in the following manner using a cubic apparatus to produce ultrahigh pressures. First, the particles in the diamond powder are coated with a suitable coat forming substance on the surfaces. The coated diamond particles are then shaped into a pellet by stamping. The pellet is surrounded by a shaped hexagonal boron nitride (h-BN) part which, in turn, is enclosed with a graphite tubular heater. Provided around the heater as a solid pressure transmitting medium is pyrophyllite from which the water of

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crystallization has been removed by heat treatment at 700°C. The sample thus prepared is placed in the cubic apparatus; the pressure is increased to a predetermined level and, then, the temperature is also elevated to a predetermined level and sintering is effected for a suitable time. Thereafter, the temperature is lowered and the pressure is also reduced. The pressure-transmitting medium is taken out of the cubic ultrahigh pressure apparatus and the sample is then recovered from the medium. In this way, one can produce a diamond sinter of high performance that is composed of diamond and which is characteristic in that it has a controlled distribution of the bonding material and/or sintering aid and/or surface modifier, that is uniform and dense, and that it has a highly controlled microstructure.

As described in detail on the foregoing pages, a powder of fine diamond or high-pressure phase boron nitride core particles having an average diameter of no more than 10 μm in terms of frequency distribution by volume was dispersed in a gaseous atmosphere and the core particles thus dispersed to a dispersity β of at least 70% were allowed to contact or impinge against a precursor of a coat forming substance, whereby the core particles were covered on their surfaces with the coat forming substance in a single-particle state. In accordance with the invent ion, the thus coated core particles or mixtures containing them were sintered at ultrahigh atmospheres of at least 2000 MPa and at elevated temperatures, whereby coated diamond or high-pressure phase boron nitride sinters of high performance were produced that had uniform, dense, firmly sintered and highly controlled microstructures.

According to another aspect of the invention, said core particles or mixtures containing them or mixtures of said core particles with bonding materials are sintered at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable, whereby one can produce coated diamond or high-pressure phase boron nitride sinters of high performance that have uniform, dense, firmly sintered and highly controlled microstructures. This offers the advantage of eliminating the constraint of the need to use equipment capable of creating ultrahigh pressures of at least 2000 MPa. It should be particularly noted that the use of ultrahigh pressure HIP apparatus or other types of HIP apparatus offers the added advantage of enabling the production of complexly shaped sinters, thereby presenting significant benefits to manufacture on an industrial scale.

According to yet another aspect of the invention, even pseudo-fine diamond or high-pressure phase boron nitride particles having an average diameter greater than 10 μm in terms of frequency distribution by volume may be covered with coat forming substances after being dispersed to a dispersity as determined by their average diameter. By sintering the thus coated pseudo-fine particles, one can produce sinters that are substantially free from graphite or a graphitic phase and which have the same features as fine-particulate sinters having an average particle diameter of no more than 10 μm.

EXAMPLES

The diamond or high-pressure phase boron nitride sinters of the present invention, as well as the processes for their production are described below with reference to examples.

Example 1

Diamond particles having an average diameter (D_M) of 1 μm and a frequency distribution by volume of ([D_M/2, 3D_M/2], ≧ 90%) were coated with elemental silicon.

The construction of the apparatus used is shown in Fig. 6 and Fig. 7 which is a partial enlarged view of Fig. 6; the apparatus is a specific example of the design shown in Fig. 5a.

As shown, the apparatus comprises: a plasma torch 3-A including a plasma chamber 3-a, a vessel 3-B for cooling a coat forming substance precursor generating chamber 3-b, a coating chamber cooling vessel 3-C in the narrow sense of the term, a coating chamber 3-c in the narrow sense of the term, a vessel 3-D for cooling a coated particle cooling chamber 3-d, a supply unit 3-E1 on the side where the feed of the coat forming substance is supplied, an agitating disperser 3-F1 and an ejector-type disperser 3-H1 which are on the side where a powder of core particles is supplied, a capillary disperser 107, and a coated particle recovery section 3-G. The supply unit 3-E1 is coupled to a feeder 112 equipped with a vessel for supplying the feed powder of the coat forming substance, and the agitating disperser 3-F1 is coupled to a feeder 111 equipped with a vessel for supplying the powder of core particles. According to the definition, the coating chamber used in Example 1 is composed of the plasma chamber 3-a, the coat forming substance precursor generating chamber 3-b, the coating chamber 3-c in the narrow sense of the term, and the coated particle cooling chamber 3-d. These make up the coating chamber in the broad sense of the term and the chamber 3-c where most part of the coating operation is performed is referred to as the "coating chamber in the narrow sense of the term".

The group of means for high dispersion treatment of particles α used in Example 1 is composed of the feeder 111 equipped with a supply vessel, agitating disperser 3-F1, ejector-type disperser 3-H1, and the capillary disperser 107 which is made of a stainless steel pipe having an inside diameter of 4 mm. The basic concept of the group is shown in Fig. 2a and it is a specific example of the group of means for high dispersion treatment of particles that is of the design shown in Fig. 3b. The group is designed in such a way that it can realize an output value β of at least 70% (β ≧ 70%)

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given the particles in a powder of diamond core particles that are characterized by ($[D_M/5, 5D_M]$, ≧ 90%) where D_M = 1 μm. The capillary disperser 107 which is the final means of treatment in the group of means for high dispersion treatment of particles is coupled directly to the coating chamber 3-c and designed in such a way as to realize β ≧ 70% in the coating start region 3-L1 of the coating space 3-L2.

A gas jet port 101 is provided on top of the plasma torch 3-A and an argon gas is supplied from a supply source 102 through this port at a rate of 20 L/min. The supplied argon gas is turned into a plasma by applied high-frequency waves, thereby forming a plasma flame in the plasma chamber 3-a within the plasma torch 3-A.

A silicon powder comprising particles with an average diameter of 10 μm serves as the feed of the coat forming substance and is supplied from the feeder 112 equipped with a vessel for supplying the feed powder of the coat forming substance. The supplied silicon powder is carried by a carrier gas 103 flowing at a rate of 5 L/min so that it is introduced into the plasma flame at a rate of 0.2 g/min via an inlet 104 provided at the bottom of the plasma torch 3-A. Being evaporated by the heat of the plasma flame, the silicon powder goes through the vapor phase to become the precursor of the coat forming substance in the precursor generating chamber 3-b.

The diamond core particles with an average diameter of 1 μm are supplied at a rate of 1.2 g/min from the feeder 111 equipped with a supply vessel of the core particles and they are dispersed with the agitating disperser 3-F1 while being carried by a carrier gas 105 that is supplied at a rate of 5 L/min. The particles are then dispersed to a dispersity (β) of 82% by means of the ejector-type disperser 3-H1 and the capillary disperser 107 with the aid of a dispersing gas 106 that is supplied at a flow rate of 10 L/min. The thusly dispersed core particles are introduced into the coating chamber.

The highly dispersed diamond particles entering the coating start region 3-L1 of the coating space 3-L2 start to contact and/or impinge against the precursor of the coat forming substance as they maintain the dispersity β at 82%.

Thus, the diamond particles are given the coat of the coat forming substance on their surfaces and they descend down the coated particle cooling chamber 3-d together with the gas, eventually reaching the recovery section 3-G. The product comprising the coated particles is separated from the gas 109 by means of a filter 110 and collected for recovery.

The recovered fine diamond particles having silicon coats on the surfaces were examined with a scanning electron microscope. As Fig. 8 shows, all of these particles were uniformly coated with superfine silicon particles of about 0.005 μm in size. The silicon coating weight was 20% by volume.

The resulting powder of diamond particles coated with 20 vol% silicon was stamped into a pellet having an outside diameter of 6 mm and a height of 2 mm. The pellet was buried in a pressure-transmitting medium surrounded by a shaped hexagonal boron nitride (h-BN) and it was vacuum-dried overnight at 200°C and at 10^{-3} torr to remove low-boiling impurities. The pellet was then set in a cubic ultrahigh pressure apparatus: the pressure was raised to 5.5 GPa at room temperature, then the temperature was elevated to 1450°C, which was held for 30 min; thereafter, the temperature was lowered and the pressure reduced.

The resulting sinter was examined by X-ray diffractiometry; the elemental silicon reacted with the diamond to change to both diamond and SiC while the elemental silicon disappeared. Quantification by X-ray analysis showed that the volume proportions of the diamond sinter and SiC were about 78% and 22%, respectively.

The surface of the sinter was polished with a diamond paste and its Vickers microhardness (Hv) was measured. The diamond sinter synthesized in Example 1 was superhard with the Hv (0.5/10) being about 12,000 and this value was comparable to or higher than that of a commercial cutting tool made of sintered diamond. Furthermore, the hardness of the sinter of Example 1 was uniform over the entire surface subjected to the hardness measurement and it was substantially free from variations.

The polished surface of the sinter resulting of the example 1 was coated with a gold film by a customary evaporation technique and examined with an electron microscope. The result is shown in the Fig. 9 electron micrograph (X5000), from which one can see that the sinter had a relative density of at least 99%. In addition, the sinter had no portion left unsintered. In areas where diamond particles contacted each other via a thin layer of the coat forming substance, the latter was bursted by the contiguous diamond particles, which hence were coupled directly as a result of sintering. In all other areas, SiC was distributed to surround the diamond particles, rendering the sinter to be characteristic in that it was dense, uniform and had the bonding material distributed provide a highly controlled microstructure. It should also be noted that the diamond particles in the sinter did not grow at all compared to the particles in the feed powder and that the coating on the diamond was formed by chemical reaction between the diamond and the elemental silicon which served as the coat forming substance; these facts combined together to offer the characteristic feature that the diamond particles in the sinter were finer than those in the feed although they were coated with silicon. This is very favorable and, hence, ideal for the mechanical characteristics of the sinter. The differences can be clearly seen by comparing Fig. 9 with Fig. 10 which is an electron micrograph (X5000) of a polished surface of the above-mentioned commercial cutting tool that was made of sintered diamond and which was coated with a gold film by a customary evaporation technique for examination. Obviously, the bonding material and the sintering aid were distributed irregularly in the diamond sinter of the commercial cutting tool to form lumps in certain areas. On the other hand, the number of areas that were devoid of the necessary sintering aid and bonding material was by no means small and unsintered portions were found there. Another major difference from the sinter of Example 1 was that every diamond particle in the cutting tool was coarse.

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Diamond is the most difficult to sinter of all substances that exist on the earth. In spite of this fact, the coated particles in a diamond powder that were synthesized in Example 1 in accordance with the invention behaved as if they were comparatively easy-to-sinter particles under industrially feasible ultrahigh pressures and elevated temperatures, thereby forming a dense, rigid and superhard structure.

Example 2

Cubic boron nitride particles having an average diameter (D_M) of 1 μm and a frequency distribution by volume of ($[D_M/2, 3D_M/2]$, ≧ 90%) were coated with alumina.

The construction of the apparatus used is shown in Fig. 11 and Fig. 12 which is a partial enlarged view of Fig. 11; the apparatus is a specific example of the design shown in Fig. 5d.

As shown, the apparatus comprises: a plasma torch 5-A including a plasma chamber 5-a, a vessel 5-B for cooling a coat forming substance precursor generating chamber 5-b, a coating chamber cooling vessel 5-C in the narrow sense of the term, a coating chamber 5-c in the narrow sense of the term, a vessel 5-D for cooling a coated particle cooling chamber 5-d, a supply unit 5-E1 on the side where the feed of the coat forming substance is supplied, an agitating disperser 5-F1 which is on the side where a powder of core particles is supplied, a capillary disperser 211 and a disperser 5-H2 that utilizes an impingement plate, and a coated particle recovery section 5-G. That part of this apparatus which was to generate the precursor of the coat forming substance was of the same design as in Example 1. The group of means for high dispersion treatment of particles α was composed of a feeder 214 equipped with a supply vessel, the agitating disperser 5-F1, the capillary disperser 211, and the disperser 5-H2 that utilizes an impingement plate. The basic concept of the group α is shown in Fig. 2a and it is a specific example of the group of means for high dispersion treatment of particles that is of the design shown in Fig. 3b. The capillary disperser 211 is made of a stainless steel pipe having an inside diameter of 4 mm. The disperser 5-H2 is the final means of treatment in the group of means for high dispersion treatment of particles α and it consists of a SiC impingement plate 213 supported by a stainless steel holder 212. The disperser 5-H2 is contained in the coating chamber 5-c in the narrow sense of the term, which shares the space with the group of means for high dispersion treatment of particles α. A coating space 5-L1 and the coating start region 5-L2 of the coating space are also contained in the coating chamber 5-c in the narrow sense of the term. The group of means α in the apparatus of Example 2 has such performance that the particles in a powder of core particles having an average diameter (D_M) of 1 μm and a frequency distribution by volume of ($[D_M/5, 5D_M]$, ≧ 90%) can be dispersed to a dispersity (β) of at least 70% (β ≧ 70%) right after impingement against the plate 213 in the disperser 5-H2 at the last stage of dispersion treatment. Therefore, coating of the core particles starts with the dispersity β held at 70% and above.

A gas jet port 201 is provided on top of the plasma torch 5-A and an argon gas is supplied from a supply source 202 through this port at a rate of 20 L/min. The supplied argon gas is turned into a plasma by applied high-frequency waves, thereby forming a plasma flame in a plasma chamber 5-a within the plasma torch 5-A.

An alumina powder comprising particles with an average diameter of 2 μm serves as the feed of the coat forming substance and is supplied at a rate of 1.0 g/min from a feeder 215 equipped with a vessel for supplying the feed powder of the coat forming substance. The supplied alumina powder is carried by a carrier gas 203 flowing at a rate of 5 L/min so that it is introduced into the plasma flame via an inlet 204 of the feed of the coat forming substance provided at the bottom of the plasma torch 5-A. Being evaporated by the heat of the plasma flame, the alumina powder goes through the vapor phase to become the precursor of the coat forming substance in a coat forming substance precursor generating chamber 5-b.

The core particles of cubic boron nitride are supplied at a rate of 0.7 g/min from the feeder 214 equipped with a vessel for supplying the powder of core particles and they are dispersed with the agitating disperser 5-F1 while being carried by a carrier gas 205 that is supplied at a rate of 20 L/min. The particles then pass through the capillary disperser 211 to enter the disperser 5-H2 with the impingement plate in the coating chamber, in which they are dispersed in a gaseous atmosphere to a dispersity (β) of 82%.

The highly dispersed core particles of cubic boron nitride, entering the coating start region 5-L1 of the coating space 5-L2 start to contact and/or impinge against the precursor of the coat forming substance as they maintain the dispersity β of 82%.

Thus, the cubic boron nitride particles are given the coat of the coat forming substance on their surfaces and they descend down a coated particle cooling chamber 5-d together with the gas, eventually reaching a coated particle recovery section 5-G. The product comprising the coated cubic boron nitride particles is separated from the gas 209 by means of a filter 210 and collected for recovery. The recovered cubic boron nitride particles had alumina coats in an amount of 50% by volume.

The recovered fine cubic boron nitride particles having alumina coats on their surfaces were examined with a scanning electron microscope. All of those particles were uniformly coated with superfine alumina particles of about 0.005 μm in size.

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The resulting cubic boron nitride particles with 50 vol% alumina were stamped into a pellet having a diameter of 8 mm and a thickness of 5 mm. The pellet was put into a Pyrex glass capsule of generally the same design as in Example 1 and sealed after degassing by heating.

Thereafter, the encapsulated pellet was set in a ultrahigh pressure HIP apparatus and sintered by holding at a temperature of 1200°C and at a pressure of 1000 MPa for 3 h.

The sinter of Example 2 was checked for its crystalline phase by powder X-ray diffraction and no diffraction peaks were observed except for the cubic boron nitride and α-form alumina.

AS Table 4 shows, the sinter was considerably dense, with a density of 95.8%, and at the same time it was superhard, with the Vickers microhardness being Hv (0.5/10) = 3750.

It should also be mentioned that the cubic boron nitride particles in the sinter were surrounded by alumina to provide a uniform distribution and a highly controlled microstructure.

Example 3

Quasi-fine diamond particles having an average diameter (DM) of 17 μm and a frequency distribution by volume of ([DM/2, 3DM/2], ≧ 90%) were coated with metallic zirconium.

The construction of the apparatus used is shown in Fig. 13 and Fig. 14 which is a partial enlarged view of Fig. 13; the apparatus is a specific example of the design shown in Fig. 5b.

As shown, the apparatus comprises: a plasma torch 6-A including a plasma chamber 6-a, a vessel 6-B for cooling a coat forming substance precursor generating chamber 6-b, a coating chamber cooling vessel 6-C in the narrow sense of the term, a coating chamber 6-c in the narrow sense of the term, a vessel 6-D for cooling a coated particle cooling chamber 6-d, a supply unit 6-E1 on the side where the feed of the coat forming substance is supplied, an agitating disperser 6-F1, a cyclone 6-I, a hopper 6-J and a rotary value 6-K which are on the side where a powder of core particles is supplied, a pipe 307 inevitable to transport, and a coated particle recovery section 6-G. That part of this apparatus which was to generate the precursor of the coat forming substance was of the same design as in Example 1. The group of means for high dispersion treatment of particles α was composed of a feeder 313 equipped with a supply vessel, the agitating disperse 6-F1 which is dispersing means, and the cyclone 6-I which is means for selecting a mixture of a gas and the particles in a powder of highly dispersed core particles. The basic concept of the group α is shown in the Fig. 2b block diagram. The section of cyclone 6-I discharging the mixture of a gas and the particles in a powder of highly dispersed core particles is connected to the coating chamber 6-c in the narrow sense of the term by means of the pipe 307 inevitable to transport, whereas the section of cyclone 6-I discharging the powder portion consisting of less highly dispersed core particles is connected to the agitating disperser 6-F1 by means of a transport pipe 310 via the hopper 6-J and the rotary valve 6-K. Using the group of means α in the apparatus of Example 3, the particles in a powder of core particles having an average (DM) of 17 μm and a frequency distribution by volume of ([DM/5, 5DM], ≧ 90%) can be dispersed to a dispersity (β) of at least 85% in the section of cyclone 6-I (i.e., the means of final treatment) discharging the powder stream of highly dispersed particles. As shown, the coating space 6-L2 and the coating start region 6-L1 of this coating space are contained in the coating chamber 6-c in the narrow sense of the term. Because of the constraint by the flange portion coupling a coating chamber cooling vessel 6-C in the narrow sense of the term with the vessel 6-D for cooling the coated particle cooling chamber 6-d, the pipe 307 was indispensable to transport, but the resulting drop in dispersity β could be held at a reduced level. Hence, coating of the core particles starts with the dispersity β held at 80% and above in the coating start region.

A gas jet port 301 is provided on top of the plasma torch 6-A and an argon gas is supplied from a supply vessel 302 through this port at a rate of 20 L/min. The supplied argon gas is turned into a plasma by applied high-frequency waves, thereby forming a plasma flame in the plasma chamber 6-a within the plasma torch 6-A.

A zirconium powder serving as the feed of the coat forming substance is supplied at a rate of 0.5 g/min from a feeder 314 equipped with a vessel for supplying the feed powder of the coat forming substance. The supplied zirconia powder is carried by a carrier gas 303 flowing at a rate of 5 L/min so that it is introduced into the plasma flame via an inlet 304 the feed of the coat forming substance provided at the bottom of the plasma torch 6-A. Being evaporated by the heat of the plasma flame, the zirconia powder goes through the vapor phase to become the precursor of the coat forming substance in the coat forming substance precursor generating chamber 6-b.

Diamond core particles are supplied at a rate of 2.0 g/min from the feeder 313 equipped with a vessel for supplying the powder of core particles and they are dispersed with the agitating disperser 6-F1 while being carried by a carrier gas 305 that is supplied at a rate of 15 L/min. The particles then pass through a pipe 306 and thence enter the cyclone 6-I. The cyclone 6-I is adjusted in such a way that the fines produced will have a maximum particle diameter of 20 μm; a mixture of the gas and the particles in a powder of highly dispersed (β = 92%) core particles which are mostly single particles passes through the pipe 307 which is indispensable to transport, so that it is discharged into the coating chamber 6-c in the narrow sense of the term via a discharge port 308. On the other hand, the powder portion consisting of less highly dispersed core particles which have been selectively separated by cyclone 6-I passes through hopper 6-J and

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rotary valve 6-K to be transported through a pipe 310 by a carrier gas 309 flowing at a rate of 10 L/min so that it is fed back to the agitating disperser 6-F1.

The highly dispersed diamond particles entering the coating start region 6-L1 of the coating space 6-L2 start to contact and/or impinge against the precursor of the coat forming substance as they maintain the dispersity (β) of 89%. Thus, the diamond particles are given the coat of the coat forming substance on their surfaces and they descend down a coated particle cooling chamber 6-d together with the gas, eventually reaching a coated particle recovery section 6-G. The product comprising the coated diamond particles is separated from the gas 311 by means of a filter 312 and collected for recovery.

The recovered diamond particles having zirconium coats on the surfaces were examined with a scanning electron microscope. All of these particles were uniformly coated with superfine zirconium particles of about 0.005 μm in size. The zirconium coating weight was 10% by volume.

To provide a bonding material for binding the resulting zirconium-coated diamond particles, another lot of diamond particles were coated with titanium carbide under generally the same conditions as those used to produce the zirconium-coated diamond particles, thereby producing a coated diamond powder in which fine diamond particles of diameters ranging from 0.5 to 2 μm (average diameter = 1 μm) were coated with 15 vol% of titanium carbide. Thirty percent by volume of the previously prepared zirconium-coated diamond particles were wet mixed in acetone with seventy percent by volume of the thus prepared titanium carbide coated diamond particles. The mixture was stamped to a pellet having an outside diameter of 6 mm and a height of 2 mm. The pellet was buried in a pressure-transmitting medium surrounded by a shaped hexagonal boron nitride (h-BN) part and it was vacuum-dried overnight at 200°C and at 10^{-3} torr to remove low-boiling impurities. The pellet was then set in a cubic ultrahigh pressure apparatus; the pressure was raised to 5.5 GPa at room temperature, then the temperature was elevated to 1450°C, which was held for 30 min; thereafter, the temperature was lowered and the pressure reduced.

The resulting sinter was examined by X-ray diffractiometry and only diamond, zirconium carbide and titanium carbide were found in it. The sinter was dense with a relative density of at least 99%. Quantification by X-ray analysis showed that the volume proportions of diamond, zirconium carbide and titanium carbide were about 86%, 3% and 11%, respectively.

The sinter was dense and rigid, forming a very highly controlled microstructure.

Example 4

Coated diamond particles were prepared by coating the bare diamond particles of Example 1 with various coat forming substances using apparatus of the same types as used in Examples 1 - 3. The names of the coat forming substances used to prepare the coated diamond particles and their coating weights (relative proportions by vol%), as well as the specific types of the apparatus used and the conditions for their use (coating operation) are shown in Table 1 together with the data for Example 1.

The coated diamond particles thus obtained were examined with a scanning electron microscope. All of the particles prepared in Runs 4-1 and 4-2 were uniformly covered with superfine particles of coat forming substances in sizes of about 0.005 μm.

The apparatus used in Run 4-1 was of the same type as used in Example 2; a metallic zirconium powder having an average diameter of 12 μm was supplied as a feed of coat forming substance from the feeder 215 at a rate of 0.6 g/min, and the core diamond particles were supplied from the feeder 214 at a rate of 1.2 g/min. The other conditions in Run 4-1 were the same as in Example 2.

The apparatus used in Run 4-2 was of the same type as used in Example 3; the group of means for high dispersion treatment of particles in this apparatus was to treat core diamond particles having an average diameter D_M of 1 μm and a distribution by volume of ($[D_M/5, 5D_M]$, ≧ 90%), so the particles in the powder of core particles could be dispersed to a dispersity of 75% or more (β ≧ 75%) at the discharge section of cyclone 6-I, making it possible to start the coating operation at a dispersity of 70% or more (β ≧ 70%) in the coating start region. In Run 4-2, a metallic titanium powder was supplied as a feed of coating forming substance from the feeder 314 at a rate of 0.6 g/min and the core diamond particles were supplied from the feeder 313 at a rate of 1.2 g/min; the cyclone 6-I was adjusted in such a way that the fines produced would have a maximum particle diameter of 1.5 μm and the dispersity that could be attained in the discharge section was 85% (β = 85%) whereas the dispersity attainable in the coating start region was 82% (β = 82%); the other conditions in Run 4-2 were the same as in Example 3.

The apparatus used in Runs 4-7 and 4-8 were both of the same type as used in Example 1 and operated under generally the same conditions as in Example 1 except that aluminum and metallic nickel were deposited in that order to give a total coating weight of 15% in Run 4-7 as calculated for NiAl (Al to Ni molar ratio being 1:1) and 20% in Run 4-8 for Ni_3Al (Al to Ni molar ratio being 1:3).

The thus prepared powders of coated diamond particles or mixtures thereof with silicon carbide whiskers (addition aids) were shaped as in Example 1 and set in a cubic ultrahigh pressure apparatus; the pressure was raised to 5.5 GPa

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at room temperature, then the temperature was elevated to 1450 - 1460°C, which was held for 30 min; thereafter, the temperature was lowered and the pressure reduced.

In Runs 4-9 and 4-10, 30% by volume of the titanium carbide and silicon carbide coated diamond particles prepared in Runs 4-4 and 4-6, respectively, were wet mixed in acetone with 10% by volume of silicon carbide whiskers as a fibrous substance (SiC; width = 0.5 μm; average length = 30 μm) and subsequently vacuum dried to produce dry blends.

Each of the sinters thus produced was entirely free from pores, could be densified to a relative density of 100% and had no portion left unsintered. As in Example 1, the surfaces of the sinters were polished with a diamond paste and their Vickers microhardness Hv (0.5/10) values were measured. The results are shown in Table 1 together with the sintering conditions including the data for Example 1.

The crystalline phases of the sinters were examined by powder X-ray diffraction. In Run 4-1, only diamond and ZrC were observed and quantification by X-ray analysis showed that the volume proportions of diamond and ZrC were about 78% and 22%, respectively. In Run 4-2, only diamond and TiC were observed and quantification by X-ray analysis showed that the volume proportions of diamond and TiC were about 76% and 24%. In Runs 4-3 to 4-8, only diamond and the coat forming substances used (TiC, TiC, SiC, SiC, NiAl and Ni_3Al, respectively) were observed; in Run 4-9, only diamond and TiC were observed in addition to SiC; in Run 4-10, only diamond and SiC were observed.

All of the sinters thus produced were superhard, dense, uniform and had a uniform distribution of bonding materials to establish highly controlled microstructures. In particular, the composite sinters produced in Runs 4-9 and 4-10 had highly controlled microstructures in which the TiC bonding material (Run 4-9) or SiC bonding material (Run 4-10) and the SiC whiskers were dispersed uniformly between coated diamond particles.

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Table 1

Run No.	Relative Proportions (vol %)				Coating Apparatus	Coating Conditions (Approximate)	Sintering Conditions			Sinter		
	Core Particle	Coat Forming Substance		Whisker			Pressure	Temperature	Time	Sinter apparatus	Density	Hardness
	Diamond	Name	Amount	SiC	Ex. No.	Ex.or Run. No.	GPa	°C	min		%	Hv
1	80	Si	20	-	1	1	5.5	1450	30	CB	≥99	12000
4-1	80	Zr	20	-	2	4-1	5.5	1450	30	CB	100	11000
4-2	80	Ti	20	-	3	4-2	5.5	1450	30	CB	100	11500
4-3	85	TiC	15	-	1	1	5.5	1460	30	CB	100	12000
4-4	80	TiC	20	-	1	4-3	5.5	1460	30	CB	100	11000
4-5	80	SiC	20	-	1	4-4	5.5	1450	30	CB	100	12000
4-6	70	SiC	30	-	2	4-5	5.5	1450	30	CB	100	11000
4-7	85	NiAl	15	-	1	1	5.5	1450	30	CB	100	8900
4-8	80	Ni_3Al	20	-	1	4-7	5.5	1450	30	CB	100	6700
4-9	72	TiC	18	10	1	4-4	5.5	1460	30	CB	100	9800
4-10	72	SiC	18	10	1	4-6	5.5	1450	30	CB	100	9400

CB: Cubic ultrahigh pressure apparatus

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Example 5

Using apparatus of the same types as used in Examples 1 - 3, high-pressure phase boron nitride powder particles, or cubic boron nitride (cBN) particles of the same type as used in Example 2 that had an average diameter (D_M) of 1 μm and a frequency distribution by volume of ($[D_M/2, 3D_M/2]$, ≧ 90%) were covered with various coat forming substances. The names of the coat forming substances used to prepare the coated cubic boron nitride particles and their coating weights (relative proportions by vol%), as well as the specific types of the coating apparatus used and the conditions for their use (generally the same) are shown in Table 2.

The apparatus used in Run 5-1 was of the same type as used in Example 1; a metallic zirconium powder having an average diameter of 12 μm was supplied as a feed of coat forming substance from the feeder 112 at a rate of 0.6 g/min, and the cubic boron nitride core particles were supplied from the feeder 111 at a rate of 1.2 g/min. The other conditions in Run 5-1 were the same as in Example 1. The apparatus used in Run 5-2 was of the same type as used in Example 2; a metallic titanium powder having an average diameter of 25 μm was supplied as a feed of coat forming substance at a rate of 0.4 g/min whereas the core particles were supplied at a rate of 1.2 g/min; the other conditions in Run 5-2 were the same as in Example 2.

The apparatus used in Run 5-3 was of the same type as used in Example 3. Notwithstanding the difference in the core particles used (diamond or cubic boron nitride), the values of dispersity (β) attained in the discharge section of cyclone 6-I and in the coating start region were the same as in Run 4-2 and titanium nitride as a feed of coat forming substance was supplied at a rate of 0.6 g/min whereas the core particles were supplied at a rate of 2.0 g/min. The other conditions in Run 5-3 were the same as in Example 3.

The coated cubic boron nitride particles thus prepared were examined with a scanning electron microscope. All of the particles prepared in Runs 5-1 to 5-3 were uniformly covered with superfine particles (ca. 0.005 μm) of coat forming substances as Fig. 15 shows (particularly for the case of Run 5-1).

The coating with NiAl in Run 5-14 and with Ni_3Al in Run 5-13, as well as the production of mixtures with SiC whiskers in Runs 5-15 and 5-16 were performed as in Runs 4-7 to 4-10, respectively.

The thus prepared powders of coated cubic boron nitride particles or mixtures thereof with SiC whiskers were shaped as in Example 1 and set in a cubic ultrahigh pressure apparatus; the pressure was raised to 5.1 - 5.6 GPa at room temperature, then the temperature was elevated to 1450 - 1500°C, which was held for 30 min; thereafter the temperature was lowered and the pressure reduced.

Each of the thus produced sinters was entirely free from pores, could be densified to a relative density of 100% and had no portion left unsintered. As in Example 1, the surfaces of the sinters were polished with a diamond paste and their Vickers microhardness Hv (0.5/10) values were measured. The results are shown in Table 2 together with the sintering conditions.

The crystalline phases of the sinters were examined by powder X-ray diffraction. In Run 5-1, Zr reacted with the cubic boron nitride, whereupon metallic Zr disappeared, changing to cubic boron nitride, ZrN and ZrB_2 which were found to be present in respective volume proportions of about 77%, 14% and 9% according to quantification by X-ray analysis. In the sinter of Run 5-2, only cubic boron nitride, TiN and TiB_2 were observed and their respective volume proportions were about 74%, 15% and 11%. In Runs 5-3 to 5-14, only the cubic boron nitride and the coating forming substances used (TiN, TiN, AlN, AlN, α- and β-Si_3N_4, α- and β-Si_3N_4, α-Al_2O_3, α-Al_2O_3, Co, Co, Ni_3Al and NiAl, respectively) were observed; in Runs 5-15 and 5-16, only TiN and α- and β-Si_3N_4, respectively, were observed in addition to the aid SiC and the cubic boron nitride core particles. It should be noted that the sinter produced in Run 5-11 and 5-12 were entirely free from the pool of metallic Co.

Fig. 16 is a graph showing the Hv (0.5/10) value of the cubic boron nitride sinter of Run 5-1 in comparison with the hardness data of four typical commercial cutting tools made from cubic boron nitride sinters using ceramic bonding materials or sintering aids. The sinter produced in Run 5-1 was superhard with the Hv (0.5/10) being about 5500 and this value was comparable to or higher than those of the commercial cutting tools made of sintered cubic boron nitride. Furthermore, the hardness of the sinter of Run 5-1 was uniform over the entire surface subjected to the hardness measurement and it was substantially free from variations.

The polished surface of the sinter of Run 5-1 was coated with a gold film by a customary evaporation technique and examined with an electron microscope. The result is shown in the Fig. 17 electron micrograph (X5000), in which the dark area represents the cubic boron nitride and the light area the ZrN-ZrB_2 base substance. As one can see from Fig. 17, the sinter was entirely free from pores and could be sintered to a relative density of 100%. In addition, it had no portion left unsintered. In areas where cubic boron nitride particles contacted each other via a thin layer of the coat forming substance, the latter was bursted by the contiguous cubic boron nitride particles, which hence were coupled directly as a result of sintering. In all other areas, the ZrN-ZrB_2 base material was distributed to surround the cubic boron nitride particles, rendering the sinter to be characteristic in that it was dense, uniform and had the bonding material distributed to provide a highly controlled microstructure. It should also be noted that the cubic boron nitride particles in the sinter did not grow at all compared to the particles in the feed powder and that the coating on the cubic boron nitride was formed by chemical reaction between the cubic boron nitride and the metallic zirconium which served as the coat

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forming substance; these factors combined together to offer the characteristic feature that the cubic boron nitride particles in the sinter were finer than those in the feed although they were coated zirconium. This is very favorable and, hence, ideal for the mechanical characteristics of the sinter. The differences can be clearly seen by comparing Fig. 17 with Fig. 18 which is an electron micrograph (X5000) of a polished surface of one of the above-mentioned commercial cutting tools that was made of sintered cubic boron nitride and which was coated with a gold film by a customary evaporation technique for examination. Obviously, the bonding material and the sintering aid were distributed irregularly in the cubic boron nitride sinter of the commercial cutting tool to form lumps in certain areas. On the other hand, the number of areas that were devoid of the necessary sintering aid and bonding material was by no means small and unsintered portions were found there. Another major difference from the sinter of Run 5-1 was that every cubic boron nitride particle in the cutting tool was coarse.

The cubic boron nitride is inherently very difficult to sinter. In spite of this fact, the coated particles in a cubic boron nitride powder that were produced in Example 5 in accordance with the invention behaved as if they were comparatively easy-to-sinter particles under industrially feasible ultrahigh pressures and elevated temperatures, thereby forming dense, rigid and superhard structures.

The sinters thus produced were similar to those produced in Examples 1 and 4 in that they were sinters or composite sinters that were superhard and which had dense, uniform and highly controlled microstructures with substantially uniform distributions of the bonding materials.

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Table 2

Run No.	Relative proportions (vol %)				Coating	Coating Conditions (Approxi-mate)	Sintering Conditions			Sinter		
	Core Particle	Coat Forming Substance		Whisker	Appara-tus		Pres-sure	Temper-ature	Time	Sinter appara-tus	Density	Hard-ness
	cBN	Name	Amount	SiC	Ex. No.	Ex.or Run. No.	GPa	°C	min		%	Hv
5-1	80	Zr	20	-	1	5-1	5.5	1450	30	CB	100	5500
5-2	80	Ti	20	-	2	5-2	5.3	1480	30	CB	100	5600
5-3	85	TiN	15	-	3	5-3	5.3	1480	30	CB	100	6400
5-4	80	TiN	20	-	3	5-3	5.3	1480	30	CB	100	5900
5-5	80	AlN	20	-	1	5-1	5.4	1450	30	CB	100	5800
5-6	70	AlN	30	-	1	5-5	5.4	1450	30	CB	100	5200
5-7	80	Si_3N_4	20	-	1	5-1	5.3	1470	30	CB	100	5900
5-8	70	Si_3N_4	30	-	1	5-7	5.3	1470	30	CB	100	5100
5-9	85	Al_2O_3	15	-	2	5-2	5.5	1450	30	CB	100	6100
5-10	80	Al_2O_3	20	-	2	5-9	5.6	1450	30	CB	100	5900
5-11	90	Co	10	-	1	5-1	5.5	1450	30	CB	100	6000
5-12	70	Co	30	-	1	5-1	5.5	1450	30	CB	100	2800
5-13	85	Ni_3Al	15	-	1	5-1	5.1	1450	30	CB	100	4300
5-14	80	NiAl	20	-	1	5-13	5.1	1450	30	CB	100	3300
5-15	72	TiN	18	10	3		5.5	1500	30	CB	100	5000
5-16	72	Si_3N_4	18	10	1		5.3	1470	30	CB	100	5100

CB: Cubic ultrahigh pressure apparatus

Example 6

Coated diamond particles were prepared by coating the bare diamond particles of Example 1 with various coat forming substances using apparatus of the same types as used in Examples 1 - 3. The names of the coat forming substances used to prepare the coated diamond particles and their coating weights (relative proportions by vol%) are shown in Table 3.

The apparatus used in Run 6-1 was of the same type as used in Example 1; an alumina powder having an average diameter of 2 μm was supplied as a feed of coat forming substance from the feeder 112 at a rate of 1.5 g/min and the core diamond particles were supplied from the feeder 111 at a rate of 0.3 g/min. The other conditions in Run 6-1 were the same as in Example 1. The apparatus used in Run 6-2 was of the same type as used in Example 2; an alumina powder having an average diameter of 2 μm was supplied as a feed of coat forming substance at a rate of 1.0 g/min and the diamond particles were supplied at a rate of 0.7 g/min. The other conditions in Run 6-2 were the same as in Example 2. The apparatus used in Run 6-3 was of the same type as in Example 3; the values of dispersity (β) attained in the discharge section of cyclone 6-I and in the coating start region were the same as in Run 4-2 and an alumina powder was supplied at a rate of 0.6 g/min whereas the diamond particles were supplied at a rate of 1.5 g/min. The other conditions in Run 6-3 were the same as in Example 3.

The apparatus used in Run 6-4 was of the same type as used in Example 1 and operated to perform the coating operation under generally the same conditions as in Run 6-1. In Runs 6-5 to 6-9, inorganic salts consisting of KCl, $BaCl_2$ and NaF were mixed with TiO_2 and ferroalloy (Fe-Ti) to prepare an immersing bath. In this bath, diamond powder particles (up to 2 μm in diameter) were dipped for 1 h by the molten salt disproportionation method with the bath being melted at 900°C. As a result, the surfaces of the diamond powder particles were coated with TiC in such a way that the amount of internal addition would be 5% by volume. The surfaces of diamond particles were further coated with the apparatus of Example 1 under generally the same conditions as in Run 6-1.

The coated diamond particles thus prepared were examined with a scanning electron microscope. All of the particles prepared in Runs 6-1 to 6-3 were uniformly covered with superfine particles (ca. 0.005 μm) of coat forming substances as Fig. 19 shows (particularly for the case of Run 6-1).

In Runs 6-10 and 6-11, the powders of alumina-coated diamond particles prepared in Runs 6-1 and 6-2, respectively, were wet mixed with SiC whiskers at a volume ratio of 90:10 in acetone for 2 h in an alumina ball mill. In Run 6-12, a powder of diamond particles was coated with 53% by volume of alumina using the apparatus of Example 1 under generally the same conditions as in Run 6-1 and then wet mixed with SiC whiskers at a volume ratio of 85:15 in acetone for 2 h in an alumina ball mill. The SiC whiskers had their surfaces coated with the target TiC by sputtering in a coating weight of 33% by volume in terms of internal addition. The mixtures was vacuum dried at 10^{-6} torr at 200°C to make dry blends.

The coated diamond particles thus prepared or mixtures thereof with SiC whiskers were stamped into disks having a diameter of 16 mm and a thickness of 5 mm in Runs 6-1 and 6-10 and into disks having a diameter of 8 mm and a thickness of 5 mm in Runs 6-2 and 6-11. The disks were placed into Pyrex glass capsules packed with a h-BN powder, degassed to 10^{-6} torr at 400°C over 12 h and then sealed. The sealed capsules were set in a HIP or a ultrahigh pressure HIP apparatus using an argon gas as a pressure-transmitting medium and sintering was performed under the conditions shown in Table 3. In Runs 6-9 to 6-12, the coated diamond particles or mixtures thereof with whiskers were stamped into pellets having a diameter of 10 mm and a thickness of 8 mm and the pellets were buried in a pyrophyllite pressure-transmitting medium surrounded by a h-BN shaped part; the assemblies were set in a piston-cylinder (PC) ultrahigh pressure apparatus and sintering was performed under the conditions shown in Table 3. Following furnace cooling, the pressure was opened to atmosphere and the sinters were recovered.

The recovered sinters were measured for their density and Vickers microhardness Hv (0.5/10) as in Example 1 and the results are shown in Table 3.

The sinters of Runs 6-1 to 6-4 were checked for their crystalline phases by powder X-ray diffraction and no diffraction peaks were observed except for the diamond and α-form alumina. Similar results were obtained in the other runs: only diffraction peaks for diamond, titanium carbide and α-form alumina were observed in Runs 6-5 to 6-7; only diffraction peaks for diamond, titanium carbide and the monoclinic and tetragonal zirconium oxide each composing the PSZ were observed in Runs 6-8 and 6-9; only diffraction peaks for diamond, α-form alumina and silicon carbide were observed in Runs 6-10 and 6-11; and only diffraction peaks for diamond, α-form alumina, silicon carbide and titanium carbide were observed in Run 6-12. No other diffraction peaks were observed.

The surface of the sinter produced in Run 6-1 was polished with a diamond paste; the polished surface was coated with a gold film by a customary evaporation technique and examined with an electron microscope. The result is shown in the Fig. 20 micrograph (X5000), in which the dark area represents the diamond and the light area the alumina bonding material.

For comparison, bare diamond particles of the same type as used in Example 6 were mixed with an alumina powder at a ratio of 70:30 in volume percent and the mixture was sintered under the same conditions as in Example 6. The resulting sinter had a density of 92% and a Vickers microhardness of 2200. The difference is clearly visible by comparing

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Fig. 20 with Fig. 21 which is an electron micrograph (X5000) of a polished surface of the comparative sinter that was coated with a gold film by a customary evaporation technique for examination. Obviously, the bonding material and the sintering aid were distributed irregularly in the comparative sinter to form lumps in certain areas. On the other hand, the number of areas that were devoid of the necessary sintering aid and bonding material was by no means small and unsintered portions were found there. Thus, the sinter produced in Run 6-1 in accordance with the invention was significantly superior to the comparative sinter in terms of density, hardness and microstructure.

Each of the sinters produced in Runs 6-5 to 6-7 presented considerable difficulty in forming a polished surface for the hardness measurement and this fact shows that those sinters had high wear resistance, which was probably due to the formation of the titanium carbide coating film by dip coating.

The foregoing data, when considered with particular reference to Figs. 20 and 21, demonstrate that the sinters produced in Example 6 were entirely free from unsintered portions, pores, defects, etc., highly dense, superhard and comprised of highly controlled microstructures in which the diamond particles were surrounded by uniform distributions of the bonding material(s), i.e., α-form alumina, the combination of titanium carbide and α-form alumina, or the combination of titanium carbide and PSZ, or in which these coated diamond particles were further surrounded with a uniform dispersion of SiC.

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Table 3

Run No.	Relative Proportions (vol%)						Sintering Conditions				Sinter	
	Coated Diamond Particles				Fibrous Substance							
	Diamond	Coat Forming Substance			Whisker	Coating Substance	Pressure	Temperature	Time	Apparatus	Density	Hardness
		TiC	Al_2O_3	PSZ	SiC	TiC	MPa	°C	hr.		%	Hv
6-1	30	-	70	-	-	-	150	1200	3	HIP1	96.0	2740
6-2	50	-	50	-	-	-	1000	1200	3	HIP2	95.0	3350
6-3	50	-	50	-	-	-	1500	1200	3	PC	95.3	3380
6-4	50	-	50	-	-	-	1500	1300	3	PC	95.5	3400
6-5	55	5	40	-	-	-	1500	1200	6	PC	94.8	3670
6-6	50	5	45	-	-	-	1500	1300	3	PC	95.0	3700
6-7	60	5	35	-	-	-	1500	1300	6	PC	94.6	3730
6-8	55	5	-	40	-	-	1500	1300	6	PC	99.3	2360
6-9	50	5	-	45	-	-	1500	1300	3	PC	99.6	2120
6-10	27	-	63	-	10	-	150	1200	3	HIP1	94.8	2660
6-11	45	-	45	-	10	-	1000	1200	3	HIP2	94.0	3220
6-12	40	-	45	-	10	5	1500	1300	3	PC	95.1	3170

HIP1: HIP apparatus incapable of producing ultrahigh pressures

HIP2: Superhigh pressure HIP apparatus

PC: Piston-cylinder (PC) ultrahigh pressure apparatus

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Example 7

Cubic boron nitride (cBN) particles of the same type as used in Example 2 were coated with various coat forming substances using apparatus of the same types as used in Examples 1 - 3. The names of the coat forming substances used to prepare the coated cubic boron nitride particles and their coating weights (relative proportions by vol%) are shown in Table 4.

The apparatus used in Runs 7-1 and 7-2 were of the same types as used in Examples 1 and 3, respectively; an alumina powder having an average diameter of 2 μm was supplied as a feed of coat forming substance at respective rates of 1.5 and 2.1 g/min and the cubic boron nitride core particles were supplied at respective rates of 0.3 and 1.5 g/min. The other conditions in Runs 7-1 and 7-2 were the same as in Example 1 and Run 4-2, respectively. The apparatus used in Runs 7-3 and 7-4 was of the same type as used in Example 1 and the other conditions were the same as in Run 7-1. In Runs 7-5, 7-6 and 7-8, the procedures of Runs 6-6, 6-7 and 6-9 were repeated, except that the surfaces of cubic boron nitride particles were dip coated with the combination of titanium nitride (TiN) and titanium diboride (TiB_2) in place of titanium carbide and, further, alumina or PSZ coating was performed using the same apparatus as in Example 1 under generally the same conditions as in Run 7-1. In Run 7-7, the apparatus of Example 1 was used and coating was performed under generally the same conditions as in Run 7-1, except that alumina was replaced by PSZ. In Runs 7-9 and 7-10, the alumina coated cubic boron nitride particles as prepared in Run 7-1 and Example 2, respectively, were each mixed with SiC whiskers as in Runs 6-10 and 6-11. In Run 7-11, cubic boron nitride particles were coated with 53% alumina using the apparatus of Example 1 under generally the same conditions as in Run 7-1 and then mixed with TiC coated SiC whiskers that were prepared as in Run 6-12.

The coated cubic boron nitride particles thus prepared were examined with a scanning electron microscope. All of the particles prepared in Runs 7-1 to 7-3 were uniformly covered with superfine particles (ca. 0.005 μm) of coat forming substances as Fig. 22 shows (particularly for the case of Run 7-1).

The powders of coated cubic boron nitride particles thus prepared in Runs 7-1 to 7-8 or the mixtures thereof with SiC whiskers which were prepared in Runs 7-9 to 7-11 were shaped by stamping as in Runs 6-1, 6-3 to 6-12, respectively, and sintered with the sinter apparatus shown in Table 4 under the sintering conditions shown in Table 4.

The sinters thus produced were measured for their density and Vickers microhardness Hv (0.5/10) as in Example 1 and the results are shown in Table 4.

The crystalline phases of the sinters were examined by powder X-ray diffraction; as in Runs 6-1 to 6-12, no diffraction peaks were observed except for the cubic boron nitride (core particles), the bonding materials or coat forming substances (α-alumina, titanium nitride, titanium diboride, as well as the PSZ composing monoclinic and tetragonal zirconium oxide), and whiskers (silicon carbide) and the titanium carbide coating thereon.

The polished surface of the sinter of Run 7-1 was coated with a gold film by a customary evaporation technique and examined with an electron microscope. The result is shown in the Fig. 23 electron micrograph (X5000), in which the dark area represents the cubic boron nitride and the light area the bonding material alumina. As one can see from Fig. 23, the sinter was entirely free from unsintered portions, pores, defects, etc. and it was comprised of a highly controlled microstructure in which the bonding material alumina was distributed uniformly around the cubic boron nitride particles.

For comparison, bare cubic boron nitride particles of the same type as used in Run 7-1 were mixed with an alumina powder at a ratio of 70:30 in volume percent and the mixture was sintered under the same conditions as in Run 7-1. The resulting sinter had a density of 94% and a Vickers microhardness of 2300. From an electron micrograph (X5000) of a polished surface of the comparative sinter that was coated with a gold film by a customary evaporation technique for examination. Obviously, the bonding material and the sintering aid were distributed irregularly in the comparative sinter to form lumps in certain areas. On the other hand, in the comparative sinter, the number of areas that were devoid of the necessary sintering aid and bonding material was by no means small and unsintered portions were found there.

In Runs 7-5, 7-6 and 7-9, the TiN-TiB_2 coating film formed by dip coating were found to be as effective as the TiC coating film formed by dip coating in Runs 6-5 to 6-7.

Thus, the sinters produced in Example 7 were entirely free from unsintered portions, pores, defects, etc., highly dense, superhard and comprised of highly controlled microstructures in which the cubic boron nitride particles were surrounded by uniform distributions of the bonding material(s), i.e., α-alumina, PSZ, the combination of TiN-TiB_2 and α-alumina, or the combination of TiN-TiB_2 and PSZ, or in which these coated cubic boron nitride particles were further surrounded with a uniform dispersion of SiC as whiskers.

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Table 4

Run No.	Relative Proportions (vol%)						Sintering Conditions				Sinter	
	Coated High-Pressure Boron Nitride Particles				Fibrous Substance							
		Coat Forming Substance			Whisker	Coating Substance	Pressure	Temperature	Time	Apparatus	Density	Hardness
	cBN	TiN-TiB_2	Al_2O_3	PSZ	SiC	TiC	MPa	°C	hr.		%	Hv
2	50	-	50	-	-	-	1000	1200	3	HIP2	95.8	3750
7-1	30	-	70	-	-	-	150	1200	3	HIP1	97.1	2960
7-2	50	-	50	-	-	-	1500	1200	3	PC	98.3	3930
7-3	50	-	50	-	-	-	1500	1300	3	PC	98.8	3970
7-4	60	-	40	-	-	-	1500	1200	6	PC	98.2	4700
7-5	50	5	45	-	-	-	1500	1300	3	PC	99.0	4030
7-6	60	5	35	-	-	-	1500	1300	6	PC	98.5	4780
7-7	60	-	-	40	-	-	1500	1300	6	PC	99.8	2300
7-8	50	5	-	45	-	-	1500	1300	3	PC	99.8	2100
7-9	27	-	63	-	10	-	150	1200	3	HIP1	96.0	2780
7-10	45	-	45	-	10	-	1000	1200	3	HIP2	95.0	3560
7-11	40	-	45	-	10	5	1500	1300	3	PC	98.7	3400

HIP1: HIP apparatus incapable of producing ultrahigh pressures

HIP2: Superhigh pressure HIP apparatus

PC: Piston-cylinder (PC) ultrahigh pressure apparatus

Example 8

Coated diamond particles were prepared by coating the bare diamond particles of Example 1 with various coat forming substances using apparatus of the same type as used in Examples 1 - 3. The names of the coat forming substances used to prepare the coated diamond particles and their coating weights (relative proportions by vol%) are shown in Table 5.

The apparatus used in Runs 8-1, 8-2 and 8-4 were of the same types as used in Examples 1, 2 and 3, respectively; a titanium carbide powder having an average diameter of 2 μm was supplied as a feed of coat forming substance at a rate of 0.4 g/min and the core diamond particles were supplied at a rate of 2.0 g/min; the other conditions in Runs 8-1, 8-2 and 8-4 were generally the same as in Example 1 and Runs 4-1 and 4-2, respectively. In each of those runs, 10% titanium carbide coated diamond particles were obtained. In Runs 8-5 and 8-6, an apparatus of the same type as used in Example 1 was operated under generally the same conditions as in Run 8-1 to produce 10% titanium carbide coated diamond particles; in Runs 8-7 and 8-8, the same procedure was repeated to produce 10% metallic titanium coated diamond particles; in Runs 8-9 and 8-10, the same procedure was repeated to yield 20% titanium carbide coated diamond particles; in Run 8-3, the 10% titanium carbide coated particles prepared in Run 8-2 were used.

The coated diamond particles thus prepared were examined with a scanning electron microscope. All of the particles prepared in Runs 8-1 to 8-4 were uniformly covered with superfine particles (ca. 0.005 μm) of coat forming substances as Fig. 25 shows (particularly for the case of Run 8-1).

The thus prepared powders of coated diamond particles and powders of bonding materials having the various formulations shown in Table 5 were added in the various proportions shown in Table 5 and wet mixed in acetone for 2 h in an alumina ball mill. Thereafter, the mixtures were vacuum dried at 10^{-6} torr and at 200°C to produce dry blends. The bonding material powder used in Runs 8-1 to 8-4 was easily sintrable alumina of high purity (i.e., the alumina powder described in the official gazette of Unexamined Published Japanese Patent Application (kokai) Sho 63-151616); in Runs 8-5 and 8-6, PSZ was used as a bonding material powder; and in Runs 8-7 to 8-10, TiC was used. Take, for example, Run 8-1; in this run, 55 vol% of 10% TiC coated diamond particles were mixed with 43.4 vol% of easily sintrable alumina of high purity as a bonding material powder, and with sintering aids for the alumina powder which were 0.6 vol% and 1.0 vol%, respectively, of magnesia (MgO) and titania (TiOx; x = 1 - 2).

In Runs 8-11 and 8-12, 90 vol% of the mixtures prepared in Runs 8-4 and 8-5, respectively, were mixed with 10 vol% of SiC whiskers and the mixtures thus prepared were used as sinter feeds.

The thus prepared mixtures of coated diamond particles with bonding material powders were stamped into disks having a diameter of 10 mm and a thickness of 8 mm in Runs 8-1, 8-7, 8-8 and 8-10. The disks were buried in a pyrophyllite pressure-transmitting medium surrounded by a h-BN shaped part and the assemblies were set in a piston-cylinder (PC) ultrahigh pressure apparatus, and sintering was performed under the conditions set forth in Table 5. In the other runs, the same mixtures of coated diamond particles with bonding material powders, or mixtures further containing SiC whiskers were stamped into disks having a diameter of 16 mm and a thickness of 5 mm. The disks were placed in a Pyrex glass capsule packed with a h-BN shaped part and the assemblies were degassed to 10^{-6} torr by heating at 400°C for 12 h and sealed. Thereafter, the capsules were set in a HIP or ultrahigh pressure HIP apparatus using an argon gas as a pressure-transmitting medium and sintering was performed under the conditions set forth in Table 5. Subsequently, the temperature was lowered and the pressure reduced for recovering the sinters.

The recovered sinters were measured for their density and Vickers microhardness Hv (0.5/10); the results are shown in Table 5 together with the sintering conditions and the types of sintering apparatus used.

The sinters were also checked for their crystalline phases by powder X-ray diffraction. In Example 8, no diffraction peaks were observed except for the diamond, coat forming substances (coating materials) and the bonding material powders or whisker SiC. Take, for example, Runs 8-1 to 8-4; in these cases, the only diffraction peaks observed were those for diamond, TiC and α-alumina. In the other runs, the only diffraction peaks observed were those for the following: diamond, TiC and PSZ composing monoclinic and tetragonal zirconium oxide (Runs 8-5 and 8-6); diamond, the TiC that was generated by the reaction between the coating metallic titanium and the diamond, as well as TiN (Runs 8-7 and 8-8); diamond and TiC (Run 8-9 and 8-10); diamond, TiC, α-alumina and SiC (Run 8-11); diamond, TiC, the PSZ composing monoclinic and tetragonal zirconium oxide, and SiC (Run 8-12).

The surface of the sinter produced in Run 8-1 was polished with a diamond paste and coated with a gold film by a customary evaporation technique and examined with an electron microscope. The result is shown in the Fig. 26 electron micrograph (X5000), in which the dark area represents the diamond and the light area the alumina-base bonding material.

As one can see from Fig. 26, all the sinters of Example 8 were entirely free from unsintered portions, pores, defects, etc., highly dense, superhard and comprised of highly controlled microstructures in which the diamond particles were surrounded by uniform distributions of the coating materials, the bonding materials (TiC, TiN, α-alumina and PSZ) and the SiC whiskers, if any.

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Table 5

Run No.	Relative Proportions (vol%)										Sintering Conditions				Sinter	
	Diamond	Coating Material			Bonding Material Powder					Whisker	Pressure	Temperature	Time	Apparatus	Density	Hardness
		TiC	TiN	Ti	PSZ	TiN	Al_2O_3	MgO	TiO_x	SiC	MPa	°C	hr.		%	Hv
8-1	50.0	5.0	-	-	-	-	43.4	0.6	1.0	-	1500	1300	3	PC	96.0	4110
8-2	30.0	3.0	-	-	-	-	65.4	0.6	1.0	-	150	1300	3	HIP1	98.8	3150
8-3	40.0	4.0	-	-	-	-	54.4	0.6	1.0	-	1000	1300	3	HIP2	98.8	3580
8-4	20.0	2.0	-	-	-	-	76.4	0.6	1.0	-	150	1300	3	HIP1	97.8	2930
8-5	30.0	3.0	-	-	67.0	-	-	-	-	-	150	1300	3	HIP1	98.5	1810
8-6	45.0	4.5	-	-	50.5	-	-	-	-	-	150	1300	3	HIP1	98.0	1990
8-7	20.0	-	-	2.0	-	78.0	-	-	-	-	1500	1300	3	PC	99.1	2860
8-8	40.0	-	-	4.0	-	56.0	-	-	-	-	1500	1300	3	PC	97.8	3430
8-9	20.0	-	4.0	-	-	76.0	-	-	-	-	1000	1300	3	HIP2	99.0	2840
8-10	40.0	-	8.0	-	-	52.0	-	-	-	-	1500	1300	3	PC	99.7	3400
8-11	18.0	1.8	-	-	-	-	68.8	0.5	0.9	10.0	150	1300	3	HIP1	99.4	2880
8-12	27.0	2.7	-	-	60.3	-	-	-	-	10.0	150	1300	3	HIP1	98.8	1880

HIP1: HIP apparatus incapable of producing ultrahigh pressures

HIP2: Superhigh pressure HIP apparatus

PC: Piston-cylinder (PC) ultrahigh pressure apparatus

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Example 9

Coated cubic boron nitride particles were prepared by coating the bare cubic boron nitride (cBN) particles of Example 1 with various coat forming substances using the apparatus employed in Examples 1 - 3. The names of the coat forming substances used to prepare those coated cubic boron nitride particles and their coating weights (relative proportions by vol%) are shown in Table 6.

The apparatus used in Runs 9-1, 9-2 and 9-3 were of the same types as used in Examples 1, 2 and 3, respectively; a titanium nitride powder having an average diameter of 2 μm was supplied as a feed of coat forming substance at a rate of 0.3 g/min and the cubic boron nitride core particles were supplied at a rate of 1.5 g/min; the other conditions in Runs 9-1, 9-2 and 9-3 were generally the same as in Example 1, Runs 4-2 and 4-2, respectively. In each of those runs, 10% titanium nitride coated cubic boron nitride particles were obtained. In Runs 9-4 and 9-5, an apparatus of the same type as used in Example 1 was operated under generally the same conditions as in Run 9-1 to produce 10% titanium nitride coated cubic boron nitride particles; in Runs 9-6 and 9-7, the same procedure was repeated to produce 10% metallic titanium coated cubic boron nitride particles; and in Runs 9-8 and 9-9, the same procedure was repeated to yield 20% titanium nitride coated cubic boron nitride particles.

The coated cubic boron nitride particles thus prepared were examined with a scanning electron microscope. All of the particles prepared in Runs 9-1 to 9-3 were uniformly covered with superfine particles (ca. 0.005 μm) of coat forming substances as Fig. 27 shows (particularly for the case of Run 9-1).

The thus prepared powders of coated cubic boron nitride particles and powders of bonding materials having the various formulations shown in Table 6 were added in the various proportions shown in Table 6. Those powders were wet mixed in acetone for 2 h in an alumina ball mill as in Example 8. Thereafter, the mixtures were vacuum dried at 10^{-6} torr and at 200°C to produce dry blends. The bonding material powders used in Example 9 were the same as those used in Example 8, i.e., easily sintrable alumina of high purity, PSZ, and TiN. As in Example 8, the use of easily sintrable high-purity alumina with an average particle diameter of 0.2 μm as a bonding material powder was accompanied by the use of sintering aids for the alumina powder which were magnesia (MgO) and titania (TiOx; x = 1 - 2).

In Runs 9-10 and 9-11, 90 vol% of the mixtures prepared in Runs 9-3 and 9-4, respectively, were mixed with 10 vol% of SiC whiskers and the mixtures thus prepared were used as sinter feeds.

The thus prepared mixtures of coated cubic boron nitride particles with bonding material powders were stamped into disks in Runs 9-1, 9-6, 9-7 and 9-9 as in Run 8-1; in the other runs, the same mixtures of coated cubic boron nitride particles with bonding material powders, or mixtures further containing SiC whiskers were stamped into disks as in Run 8-2. The disks were then sintered with the sinter apparatus listed in Table 6 under the sinter conditions also set forth in Table 6. Thereafter, the temperature was lowered and the pressure reduced for recovering the sinters.

The recovered sinters were measured for their density and Vickers microhardness Hv (0.5/10); the results are shown in Table 6 together with the sintering conditions and the types of sintering apparatus used.

The sinters were also checked for their crystalline phases by powder X-ray diffraction. In Example 9, no diffraction peaks were observed except for the cubic boron nitride, coat forming substances (coating materials) and the bonding materials or whisker SiC. Take, for example, Runs 9-1 to 9-3; in these cases, the only diffraction peaks observed were those for cubic boron nitride, TiN and α-alumina. In the other runs, the only diffraction peaks observed were those for the following: cubic boron nitride, TiN and the PSZ composing monoclinic and tetragonal zirconium oxide (Runs 9-4 and 9-5); cubic boron nitride, the TiB_2 that was generated by the reaction between the coating metallic titanium and cubic boron nitride, as well as TiN (Runs 9-6 and 9-7); cubic boron nitride and TiN (Runs 9-8 and 9-9); cubic boron nitride, TiC, α-alumina and SiC (Run 9-10); and cubic boron nitride, TiC, the PSZ composing monoclinic and tetragonal zirconium oxide, and SiC (Run 9-11).

Quantification by X-ray analysis showed that the sinter of Run 9-6 consisted of cubic boron nitride, TiB_2 and TiN in proportions of 19.5%, 1.0% and 79.5%, respectively, by volume whereas the sinter of Run 9-7 had relative volume proportions of 39.1%, 2.0% and 58.9%.

The surface of the sinter produced in Run 9-1 was polished with a diamond paste and coated with a gold film by a customary evaporation technique and examined with an electron microscope. The result is shown in the Fig. 28 electron micrograph (X5000), in which the dark area represents the cubic boron nitride and the light area the alumina base bonding material.

As one can see from Fig. 28, all the sinters of Example 9 were entirely free from unsintered portions, pores, defects, etc., highly dense, superhard and comprised of highly controlled microstructures in which the cubic boron nitride particles were surrounded by uniform distributions of the coating materials, the bonding materials (TiN, TiB_2, α-alumina and PSZ) and the SiC whiskers, if any.

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Table 6

Run No.	Relative Proportions (vol %)									Sintering Conditions				Sinter	
		Coating Material		Bonding Material Powder					Whisker	Pressure	Temperature	Time	Apparatus	Density	Hardness
	cBN	TiN	Ti	PSZ	TiN	Al_2O_3	MgO	TiO_x	SiC	MPa	°C	hr.		%	Hv
9-1	50.0	5.0	-	-	-	43.4	0.6	1.0	-	1500	1300	3	PC	97.5	4020
9-2	40.0	4.0	-	-	-	54.4	0.6	1.0	-	1000	1300	3	HIP2	98.7	3500
9-3	20.0	2.0	-	-	-	76.4	0.6	1.0	-	150	1300	3	HIP1	98.3	2870
9-4	30.0	3.0	-	67.0	-	-	-	-	-	150	1300	3	HIP1	99.8	1830
9-5	45.0	4.5	-	50.5	-	-	-	-	-	150	1300	3	HIP1	99.6	2010
9-6	20.0	-	2.0	-	78.0	-	-	-	-	1500	1300	3	PC	99.0	2890
9-7	40.0	-	4.0	-	56.0	-	-	-	-	1500	1300	3	PC	98.0	3430
9-8	20.0	4.0	-	-	76.0	-	-	-	-	1000	1300	3	HIP2	99.0	2900
9-9	40.0	8.0	-	-	52.0	-	-	-	-	1500	1300	3	PC	99.4	3510
9-10	18.0	1.8	-	-	-	68.8	0.5	0.9	10.0	150	1300	3	HIP1	99.8	2790
9-11	27.0	2.7	-	60.3	-	-	-	-	10.0	150	1300	3	HIP1	99.7	1840

HIP1: HIP apparatus incapable of producing ultrahigh pressures

HIP2: Superhigh pressure HIP apparatus

PC: Piston-cylinder (PC) ultrahigh pressure apparatus

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Examples 10 and 11

Using the apparatus employed in Examples 1 - 3, pseudo-fine diamond particles (Example 10) or pseudo-fine particles in a high-pressure phase boron nitride powder (Example 11) were covered with various coat forming materials. The pseudo-fine diamond particles were the same as those used in Example 3; the pseudo-fine particles in a high-pressure phase boron powder were pseudo-fine cubic boron nitride (cBN) particles that had an average diameter (D_M) of 17 μm and a frequency distribution by volume of ($[D_M/2, 3D_M/2]$, ≧ 90%). The names of the coat forming substances used to prepare the pseudo-fine coated diamond and cubic boron nitride particles and their coating weights (relative proportions by vol%), as well as the specific types of the coating apparatus used and the conditions for their use (generally the same) are shown in Tables 7 and 8 together with the data for Example 3.

The apparatus used in Runs 10-1 and 11-1 was of the same type as used in Example 1; the group of means for high dispersion treatment of particles in this apparatus was to treat the pseudo-fine particles of either a diamond powder or a cubic boron nitride powder, in which the core particles had an average diameter of 17 μm and a frequency distribution by volume of ($[D_M/5, 5D_M]$, ≧ 90%) and, hence, said group of means was designed in such a way that it could realize an output dispersity (β) value of at least 80% (β ≧ 80%) for the core particles in those powders while, at the same time, the coating operation could be started with a dispersity (β) of at least 80% (β ≧ 80%) in the coating start region. A titanium carbide powder (Run 10-1) or a titanium nitride powder (Run 11-1) that were feeds for coat forming substances and which had an average particle diameter of 2 μm were supplied from the feeder 112 at a rate of 0.3 g/min whereas the pseudo-fine diamond or cubic boron nitride core particles were supplied from the feeder 111 at a rate of 3.0 g/min and introduced into the coating chamber after being dispersed to a dispersity (β) of 89%, and the dispersity (β) in the coating start region 3-L1 was 89%. The other conditions in Examples 10 and 11 were the same as in Example 1. The coating weights of titanium carbide and titanium nitride were each 5% by volume.

The apparatus used in Runs 10-2 and 11-2 was of the same type as used in Example 2; the dispersity (β) value attainable in these runs was the same as in Runs 10-1 and 11-1; a metallic titanium powder having an average particle diameter of 25 μm was supplied as a feed for coat forming substance from the feeder 215 at a rate of 0.5 g/min, and the pseudo-fine diamond or cubic boron nitride core particles were supplied from the feeder 214 at a rate of 2.5 g/min; the other conditions in Runs 10-2 and 11-2 were the same as in Example 2. The apparatus used in Run 11-3 was of the same type as used in Example 3; a zirconium powder having an average particle diameter of 25 μm was supplied as a feed for coat forming substance from the feeder 314 at a rate of 0.5 g/min and the pseudo-fine cubic boron nitride core particles were supplied from the feeder 313 at a rate of 2.0 g/min; the other conditions in Run 11-3 were the same as in Example 3. In Runs 10-2, 11-2 and 11-3, the coating weights of metallic titanium and zirconium were each 10% by volume.

The apparatus used in Runs 10-3, 10-4, 11-4 and 11-5 was of the same type as used in Example 1 and operated under generally the same conditions as in Example 1 to prepare the following in the respective runs: pseudo-fine diamond particles first coated with 5 vol% TiC, then with 50 vol% alumina; pseudo-fine diamond particles coated with 10 vol% TiC; pseudo-fine cubic boron nitride particles coated with 50 vol% alumina; and pseudo-fine cubic boron nitride particles coated with 10 vol% TiN.

The coated pseudo-fine diamond and cubic boron nitride particles were examined with a scanning electron microscope. All of the particles prepared in Examples 10 and 11 were uniformly covered with superfine particles (ca. 0.005 μm) of coat forming substances (TiC, TiN, Ti and Zr) as in Example 3 and as Fig. 29 (for the particular case of Run 10-1) and Fig. 30 (for the particular case of Run 11-1) show.

The thus prepared powders of pseudo-fine coated diamond or cubic boron nitride particles, or mixtures thereof with the bonding materials listed in Table 7 or 8 were shaped, set in the various types of sinter apparatus shown in Tables 7 and 8, and sintered under the various sintering conditions also set forth in Tables 7 and 8. Thereafter, the temperature was lowered and the pressure reduced for recovering the sinters. The specific procedures were as follows.

In Runs 10-1 and 10-2, 60% by volume of the powders of pseudo-fine diamond particles coated with TiC and Ti, respectively, were wet mixed in acetone with 40% by volume of bonding materials that were the powders of fine coated diamond particles as prepared by coating fine diamond particles of 0.5 - 2 μm in diameter (average diameter = 1 μm) with 15 vol% of TiC under generally the same conditions. In Runs 11-1, 11-2 and 11-3, 60% by volume of the powders of pseudo-fine cubic boron nitride particles coated with TiN, Ti and Zr, respectively, were wet mixed in acetone with 40% by volume of bonding materials that were the powders of fine coated cubic boron nitride particles as prepared by coating fine cubic boron nitride particles of 0.5 - 2 μm in diameter (average diameter = 1 μm) with 15 vol% of TiC under generally the same conditions. Thereafter, the resulting wet mixtures were shaped, vacuum dried and sintered with a cubic ultrahigh pressure apparatus as in Example 3.

In Runs 10-3 and 11-4, the powder of TiC and alumina coated pseudo-fine diamond particles and the powder of alumina coated fine cubic boron nit ride particles, respectively, were stamped into disks having a diameter of 8 mm and a thickness of 5 mm; the disks were placed in Pyrex glass capsules packed with a h-BN powder. After degassing at 10^{-6} torr by heating at 400°C for 12 h, the capsules were sealed, set in a HIP apparatus using an argon gas as a pressure-transmitting medium and sintered under the conditions set forth in Tables 7 and 8.

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In Runs 10-4 and 11-5, the powder of TiC coated pseudo-fine diamond particles and the powder of TiN coated fine cubic boron nitride particles were respectively wet mixed in 40% by volume as in Run 8-2 with the associated bonding materials that were 53.4%, 0.6% and 1.0% by volume of the high-purity and easily sintrable alumina, magnesia (MgO) and titania (TiOx; x = 1 - 2) which were used in Run 8-1. The mixtures were vacuum dried, shaped into disks, placed into capsules, degassed, sealed, set in a HIP apparatus and sintered under the conditions set forth in Tables 7 and 8.

The sinters thus produced were measured for their density and Vickers microhardness Hv (0.5/10). The results are shown in Tables 7 and 8 together with the sintering conditions and the types of sinter apparatus used.

As for the Vickers microhardness Hv (0.5/10) measurement of the sinters of the coated psudo-fine particles, the hardness values obtained by the measurement were the values of the psudo-fine particles and not the values of the sinters, since particles sizes of the psudo-fine particles were larger than those of the fine particles and the hardness values of the sinters could not be measured. Therefore, in Tables 7 and 8 the Vickers microhardness values of the sinters were not shown.

The sinters were also checked for their crystalline phases by powder X-ray diffraction. In Examples 10 and 11, no diffraction peaks were observed except for the core particles (diamond or cubic boron nitride), coating materials (TiC, TiN and α-alumina), the products of reaction between the core particles and the metallic coating materials (TiC, ZrC, TiN, TiB_2, ZrN and ZrB_2) and the bonding materials (the diamond or cubic boron nitride in the core particles, TiC or TiN and α-alumina as the coating materials). Take, for example, Runs 10-1 and 10-2; in these cases, the only diffraction peaks observed were those for diamond and TiC. In the other runs, the only diffraction peaks observed were those for the following: diamond, TiC and α-alumina (Runs 10-3 and 10-4); cubic boron nitride and TiN (Run 11-1); cubic boron nitride, TiN and TiB_2 (Run 11-2); cubic boron nitride, TiN, ZrN and ZrB_2 (Run 11-3); cubic boron nitride and α-alumina (Run 11-4); and cubic boron nitride, TiN and α-alumina (Run 11-5). Quantification by X-ray analysis showed that the sinter of Run 10-2 consisted of 87% diamond and 13% TiC; the sinter of Run 11-2 consisted of cubic boron nitride, TiN and TiB_2 in proportions of about 87%, 10% and 3%, respectively, by volume; and the sinter of Run 11-3 consisted of cubic boron nitride, ZrN, ZrB_2 and TiN in proportions of about 86%, 2%, 1% and 11%, respectively, by volume.

The polished surface of the sinter of Run 10-1 was coated with a gold film by a customary evaporation technique and examined with an electron microscope. The result is shown in the Fig. 31 electron micrograph (X5000), in which the dark area represents the diamond and the light area TiC. As one can see from Fig. 31, the sinter was entirely free from pores and could be sintered to a relative density of 99%. In addition, it had no portion left unsintered. In areas where pseudo-fine diamond particles and/or fine diamond particles contacted each other via a thin layer of the coat forming substance, the latter was bursted by the contiguous pseudo-fine diamond particles and/or fine diamond particles, which hence were coupled directly as a result of sintering. In all other areas, TiC was distributed uniformly around the pseudo-fine diamond particles, rendering the sinter to be characteristic in that the coated pseudo-fine diamond particles had a dense, uniform and extremely highly controlled distribution. The diamond particles in the sinter were also characterized in that they did not grow at all compared to the particles in the feed powder. It has herefore been impossible to produce sinters having such an extremely highly controlled microstructure. Fig. 32 is an electron micrograph (X5000) showing a polished surface of the sinter of Run 11-1 and this was taken by the same method as used to prepare Fig. 31. Again, this sinter had established therein a microstructure in which pseudo-fine cubic boron nitride particles and/or fine cubic boron nitride particles and TiN as the coat forming substance were distributed uniformly, densely and in an extremely highly controlled manner.

Thus, in spite of the fact that diamonds and cubic boron nitrides are inherently very difficult to sinter, the coated pseudo-fine diamond and high-pressure phase boron nitride particles prepared in accordance with the invention behaved as if they were comparatively easy-to-sinter particles under industrially feasible ultrahigh pressures and elevated temperatures, thereby forming dense, rigid and superhard structures.

The sinters thus produced in Examples 10 and 11 were similar to that produced in Example 3 in that they were sinters or composite sinters that were superhard and which had dense, uniform and highly controlled microstructures with substantially uniform distributions of the bonding materials.

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Table 7

Ex. or Run No.	Relative Proportions (vol %)										Sintering Conditions				Sinter
	Core Particle	Coating Material					Bounding Material Powder				Pressure	Temperature	Time	Sinter Apparatus	Density
	Diamond	TiC	Ti	Zr	Al_2O_3		Core Particle: Diamond	Coating material: TiC	Al_2O_3	MgO/TiOx	GPa	°C	min		%
3	27	-	-	3	-		59.5	10.5	-	-	5.5	1450	30	CB	≥99
10-1	57	3	-	-	-		34	6	-	-	5.5	1450	30	CB	≥99
10-2	54	-	6	-	-		34	6	-	-	5.5	1450	30	CB	≥99
10-3	45	5	-	-	50		-	-	-	-	0.15	1200	180	HIP1	≥99
10-4	36	4	-	-	-		-	-	53.4	0.6/1.0	0.15	1300	180	HIP1	≥99

Table 8

Run. No.	Relative Proportions (vol %)												Sintering Conditions			Sinter
	Core Particle	Coating Material						Bounding Material Powder					Pressure	Temperature	Time	Sinter Apparatus	Density
	CBN	TiN	Ti	Zr	Al_2O_3			Core Particle	Coating material				GPa	°C	min		%
								CBN	TiN	Al_2O_3	MgO/TiOx						
11-1	57	3	-	-	-			34	6	-	-		5.5	1450	30	CB	≥99
11-2	54	-	6	-	-			34	6	-	-		5.5	1450	30	CB	≥99
11-3	27	-	-	3	-			59.5	10.5	-	-		5.5	1450	30	CB	≥99
11-4	50	-	-	-	50			-	-	-	-		0.15	1200	180	HIP1	≥99
11-5	36	4	-	-	-			-	-	53.4	0.6/1.0		0.15	1300	180	HIP1	≥99

Claims

1. A process for producing a diamond or high-pressure phase boron nitride sinter comprising the step of preparing coated diamond or high-pressure phase boron nitride particles and sintering said coated diamond or high-pressure phase boron nitride particles or mixtures containing such particles or mixtures of coated diamond or high-pressure phase boron nitride particles with bonding material,

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures no less than 2000 MPa and at elevated temperatures; or

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures of less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable; or

sintering said mixtures of coated diamond or high-pressure phase boron nitride particles with a bonding material in a volume ratio of (1 - 90):(99 - 10), said bonding material being sintrable to a density of at least 85% at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such conditions that diamond and/or high-pressure phase boron nitride particles are thermodynamically metastable, at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond and/or high-pressure phase boron nitride is thermodynamically metastable if not stable.

wherein said coated diamond or high-pressure phase boron nitride particles are prepared by a method comprising the steps of charging a powder of diamond or high-pressure phase boron nitride core particles into a coating space and then permitting a precursor of a coat forming substance which is generated via the vapor phase and/or a precursor of a coat forming substance in a vapor-phase state to contact and/or impinge against the particles in said powder of core particles so that their surfaces are coated with the coat forming substance and

said coated diamond or high-pressure phase boron nitride particles are prepared by coating means comprising:

(A) a dispersing step in which the particles in the powder of core particles are dispersed by a group of means for high dispersion treatment of particles in a gaseous atmosphere to form a mixture of a gas and the particles in a powder of highly dispersed particles, the final treating means in said group of means for high dispersion treatment of particles being selected from between:

(a) dispersing means for dispersing the particles in the powder of core particles in a gaseous atmosphere; and

(b) means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles which comprises:

(b-1) means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles that separates a portion of the powder that is composed of less highly dispersed particles from the mixture of a gas and the particles in the powder of core particles in which the particles in the powder of core particles are dispersed in a gaseous atmosphere, thereby selecting a mixture of a gas and the particles in a powder of highly dispersed core particles in which the particles in the powder of core particles are present in the gaseous atmosphere mainly in a single-particle state; and

(b-2) feedback means by which the portion of the powder that is composed of less highly dispersed particles and which has been separated by said means for selecting a mixture of a gas and the particles in a powder of highly dispersed particles is transported to the final dispersing means among the dispersing means in the group of means for high dispersion treatment of particles and/or treating means upstream of the final dispersing means; and

(B) a coating step in which the particles in the powder of core particles that have been dispersed in the dispersing step (A) start to be coated by being allowed to contact and/or impinge against the precursor of the coat forming substance in the coating start region of the coating space as they are dispersed to satisfy the following conditions:

the dispersity β should be at least 70% if those particles have an average diameter of no more than 10 μm in the frequency distribution by volume;

the dispersity β should be at least 80% if those particles have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume;

the dispersity β should be at least 90% if those particles have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume;

the dispersity β should be at least 95% if those particles have an average diameter in excess of 50 μm

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but no more than 300 μm in the frequency distribution by volume;

the dispersity β should be at least 97% if those particles have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume; and

the dispersity β should be at least 99% if those particles have an average diameter in excess of 800 μm in the frequency distribution by volume, and wherein said sintering step is performed by

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures no less than 2000 MPa and at elevated temperatures; or

sintering said coated diamond or high-pressure phase boron nitride particles or said mixtures containing such particles at pressures of less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond or high-pressure phase boron nitride is thermodynamically metastable if not stable; or

sintering said mixtures of coated diamond or high-pressure phase boron nitride particles with a bonding material in a volume ratio of (1 - 90):(99 - 10), said bonding material being sintrable to a density of at least 85% at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such conditions that diamond and/or high-pressure phase boron nitride particles are thermodynamically metastable, at pressures less than 2000 MPa and at temperatures not exceeding 1850°C under such sintering pressure and temperature conditions that diamond and/or high-pressure phase boron nitride is thermodynamically metastable if not stable.

2. A process for producing a diamond or high-pressure phase boron nitride sinter according to claim 1 wherein said coated diamond or high-pressure phase boron nitride particles are prepared through the following additional step(s):

a step of disagglomeration or otherwise size reduction in which lumps of the coated diamond and/or high-pressure phase boron nitride particles that form as a result of association of several particles that contact one another via the coat forming substance on the coated particles are disagglomerated and/or otherwise reduced in size; and/or

a step of selective separation in which the associating lumps of the coated diamond or high-pressure phase boron nitride particles are selectively separated from the coated diamond or high-pressure phase boron nitride particles on a primary particle basis.

3. A process for producing a diamond or high-pressure phase boron nitride sinter according to claim 1 wherein the particles in the powder of diamond and/or high-pressure phase boron nitride core particles to be coated with the coat forming substance are coated by a dip method using a molten salt bath with one or more layers of the coat forming substance that derives from the dip method.

4. A process for producing a diamond or high-pressure phase boron nitride sinter according to claim 1, wherein the dispersing step is performed by:

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a

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powder of core particles having an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%; and

said coated diamond or high-pressure phase boron nitride particles being prepared by:

a method in which the mixture of a gas and the particles in the powder of highly dispersed core particles as formed by one of the means in said group of means for high dispersion treatment of particles is either discharged directly to the coating step or transported thereto via at least one member indispensable to transport that is selected from the group consisting of a hollow member, an intermediate member composed of a member that forms a hollow portion, and a pipe and which is provided between the dispersing and coating steps, as the mixture emerges from a discharge section that discharges said mixture of a gas and the particles; and/or

a method in which the mixture of a gas and the particles in the powder of highly dispersed core particles as formed by one of the means in said group of means for high dispersion treatment of particles is transported to the coating step via at least one means selected from the group consisting of means for maintaining the dispersion in a gaseous atmosphere of the highly dispersed core particles in the mixture of a gas with the core particles which have been dispersed in the gaseous atmosphere to attain one of the dispersities set forth above, means for enhancing the dispersion in a gaseous atmosphere of the highly dispersed core particles in the mixture of a gas with the core particles which have been dispersed in the gaseous atmosphere to attain one of the dispersities set forth above, and means for separating a mixture of a gas and the particles in a powder of less highly dispersed core particles from said gas-particle mixture so as to select a mixture of a gas and the particles in a powder of highly dispersed core particles in which the core particles are present in the gaseous atmosphere mainly in a single-particle state.

5. A process for producing a diamond or high-pressure phase boron nitride sinter according to claim 1 wherein the dispersing step is performed by:

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

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a group of means for high dispersion treatment of particles that has such dispersing performance that a powder of core particles having an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%; and

said coated diamond or high-pressure phase boron nitride particles being prepared by performing at least one part of the dispersing step in such a way that it shares one or more parts of the space with at least one part of the coating step.

6. A process for producing a diamond or high-pressure phase boron nitride sinter according to claim 1 wherein said coated diamond or high-pressure phase boron nitride particles are prepared with the coating start region of the coating space being located in either one of the following space regions that includes planes through which all particles in the powder of highly dispersed core particles as mixed with a gas will pass:

a space region in which a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a space region in which a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a space region in which a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a space region in which a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

a space region in which a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

a space region in which a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%, or wherein

said coated diamond or high-pressure phase boron nitride particles are prepared with the coating start region of the coating space being located in either one of the following space regions that includes planes through which all particles to be recovered into the recovery section of the recovery means will pass:

a space region in which a powder of core particles that have an average diameter of no more than 10 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 70%;

a space region in which a powder of core particles that have an average diameter in excess of 10 μm but no more than 20 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by said group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 80%;

a space region in which a powder of core particles that have an average diameter in excess of 20 μm but no more than 50 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles

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in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 90%;

a space region in which a powder of core particles that have an average diameter in excess of 50 μm but no more than 300 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 95%;

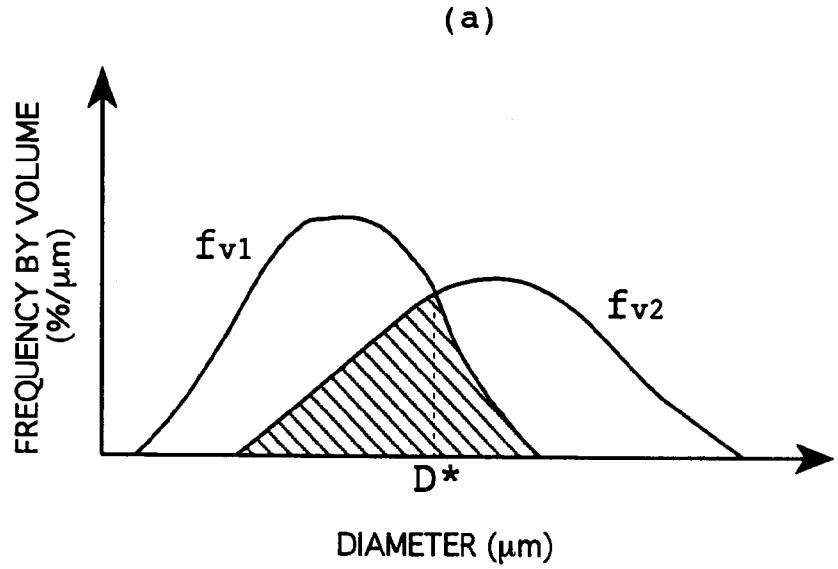
a space region in which a powder of core particles that have an average diameter in excess of 300 μm but no more than 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 97%; and

a space region in which a powder of core particles that have an average diameter in excess of 800 μm in the frequency distribution by volume is dispersed in a gaseous atmosphere by the final treatment by the group of means for high dispersion treatment of particles, thereby forming a mixture of a gas and the particles in the powder of highly dispersed core particles and that the dispersity β of the particles in said powder of core particles is adjusted to at least 99%.

7. A process for producing a diamond or high-pressure phase boron nitride sinter according to claim 1 wherein the particles in the powder of core particles to be used have a size distribution of ($[D_M/5, 5D_M]$, $\geqq$ 90%) in terms of frequency distribution by volume, where D_M represents the average particle diameter.

8. A diamond or high-pressure phase boron nitride sinter that is produced by either one of the processes for producing a diamond or high-pressure phase boron nitride sinter as recited in claims 1 - 7.

FIG.1


(a)
FREQUENCY BY VOLUME (%/μm)
fv1
fv2
D*
DIAMETER (μm)

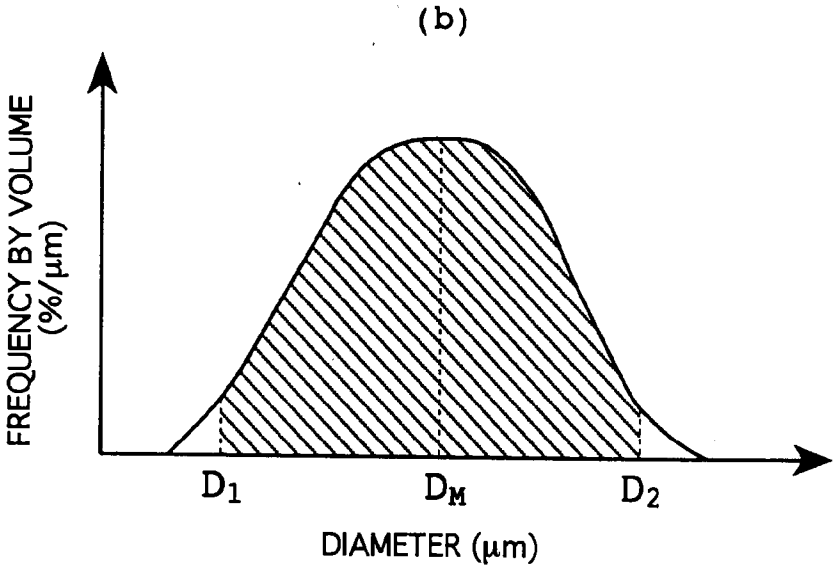
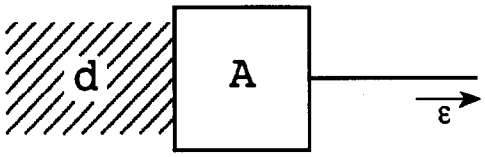
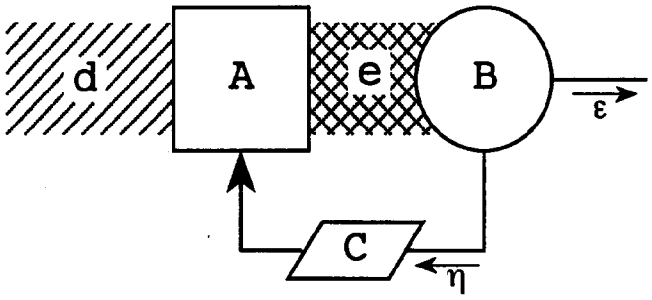

(b)
FREQUENCY BY VOLUME (%/μm)
D1
DM
D2
DIAMETER (μm)

FIG.2

(a)



(b)



(c)

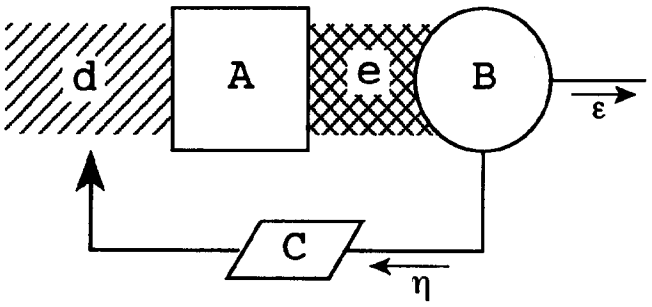


FIG.3

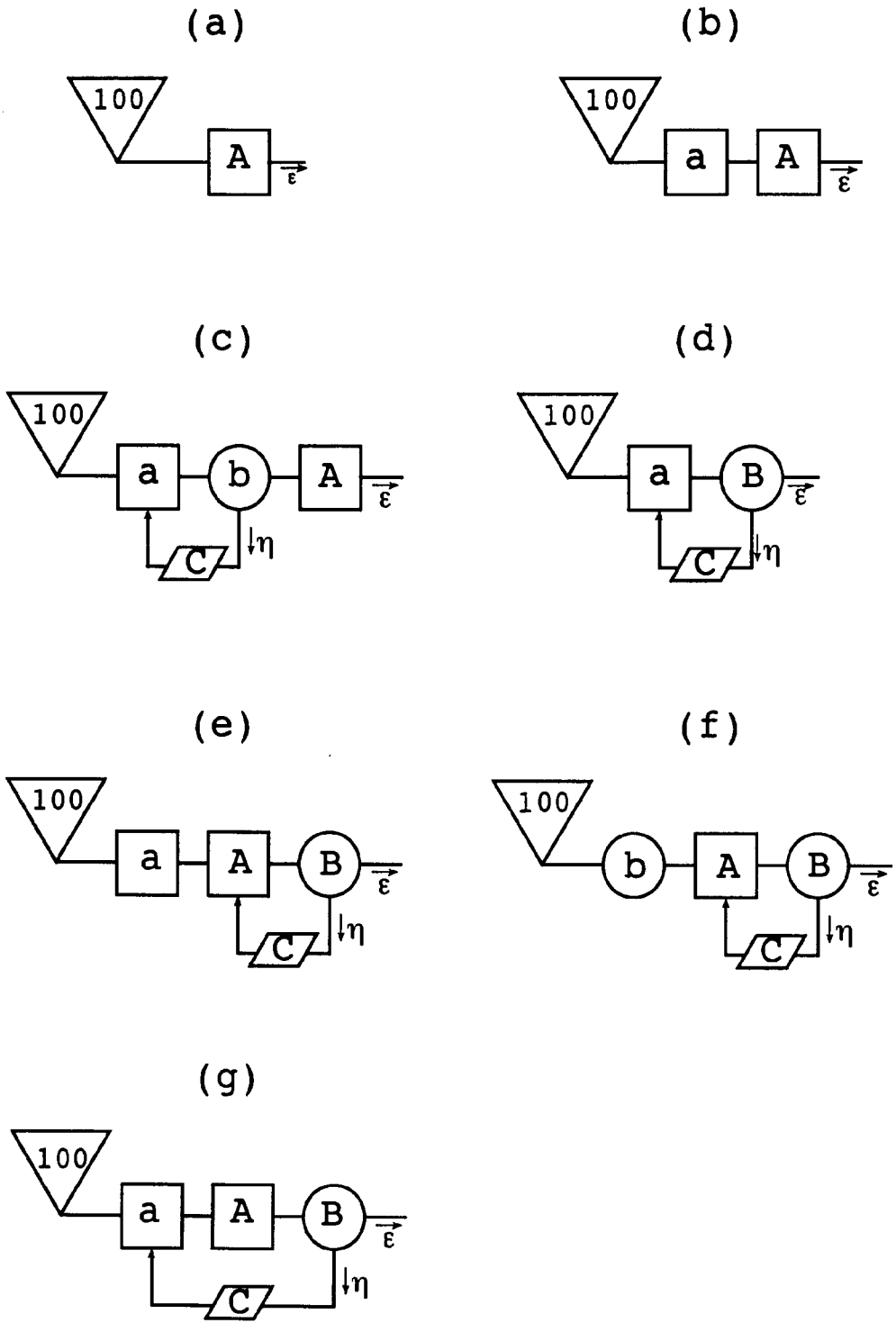

(a)
100
A
ε
(b)
100
a
A
ε
(c)
100
a
b
A
ε
C
η
(d)
100
a
B
ε
C
η
(e)
100
a
A
B
ε
C
η
(f)
100
b
A
B
ε
C
η
(g)
100
a
A
B
ε
C
η

FIG.4

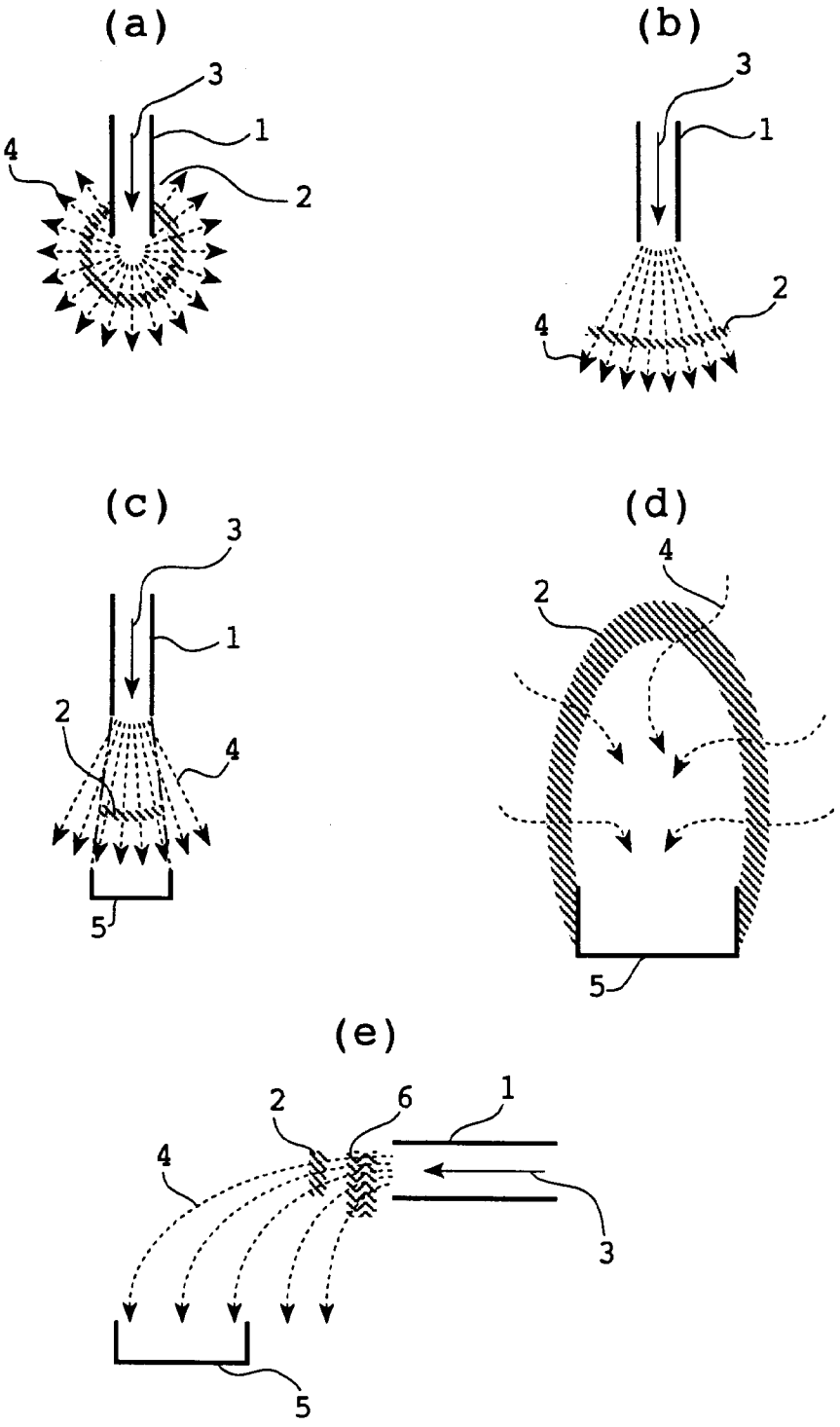


FIG. 5

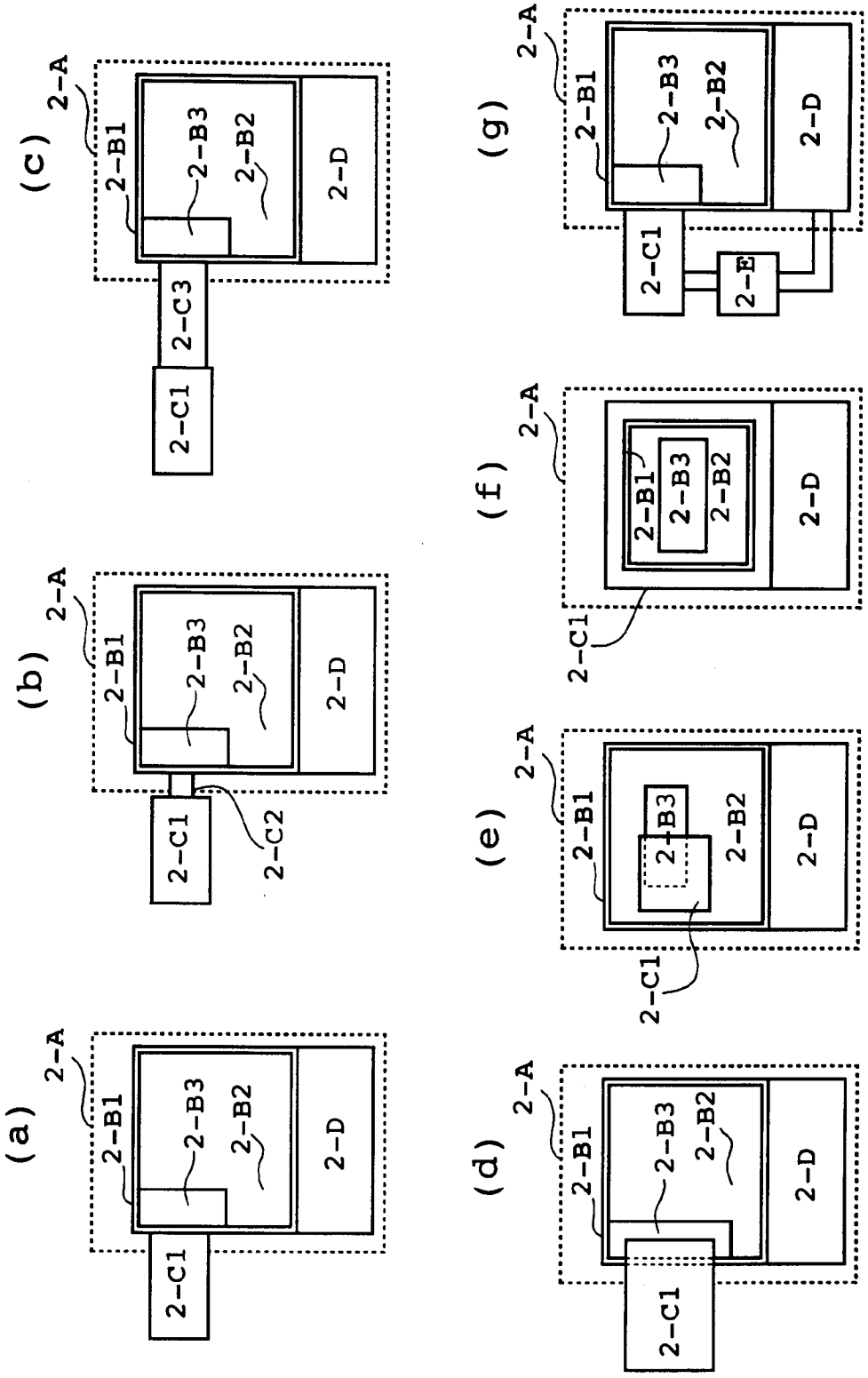

(a)
2-A
2-B1
2-B3
2-B2
2-D
2-C1
(b)
2-A
2-B1
2-B3
2-B2
2-D
2-C1
2-C2
(c)
2-A
2-B1
2-B3
2-B2
2-D
2-C3
2-C1
(d)
2-A
2-B1
2-B3
2-B2
2-D
2-C1
(e)
2-A
2-B1
2-B3
2-B2
2-D
2-C1
(f)
2-A
2-B1
2-B3
2-B2
2-D
2-C1
(g)
2-A
2-B1
2-B3
2-B2
2-D
2-C1
2-E

FIG.6

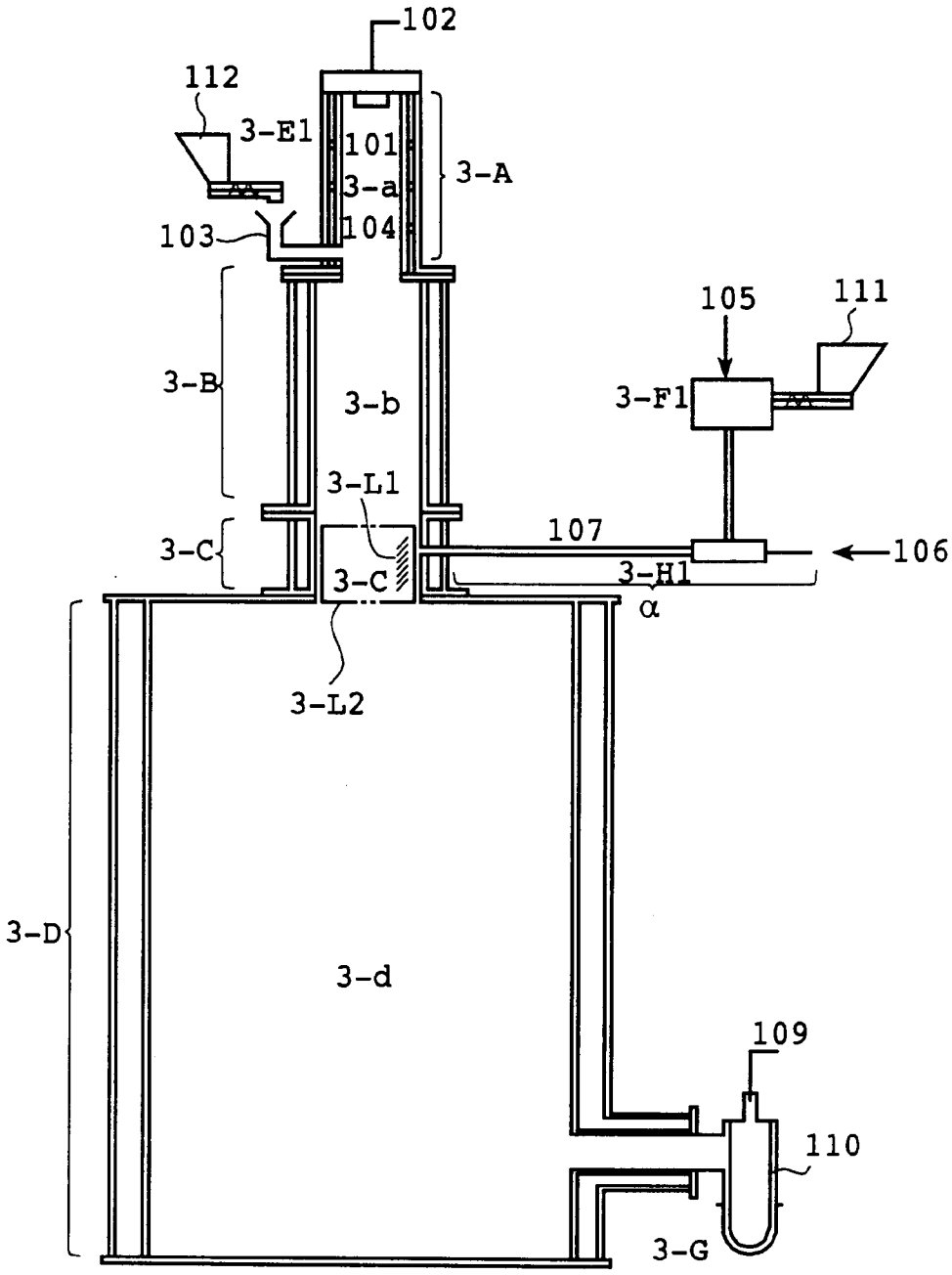

102
112
3-E1
101
3-a
104
3-A
103
105
111
3-B
3-b
3-F1
3-L1
107
106
3-C
3-C
3-H1
α
3-L2
3-D
3-d
109
110
3-G

FIG.7

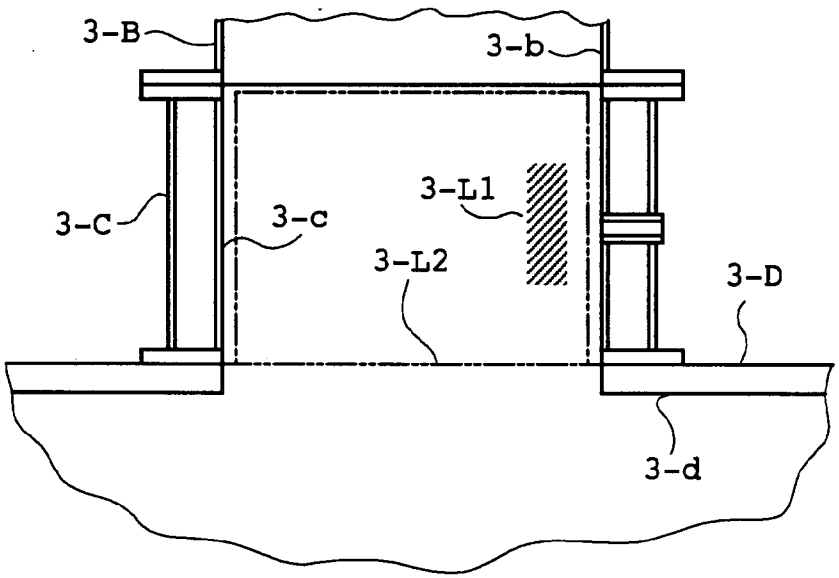


FIG.8



FIG.9

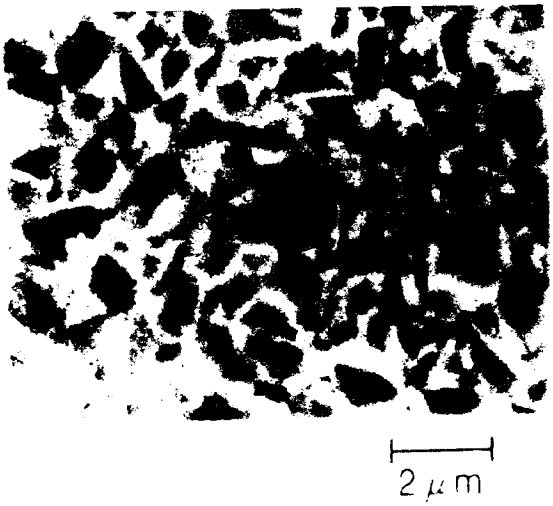


FIG.10

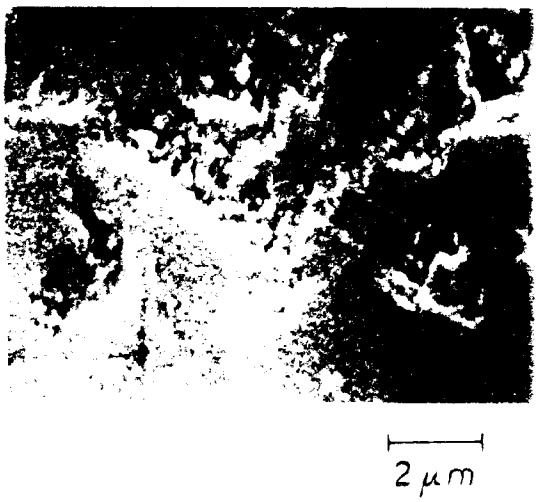


FIG.11

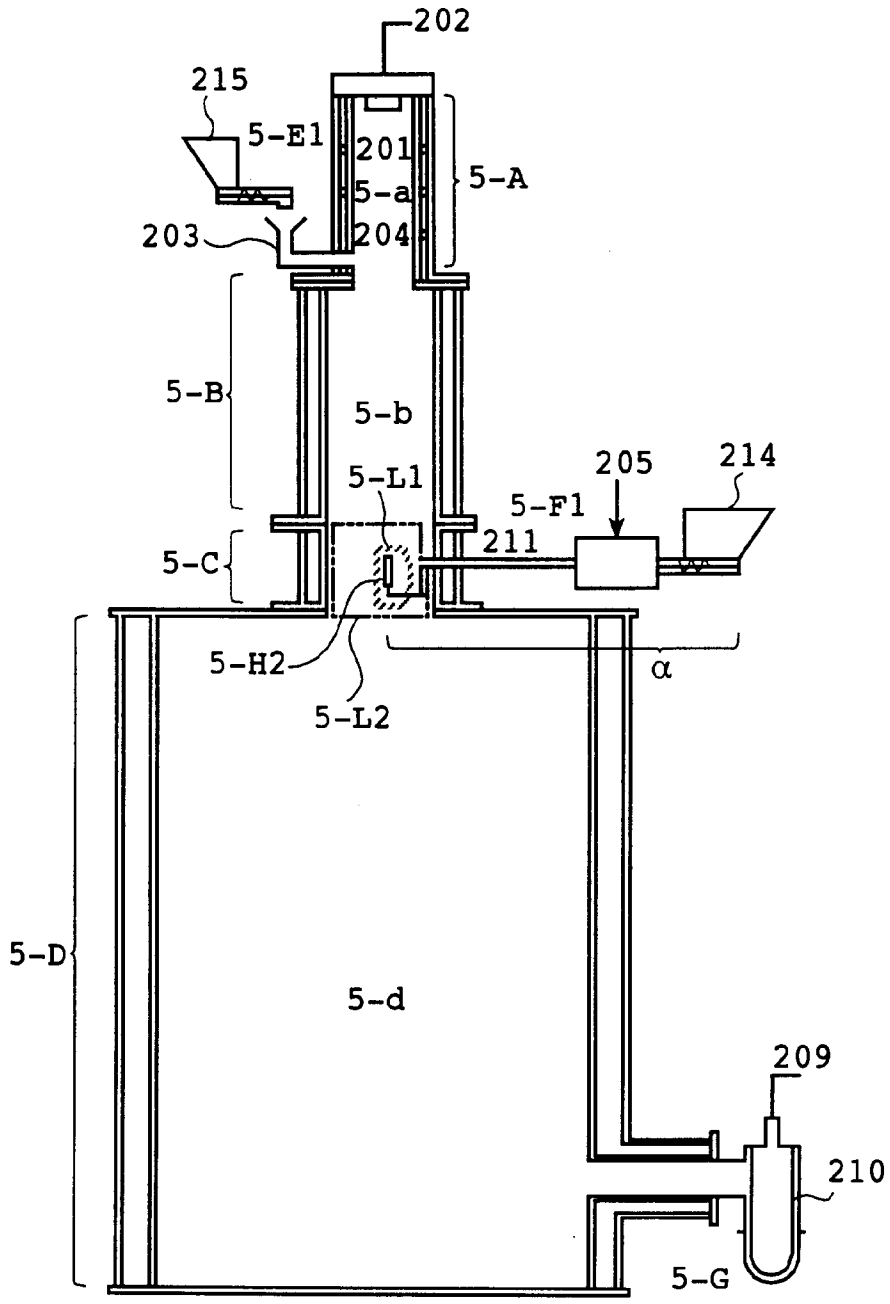

202
215
5-E1
201
5-A
5-a
203
204
5-B
5-b
205
214
5-L1
5-F1
211
5-C
5-H2
α
5-L2
5-D
5-d
209
210
5-G

FIG.12

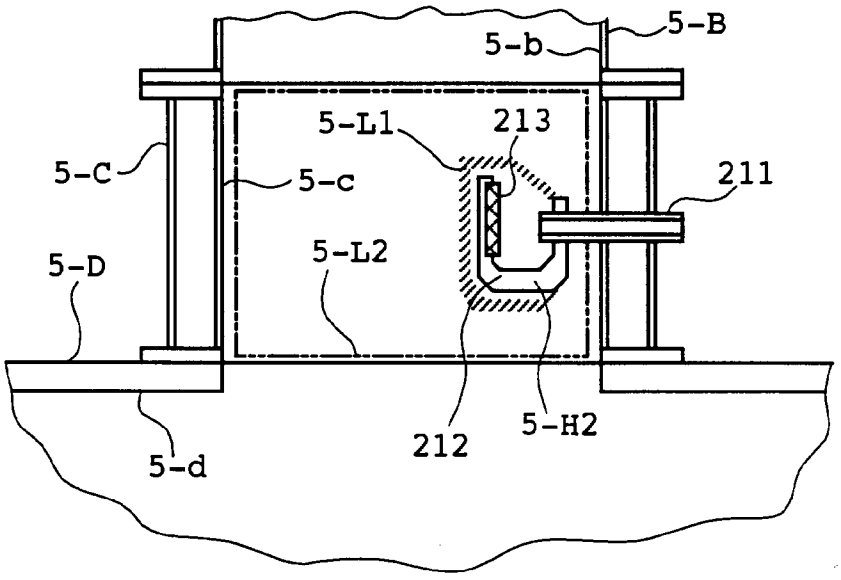


FIG.13

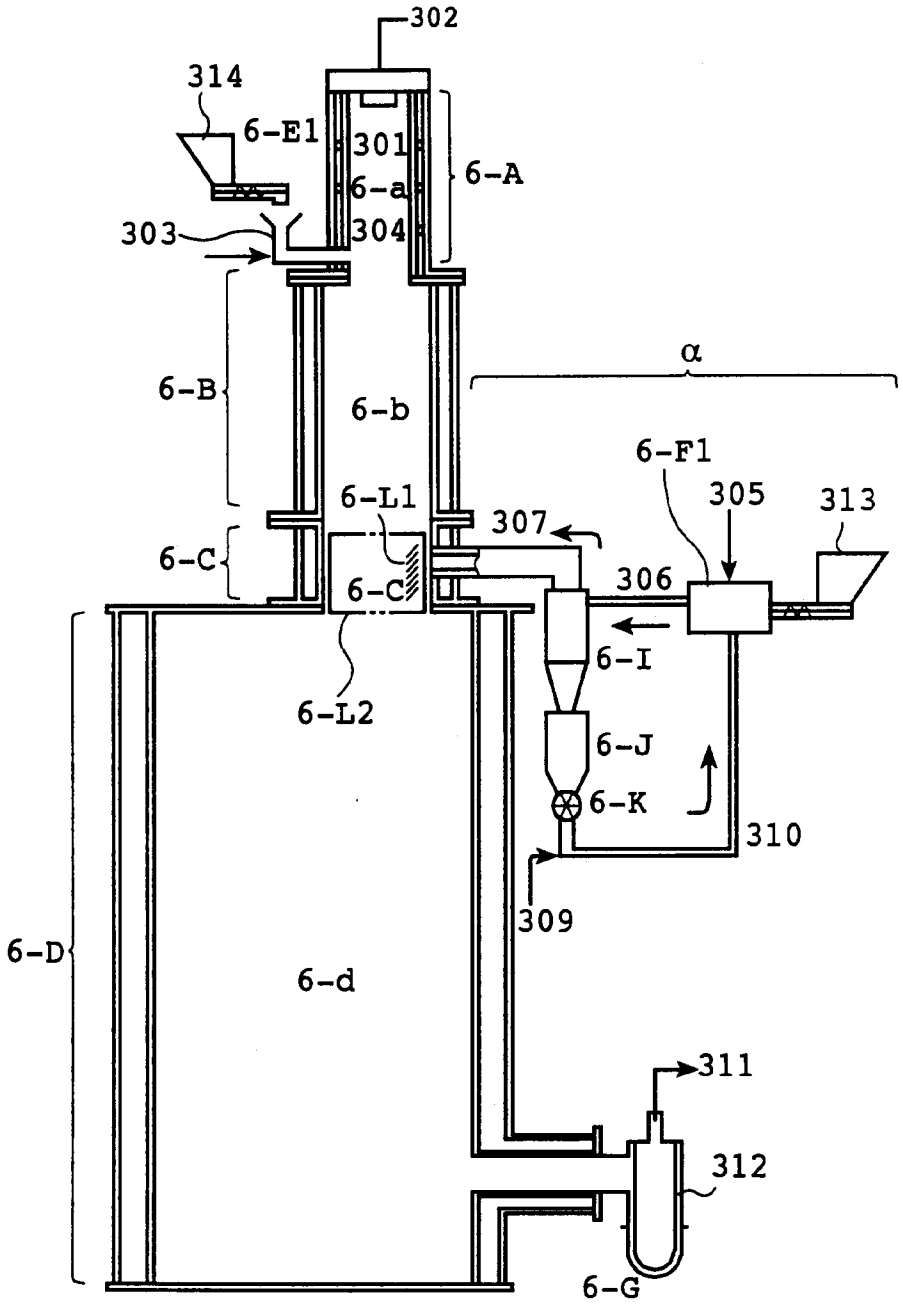

302
314
6-E1
301
6-A
6-a
303
304
α
6-B
6-b
6-F1
305
313
6-L1
307
6-C
6-C
306
6-I
6-L2
6-J
6-K
310
309
6-D
6-d
311
312
6-G

FIG.14

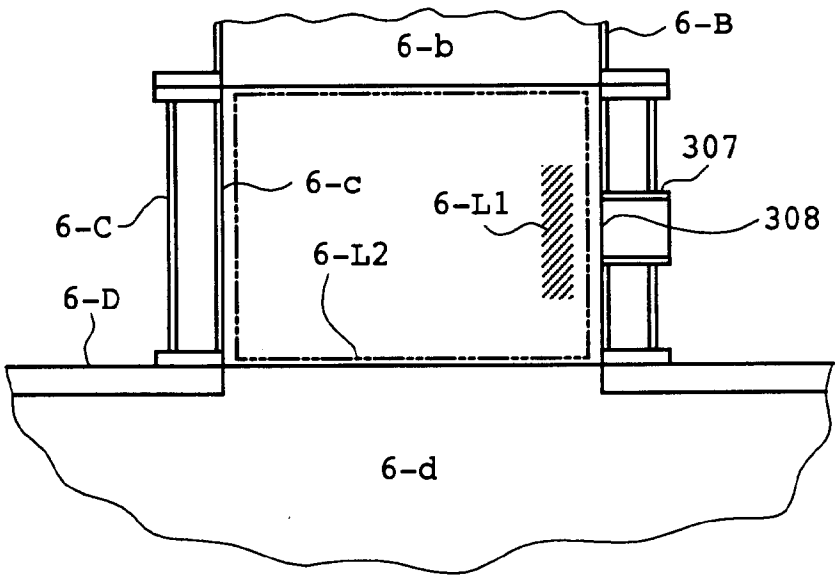


FIG.15



FIG.16

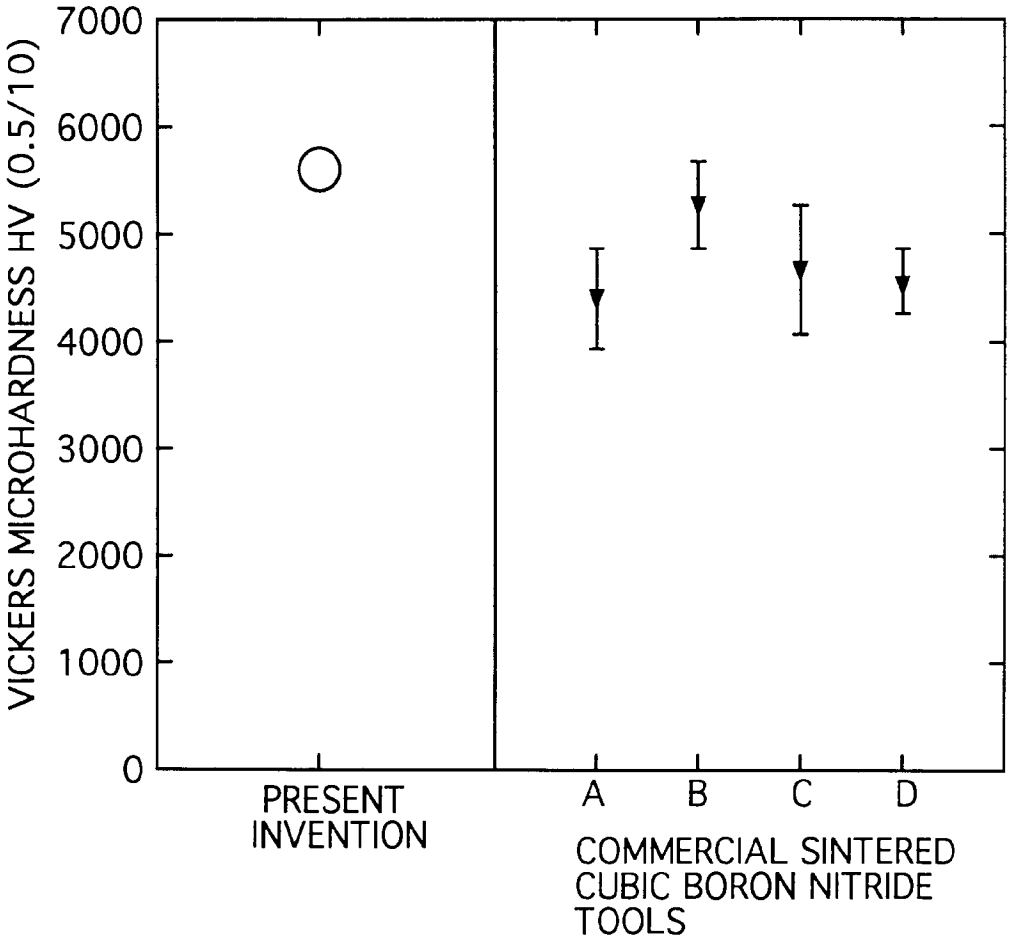

VICKERS MICROHARDNESS HV (0.5/10)
7000
6000
5000
4000
3000
2000
1000
0
PRESENT INVENTION
A
B
C
D
COMMERCIAL SINTERED CUBIC BORON NITRIDE TOOLS

FIG.17



FIG.18

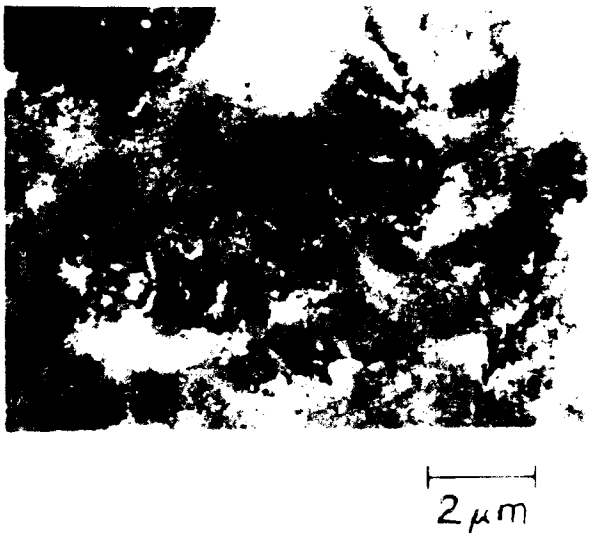


FIG.19



FIG.20

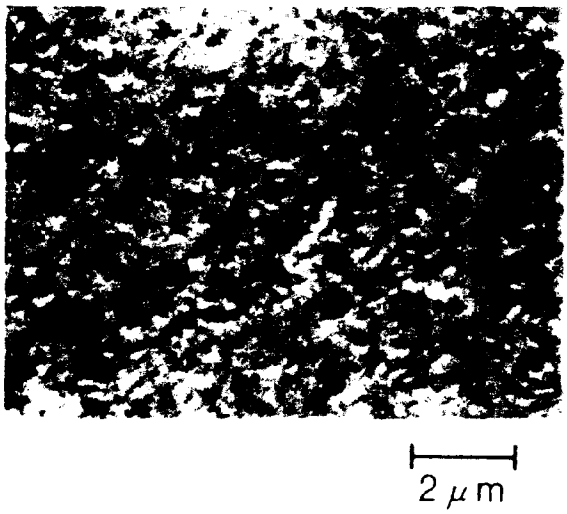


FIG.21

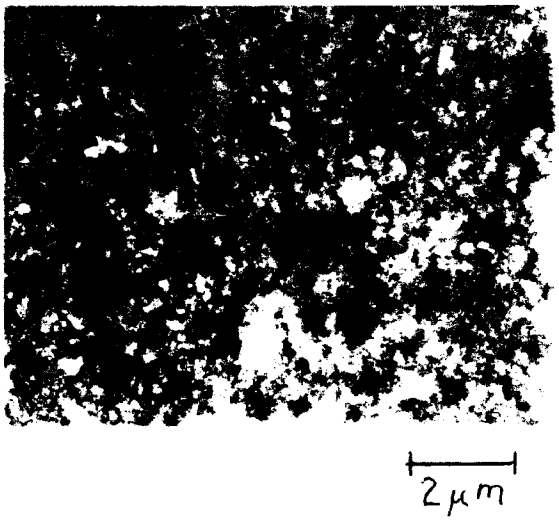


FIG.22



FIG.23

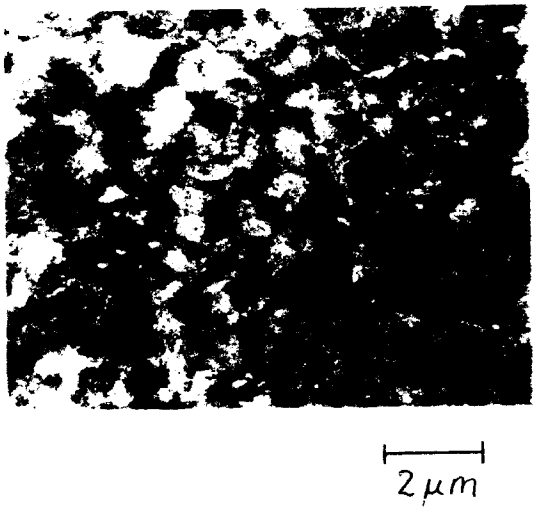


FIG.24

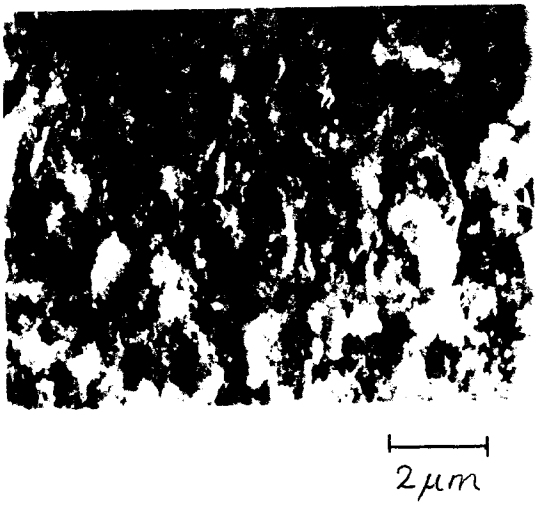


FIG.25

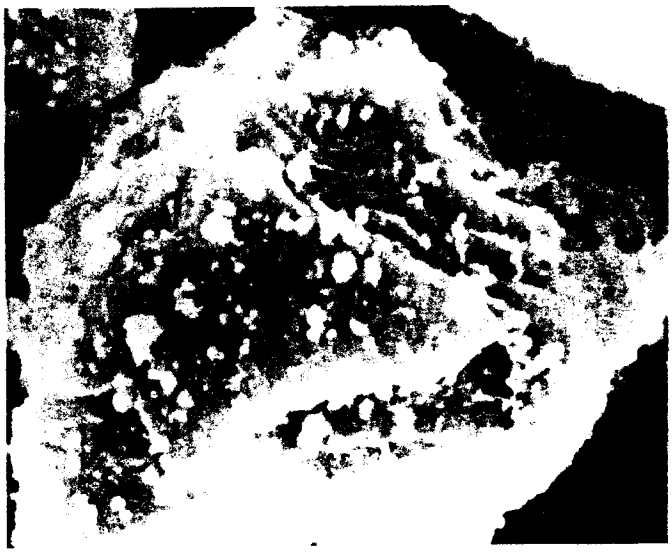


FIG.26

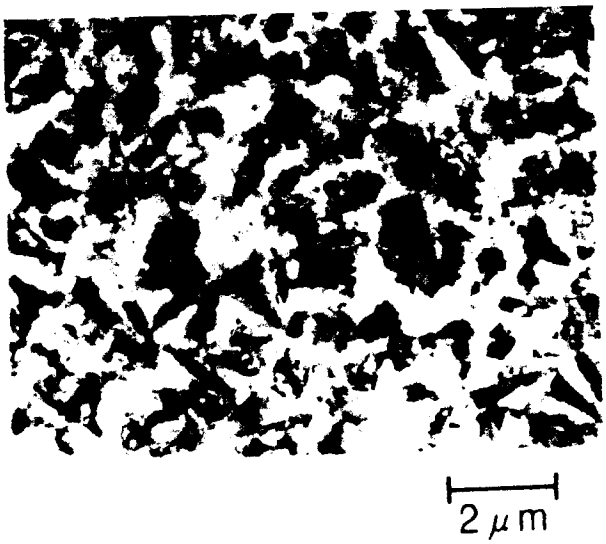


FIG.27



FIG.28

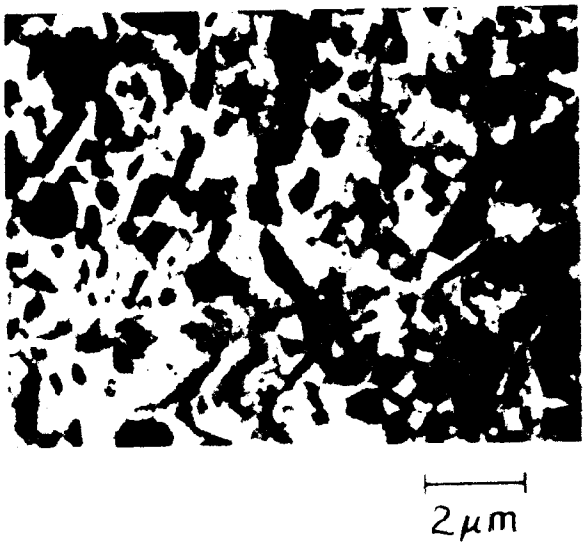


FIG.29



FIG.30

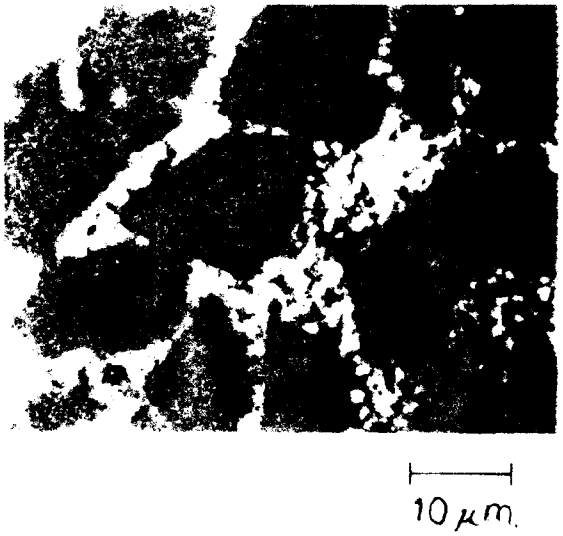


FIG.31



FIG.32

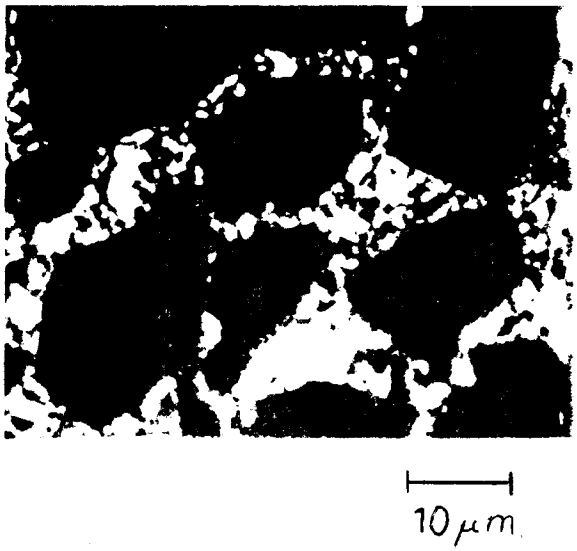


FIG.33a

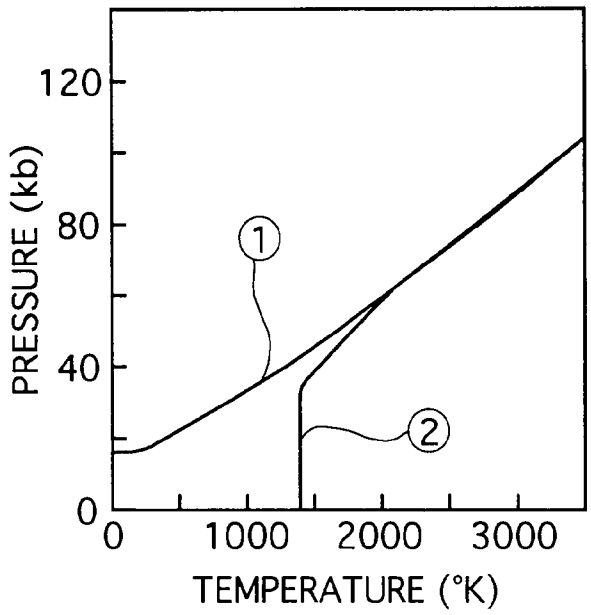
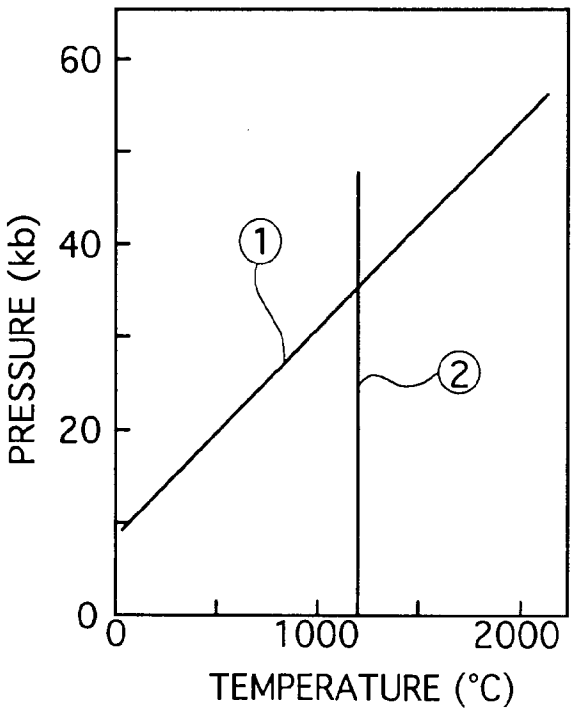


FIG.33b



European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 94 11 8222

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.6)
X	EP-A-0 273 573 (GA TECHNOLOGIES INC) 6 July 1988 * page 3, line 3 - line 29 *	1,2,4-8	C23C14/22
X	GB-A-2 214 195 (INCO LTD) 31 August 1989 * page 4, line 21 - page 5, line 31 *	1,2,4-8	
A,D	GB-A-2 242 443 (NISSHIN FLOUR MILLING CO) 2 October 1991 * example 4 *	1-8	
A,D	PATENT ABSTRACTS OF JAPAN vol. 014 no. 202 (C-0713) ,25 April 1990 & JP-A-02 043377 (SEIJI MOROOKA;OTHERS: 01) 13 February 1990, * abstract *	1-8	

TECHNICAL FIELDS SEARCHED (Int.Cl.6)

C23C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	26 April 1995	Schruers, H

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

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(54) Single-crystal diamond of very high thermal conductivity

(57) Single-crystal diamond consisting of isotopically pure carbon-12 or carbon-13 has been found to have a thermal conductivity higher than that of any substance previously known, typically at least 40% higher than that of naturally occurring IIA diamond. It may be prepared by a method comprising comminution of diamond of high isotopic purity, such as that obtained by low pressure chemical vapor deposition employing an isotopically pure hydrocarbon in combination with hydrogen, followed by conversion of the comminuted diamond to single-crystal diamond by diffusion under high pressure through a metallic catalyst-solvent material to a region containing a diamond seed crystal.

GB 2 239 011 A

SINGLE-CRYSTAL DIAMOND OF VERY HIGH THERMAL CONDUCTIVITY

This invention relates to the preparation of single crystal diamond of extremely high thermal conductivity.

Diamond substances with high thermal conductivity are known in the art. For example, type IIA natural diamond, characterized by a very high degree of purity, has a thermal conductivity at 25°C (298°K) on the order of 21 watts/cm.°K, the highest of any material known prior to the present invention. Its electrical conductivity, on the other hand, is so low as to be negligible.

These properties make diamond an excellent material for conducting heat away from heat-generating objects or units. It may be used as a heat sink or as a conductor/spreader to conduct heat from the heat-generating object or unit to a heat sink of some other material.

Various areas exist in which heat conductors of very high thermal conductivity are necessary. One example is in repeating stations for fiber optic networks. Signals are transmitted by laser light over the fibers of such networks for very great distances. Since these signals decrease substantially in intensity over several kilometers, it is necessary to construct "repeating stations" periodically along the network, for the purpose of increasing the intensity of the light transmitted along the network. In a typical repeating station of this type, a photodetector is employed to convert the weakened signal transmitted by fiber optics to an electrical signal, which is then magnified, reconverted to a light signal by a light-emitting diode, and transmitted in turn along the next segment of the network.

In order to minimize the requisite number of repeating stations, optimum magnification of the signal in any station is desirable. However, the amount of radiant energy of any kind generated electrically is proportional to the fourth power of the current employed. While a portion of such radiant energy is in the form of light, the remainder thereof is lost as heat. In any individual station, therefore, very large amounts of heat are generated, requiring efficient heat conductors to maintain the operativeness of the repeating station.

The use of natural type IIA diamond as a conductor of heat in these areas has not been foreclosed despite its very high cost since the operative heat-conducting units are very small, typically about 1 mm. on a side. When larger heat-conducting elements are required, expense considerations become important and the use of natural diamond may accordingly be foreclosed.

Conventionally produced high-pressure synthetic diamond of gem quality is lower in cost than natural diamond. However, synthetic diamond of this type having high thermal conductivity cannot effectively be produced directly from graphite because a profound contraction in volume occurs in the conversion and introduces imperfections into the crystalline structure. For the most part, diamond prepared by low-pressure chemical vapor deposition (hereinafter sometimes "CVD") processes are not single crystal diamond and have substantially lower thermal conductivities, typically on the order of 12 watts/cm.°K at about 300°K (hereinafter sometimes "room temperature conductivity").

In U.S. Patent 3,895,313, there are disclosed various diamond materials which allegedly have very high thermal conductivities, and which allegedly are useful as optical elements for very high-power laser beams. In particular, it is stated that synthetic diamond grown from

isotopically pure carbon-12 or carbon-13 would be useful in this way, with room temperature conductivity values in the range of 10-20 watts/cm.°K being mentioned. This is, of course, the order of magnitude of natural type IIA diamond and also of diamond produced by chemical vapor deposition. It is further suggested that at a temperature of 70°K (-203°C), below the temperature of liquid nitrogen, a thermal conductivity exceeding 200 watts/cm.°K may be obtained, perhaps in diamond which has high isotopic purity and "relevant properties which closely approach the limits predicted by the theory of the perfect solid state" (i.e., are in single-crystal form). However, no methods for the preparation of such diamond are suggested, and the state of the art has hitherto been inadequate to put them in the possession of the public.

The present invention provides a method for preparing single-crystal diamond of very high chemical and isotopic purity. The raw material for such diamond is itself diamond, which eliminates the volume contraction encountered in the high-pressure conversion of graphite to diamond. The thermal conductivity of the diamond so produced has been found to be higher than that of any substance presently known including natural type IIA diamond, and also higher than the values in the aforementioned U.S. Patent 3,895,313. Accordingly, it is eminently suitable for use as a conductor of heat and also in numerous other areas.

In one of its aspects, the invention is a method for preparing single-crystal diamond of high isotopic purity which comprises the steps of:

(A) preparing diamond consisting of isotopically pure carbon-12 or carbon-13; and

(B) converting said diamond to single-crystal diamond by diffusion under high pressure through a metallic

catalyst-solvent material to a region containing a diamond seed crystal.

An essential feature of the method of this invention is the employment of isotopically pure carbon-12 or carbon-13. As explained hereinafter, it has been found that the increase in thermal conductivity resulting from the employment of chemically and isotopically pure carbon is vastly greater than would be expected based on theoretical considerations. In general, the isotopic purity of the hydrocarbon should be at least 99.2% by weight; that is, the other isotope should be present in a maximum amount of 8 parts per 1000. An isotopic purity of at least 99.9% by weight is preferred. The hydrocarbon should also have a high degree of chemical purity.

Various methods may be employed in step A for the preparation of diamond in isotopically pure form. For example, a gaseous carbon compound such as carbon monoxide may be separated into carbon-12 and carbon-13 species via differences in diffusivity and then converted to solid carbon by art-recognized means, such as combustion in a reducing flame in the case of carbon monoxide. The carbon thus formed may then be converted to diamond under conventional conditions, including high temperature and high pressure conditions or CVD conditions.

Alternatively, other methods may be employed including shock formation and CVD processes under conditions which produce a mixture of diamond and graphite. In processes of the latter type, the carbon-13 species will concentrate in the diamond phase and the carbon-12 species in the graphite phase. Other diamond precursors which may be employed in enriched form include pyrolytic graphite, amorphous or glassy carbon, liquid hydrocarbons and polymers.

It is usually found that conventional methods of CVD diamond formation are most convenient for the preparation of isotopically pure diamond. In such methods, a layer of diamond is deposited on at least one substrate. Any substrate material suitable for diamond deposition thereon may be employed; examples of such materials are boron, boron nitride, platinum, graphite, molybdenum, copper, aluminum nitride, silver, iron, nickel, silicon, alumina and silica, as well as combinations thereof. Metallic molybdenum substrates are particularly suitable under many conditions and are often preferred.

The method of chemical vapor deposition of diamond on a substrate is known, and the details need not be repeated herein. In brief, it requires high-energy activation of a mixture of hydrogen and a hydrocarbon, typically methane, whereupon the hydrogen gas is converted to atomic hydrogen which reacts with the hydrocarbon to form elemental carbon. Said carbon then deposits on the substrate in the form of diamond. Activation may be achieved by conventional means involving high-energy activation which produces atomic hydrogen from molecular hydrogen; such means include thermal means typically involving heated filaments, flame means, D.C. discharge means and radiation means involving microwave or radio-frequency radiation or the like.

Thermal and especially filament methods, employing one or more resistance heating units including heated wires or filaments, are often preferred for the purposes of this invention. In such methods, the filaments are typically of metallic tungsten, tantalum, molybdenum and rhenium; because of its relatively low cost and particular suitability, tungsten is often preferred. Filament diameters of about 0.2-1.0 mm. are typical, with about 0.8 mm. frequently being preferred. Distances from filaments to substrate(s) are generally on the order of 5-10 mm.

Said filaments are typically heated at temperatures of at least 2000°C and the optimum substrate temperature is in the range of 900-1000°C. The pressure in the deposition vessel is maintained up to about 760 torr, typically on the order of 10 torr. The hydrogen-hydrocarbon mixture generally contains hydrocarbon in an amount up to about 2% by volume based on total gases. For a description of illustrative CVD methods of diamond preparation, reference is made to copending, commonly owned applications U.S. Serial Nos. 07/389,210 and 07/389,212.

Isotopically pure hydrocarbon is employed in the CVD method, when used. In order to avoid contamination thereof, it is essential to employ equipment which does not contain natural carbon as an impurity. For this purpose, the CVD chamber should be constructed of materials substantially incapable of dissolving carbon. Typical materials of this type are quartz and copper.

As between carbon-12 and carbon-13, the former is usually preferred for various reasons. In the first place, carbon-12 is present in nature in much higher proportions than carbon-13, the latter typically occurring in amounts no higher than about 1% by weight; therefore, the use of carbon-12 involves minimum expense. In the second place, thermal conductivity is inversely proportional to the square of the mass number of the isotope, and diamond prepared from carbon-12 can therefore be expected to have a thermal conductivity about 17% greater than those prepared from carbon-13. In some applications, however, carbon-13 is preferred and its preparation and use are part of the invention.

The thickness of the CVD diamond layer deposited on the substrate is not critical. In general, it is convenient to deposit at least as much diamond as will be needed to produce a single crystal of the desired size. Of course, the

production of a larger amount of CVD diamond for use to make several crystals is also contemplated.

It is possible to convert the product of the CVD process directly to diamond of high thermal conductivity by high pressure means, as described hereinafter, employing the same in the form of a slab, sheet or broken pieces thereof. However, the method of this invention is most efficiently conducted if the isotopically pure diamond is first comminuted.

Comminution may be achieved by art-recognized means such as crushing and powdering. The particle size thereof is not critical so long as a sufficient degree of comminution is attained; the form known in the art as "grit diamond" is suitable.

Step B, the production of single crystal diamond, is conventional except that the isotopically pure diamond produced in step A is the raw material employed. Two things are achieved by using diamond rather than graphite or some other allotrope of carbon as the raw material: an easily obtained isotopically pure material may be employed, and the contraction in volume encountered in the conversion of graphite and other allotropes to diamond is avoided, permitting production of a single crystal of regular structure and high quality.

The process for producing single-crystal diamond under high pressure is also known in the art, and a detailed description thereof is not deemed necessary. Reference is made, for example, to Encyclopedia of Physical Science & Technology, vol. 6, pp. 492-506 (Academic Press, Inc., 1987); Strong, The Physics Teacher, January 1975, pp. 7-13; and U.S. Patents 4,073,380 and 4,082,185, for general descriptions of the process. It generally involves diffusion of the carbon employed as a source material through a liquid bath of a metallic catalyst-solvent material, at pressures on the order

of 50,000-60,000 atmospheres and temperatures in the range of about 1300-1500°C. A negative temperature gradient, typically of about 50°C, is preferably maintained between the material being converted and the deposition region, which contains a diamond seed on which crystal growth can begin.

Catalyst-solvent materials useful in step B are known in the art. They include, for example, iron; mixtures thereof with nickel, aluminum, nickel and cobalt, nickel and aluminum, and nickel, cobalt and aluminum; and mixtures of nickel and aluminum. Iron-aluminum mixtures are frequently preferred for the production of single-crystal diamond, with a material consisting of 95% (by weight) iron and 5% aluminum being particularly preferred for the purposes of the invention.

Following preparation of the single-crystal diamond by the method of this invention, it is often preferred to remove the portion attributable to the seed crystal by polishing. This is particularly true if the seed crystal is not isotopically pure.

Studies on single-crystal diamond prepared according to the invention and having various degrees of isotopic purity have shown that at carbon-12 purity levels of 99.2%, 99.5% and 99.9% by weight, the room temperature conductivities are, respectively, 10%, 25% and 40% greater than that of natural type IIA diamond. At lower temperatures, even higher differences in thermal conductivity are to be expected. Such thermal conductivities are higher than those of any material previously known. Single-crystal diamond of this type is another aspect of the invention, as is diamond prepared by the method described herein.

The reasons for the extremely high thermal conductivity of the single-crystal diamond of this invention are not fully understood. It is assumed, however, that the phenomenon is principally a function of the mean free path of

the phonons (i.e., lattice vibration modes) in the diamond crystals. Thermal conductivity is directly proportional to specific heat, sound velocity in and phonon mean free path of the crystal, and isotope effects on specific heat and sound velocity are negligible.

In a simplified calculation, the reciprocal of the phonon mean free path can be considered as equal to the sums of the reciprocals of the mean free paths attributable to phonon-phonon scattering and to isotope effects. It has been calculated that the isotope-related mean free path is 34,000 Angstroms and the phonon scattering-related path is 1900 Angstroms; consequently, the isotope effect would account for a decrease in mean free path on the order of only about 5.2%. One possible reason for the substantially greater observed isotope effect on thermal conductivity is that contrary to theory, the isotopic constitution of the diamond has a direct effect on the mean free path attributable to phonon-phonon scattering. This effect has apparently not been previously recognized.

By reason of the aforementioned high thermal conductivity value and essentially non-existent electrical conductivity, the isotopically pure single crystal diamond of the present invention is singularly useful as a conductor of heat from electronic devices and similar heat-generating sources. Articles comprising such a source in contact with said diamond as a thermal conductor are another aspect of the invention.

A further aspect is abrasive articles comprising said diamond. Such articles can be expected to have extraordinarily long life by reason of their ability to dissipate frictional heat generated during their use. Typical areas of application include abrasive grit, diamond compacts, wire drawing dies, saw blades, scribing tools, drills, tool sharpeners, and polishing tools for optical

items, stone and precious stones including diamonds and articles made therefrom.

Still another aspect is light-filtering articles comprising said diamond with a pinhole aperture therein. They are useful, for example, as spatial filters for laser beams and the like. Articles of this type fabricated from natural diamond are subject to radiation-induced damage, probably thermal in nature. The substantially higher thermal conductivity of the diamond of this invention may be expected to greatly minimize damage of this kind.

The invention is illustrated by an example in which a layer of CVD diamond was first deposited on a molybdenum substrate in a chamber constructed of quartz and copper, neither of which dissolves substantial amounts of carbon. The substrate was vertically disposed in a plane parallel to and 8-9 mm. distant from the plane of a tungsten filament about 0.8 mm. in diameter. The vessel was evacuated to a pressure of about 10 torr, the filament was heated to about 2000°C by passage of an electric current and a mixture of 98.5% (by volume) hydrogen and 1.5% methane was passed into the vessel. The methane employed was substantially impurity-free and 99.9% thereof contained the carbon-12 isotope. Upon removal and mass spectroscopic analysis of the diamond thus obtained, it was found that 99.91% of the carbon therein was carbon-12.

Thermal conductivity of the isotopically pure CVD diamond was measured by the mirage detection of thermal waves generated by a modulated argon-ion beam impinging on the diamond crystals, in accordance with a conventional method. The room temperature conductivity was shown to be about 12 watts/cm.°K. A control sample of similar CVD diamond prepared from methane having the naturally occurring isotope distribution (98.96% C-12, 1.04% C-13) had essentially the same conductivity.

The isotopically pure CVD diamond was crushed and powdered, and was used as a source of carbon for the growth of a single-crystal diamond under high pressure and high temperature conditions. Specifically, a conventional belt apparatus was employed at 52,000 atmospheres and 1400°C, employing a catalyst-solvent mixture of 95% (by weight) iron and 5% aluminum. A small (0.005 carat) single-crystal diamond seed of normal isotopic distribution was used to initiate growth, and a negative temperature gradient of about 50°C was maintained between the CVD diamond and the seed crystal. The process was continued until a single crystal of 0.95 carat had been produced. It was shown by analysis that 99.93% of the carbon therein was the C-12 isotope.

The diamond was polished on a standard diamond scaife to remove the seed crystal, and its room temperature conductivity was compared with those of several other materials, including a control single-crystal diamond prepared from the CVD diamond with normal isotope distribution. The results were as follows, all values being in watts/cm.°K:

Isotopically pure C-12 diamond (this invention)	31.5
Control	21.18
Naturally occurring type IIA diamond	21.2
CVD diamond	12.0
Cubic boron nitride	7.6
Silicon carbide	4.9
Copper	4.0
Beryllium oxide	3.7
Boron phosphide	3.6
Aluminum nitride	3.2
Silicon	1.6
Aluminum oxide	0.2

Thus, the room temperature conductivity of the diamond of this invention is 48.7% greater than that of the control. It is also much higher than the room temperature conductivity of any other diamond or non-diamond material which has been measured.

At 70°K, below the boiling point of liquid nitrogen, the diamond of the present invention is theoretically predicted to have a conductivity of about 2675 watts/cm.°K, more than 13 times the minimum value predicted in the aforementioned U.S. Patent 3,895,313.

CLAIMS

1. A method for preparing single-crystal diamond of high isotopic purity which comprises the steps of:

(A) preparing diamond consisting of isotopically pure carbon-12 or carbon-13; and

(B) converting said diamond to single-crystal diamond by diffusion under high pressure through a metallic catalyst-solvent material to a region containing a diamond seed crystal.

2. A method as claimed in claim 1 wherein the carbon in the hydrocarbon is carbon-12.

3. A method as claimed in claim 1 or claim 2 wherein the product of step A is comminuted.

4. A method as claimed in any of the preceding claims wherein the carbon in the hydrocarbon is at least 99.2% isotopically pure.

5. A method as claimed in any of the preceding claims wherein the diamond of step A is prepared by chemical vapor deposition.

6. A method as claimed in any of the preceding claims wherein the equipment employed in step A is constructed of materials substantially incapable of dissolving carbon.

7. A method as claimed in claim 4 wherein the particle size achieved by comminution is that of grit diamond.

8. A method as claimed in claim 7 or claim 4 wherein step A is conducted at a filament temperature of at least 2000°C, a substrate temperature in the range of 900-1000°C and a pressure of about 10 torr.

9. A method as claimed in claim 7 or claim 8 wherein the filaments are of tungsten and the substrate is molybdenum.

10. A method as claimed in claim 6 wherein the carbon in the hydrocarbon is at least 99.9% isotopically pure.

11. A method asclaimed in claim 10 wherein the catalyst-solvent material employed in step B is an iron-aluminum mixture.

12. A method as claimed in claim 11 wherein a negative temperature gradient is maintained in step B between the material being converted and the deposition region.

13. A method as claimed in claim 12 wherein the catalyst-solvent material employed in step B is a mixture of 95% iron and 5% aluminum by weight.

14. A method as claimed in claim 13 wherein the temperature gradient is about 50°C.

15. A method as claimed in claim 12 wherein the pressure in step B is in the range of 50,000-60,000

atmospheres and the temperature is in the range of 1300-1500°C.

16. A method as claimed in claim 15 wherein the seed crystal is single-crystal diamond of normal isotopic distribution.

17. A method as claimed in claim 16 wherein the portion of the product diamond attributable to the seed crystal is removed by polishing.

18. Single-crystal diamond consisting of at least 99.2% by weight isotopically pure carbon-12 or carbon-13, said diamond having a thermal conductivity at 300°K at least 10% greater than that of natural type IIA diamond.

19. Diamond as claimed in claim 18 which consists of carbon-12.

20. An article comprising a heat-generating source in contact with the diamond of claim 18 as a thermal conductor.

21. An abrasive article comprising the diamond of claim 18.

22. A light-filtering article comprising the diamond of claim 18 with a pinhole aperture therein.

23. Single-crystal diamond consisting of at least 99.5% by weight isotopically pure carbon-12 or carbon-13, said diamond having a thermal conductivity at 300°K at

least 25% greater than that of natural type IIA diamond.

24. Single-crystal diamond consisting of at least 99.9% by weight isotopically pure carbon-12 or carbon-13, said diamond having a thermal conductivity at 300°K at least 40% greater than that of natural type IIA diamond.

25. Single-crystal diamond prepared by the method of claim 1.

26. Single-crystal diamond prepared by the method of claim 2.

27. Single-crystal diamond prepared by the method of claim 4.

28. Single-crystal diamond prepared by the method of claim 10.

29. Single-crystal diamond prepared by the method of claim 17.

30. A method as claimed in claim 1 substantially as hereinbefore described in any one of the examples.

31. A single crystal diamond as claimed in claim 18 substantially as hereinbefore described in any one of the examples.

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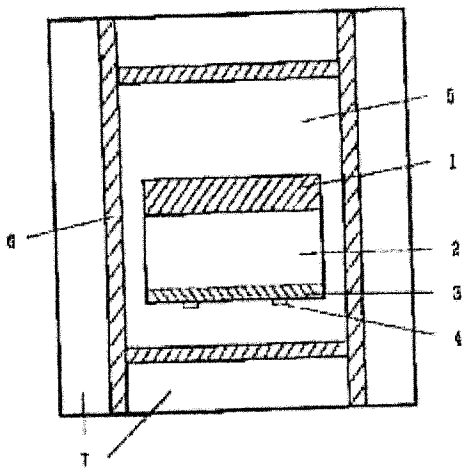
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(72)Inventor : SUMIYA HITOSHI
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(54) SYNTHESIS OF SINGLE CRYSTAL DIAMOND

(57)Abstract:
PURPOSE: To advantageously produce a colorless, transparent high-quality single- crystal diamond in the synthesis thereof employing temp. difference process by a method where Ti, etc., are added to a solvent metal as nitrogen getter, a metal plate such as made of Cu is interposed between the solvent metal and seed crystal and, in this condition, the synthesis of the diamond is started.
CONSTITUTION: In the synthesis of a single crystal diamond employing temp. difference process, one or more metals selected as nitrogen getter from among Ti, Zr, Hf, V, Nb and Ta are added to a solvent metal 2, a metal plate 3 consisting of one or more metals selected from among Cu, Ag, Au, Zn and Cd is interposed between the solvent metal 2 and the seed crystal 4 and, in this condition, the diamond synthesis is started. Since, in this way, a colorless, transparent high quality IIa type diamond almost free from inclusion can be synthesized inexpensively and stably, a synthetic diamond useable in accessory or optical part application can be produced advantageously.



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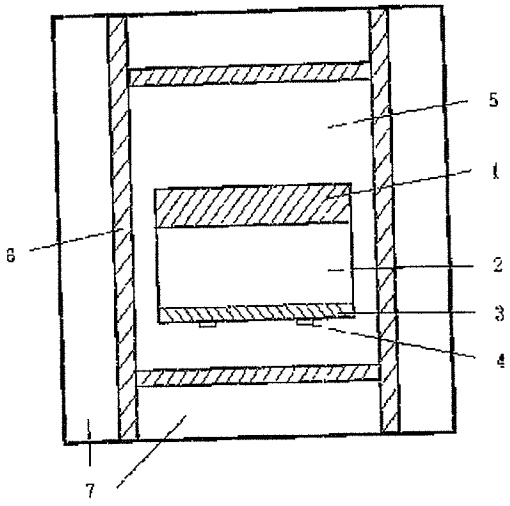
(74)代理人　弁理士　内田　明　(外２名)

(54)【発明の名称】　ダイヤモンド単結晶の合成方法

(57)【要約】

【目的】　装飾用途や光学部品などに用いることができる無色透明で良質なダイヤモンド単結晶の新規な合成方法を提供する。

【構成】　温度差法によるダイヤモンド単結晶合成において、溶媒金属に窒素ゲッターとしてＴｉ，Ｚｒ，Ｈｆ，Ｖ，Ｎｂ，Ｔａから選ばれる一種もしくは二種以上の金属を添加し、かつ、前記溶媒金属と種結晶との間にＣｕ，Ａｇ，Ａｕ，Ｚｎ，Ｃｄから選ばれる一種もしくは二種以上からなる金属板を配置した状態でダイヤモンドの合成を開始することを特徴とする。これにより、無色透明でインクルージョンの殆どない良質なＩＩａ型ダイヤモンド結晶を安価に且つ安定に合成できるので、装飾用途や光学部品に供し得る合成ダイヤモンドの有利な製法である。



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【特許請求の範囲】

【請求項１】　温度差法によるダイヤモンド結晶合成において、溶媒金属に窒素ゲッターとしてＴｉ，Ｚｒ，Ｈｆ，Ｖ，Ｎｂ，Ｔａから選ばれる一種もしくは二種以上の金属を添加し，かつ，前記溶媒金属と種結晶との間にＣｕ，Ａｇ，Ａｕ，Ｚｎ，Ｃｄから選ばれる一種もしくは二種以上からなる金属板を配置した状態でダイヤモンドの合成を開始することを特徴とするダイヤモンド単結晶の合成方法。

【請求項２】　前記の溶媒金属と種結晶との間に配置される金属板の厚みは０．０１ｍｍ以上．１ｍｍ以下であることを特徴とする請求項１記載のダイヤモンド単結晶の合成方法。

【請求項３】　前記窒素ゲッターとして用いられるＴｉ，Ｚｒ，Ｈｆ，Ｖ，Ｎｂ，Ｔａから選ばれる一種もしくは二種以上の金属の含有量が、溶媒金属に対して０．２～１０重量%であることを特徴とする請求項１または２記載のダイヤモンド単結晶の合成方法。

【請求項４】　前記溶媒金属は、Ｆｅ，Ｃｏ，Ｎｉ，Ｍｎ，Ｃｒの中から選ばれる一種もしくは二種以上からなり，且つ０．１～６．０重量%の炭素を含むことを特徴とする請求項１または２または３記載のダイヤモンド単結晶の合成方法。

【発明の詳細な説明】

【０００１】

【産業上の利用分野】本発明は装飾用途や光学部品などに用いられる無色で透明なダイヤモンド単結晶の合成方法に関するものである。

【０００２】

【従来の技術】現在市販されている装飾用ダイヤモンドは，主に南アフリカ、ロシアより産出されるものの中から，無色透明で内部欠陥の少ないものを選別して用いられている。天然装飾用ダイヤモンドは宝石の中でも最も販売量が多い。また、ダイヤモンドを用いた光学部品として，レーザー窓やＩＲアンビルセルなどがあるが，いずれも天然原石の中から赤外領域に光の吸収のない透明なダイヤモンド（IIa型とよばれる）が選ばれて用いられている。しかし、透明無色な原石の産出は極めて少なく，安定供給や価格に問題がある。一方、人工合成によるダイヤモンドは通常，超高圧高温下で合成する際に溶媒中の窒素が結晶格子内に取り込まれるために黄色く着色してしまうが，溶媒中に窒素ゲッターを添加することで無色透明のダイヤモンドを得ることができる。この窒素ゲッターとしては、たとえば、The Journal of Physical Chemistry, vol.75, No.12 (1971) p1838 に示されているように，Ａｌがよく知られている。具体的には、米国特許第４０３４０６６号明細書には、Ｆｅ溶媒にＡｌを３～５重量%添加することにより宝石級の無色透明なダイヤモンド単結晶が得られると記載されている。Ａｌ以外の窒素ゲッターを用いた例として、たとえば無機

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材質研究所研究報告書第３９号、ｐ１６～にＴｉやＺｒを溶媒金属に添加することで結晶中の窒素が除去されたという報告がある。

【０００３】

【発明が解決しようとする課題】しかし、特に無色透明の合成ダイヤモンドは合成コストが天然ダイヤモンドよりはるかに高くなるため工業生産は行われていない。この理由は、合成には高価で特殊な装置が必要である上に，Ａｌなどを窒素ゲッターとして添加した場合，その添加量の増加に従って溶媒が結晶中に取り込まれ（以下インクルージョンと呼ぶ）て，不良結晶となることが多くなるため，良質な結晶とするためには成長速度を大幅に下げる必要があるからである。とくにＴｉやＺｒを窒素ゲッターとして用いた場合は合成中に溶媒中に生成したＴｉＣやＺｒＣなどの炭化物が原因でより多くのインクルージョンが結晶中に取り込まれるようになる。

【０００４】本発明者らが行った実験による結果では、窒素ゲッターとしてＡｌを用い、溶媒金属に均一混合した場合、無色透明なダイヤモンド結晶を合成するためには，その添加量は溶媒に対し少なくとも４重量%（約１２体積%）必要であるが，この場合インクルージョンの巻き込みなしに結晶成長させるためには成長速度を１ｍｇ／ｈｒ以下にする必要があった。この成長速度では、たとえば１カラット（２００ｍｇ）の結晶を合成するには２００時間以上の合成時間を要し，製造コストは膨大なものとなる。また、Ｔｉ，Ｚｒなど，Ａｌより窒素との反応性の高い物質を窒素ゲッターとして溶媒に均一添加した場合、添加量は１重量%でも無色透明な結晶となる。しかし、これらは炭化物を形成しやすく、成長速度を大幅に低下させたとしてもＴｉＣやＺｒＣなどの炭化物の影響で、良質な結晶は殆ど得られない。本発明はかかる問題点を解決し、無色透明でインクルージョのほとんどない結晶を，安価にしかも安定して合成できる方法を提供し、人工合成ダイヤモンドの装飾用途又は光学部品用途への使用を可能とするものである。

【０００５】

【課題を解決するための手段】本発明者らは、ＴｉやＺｒを窒素ゲッターとして溶媒に添加して成長させたダイヤモンド結晶を観察したところ、インクルージョンのほとんどは種結晶を起点として連続して結晶中に取り込まれていることがわかった。さらに、詳細に調べると成長初期に種結晶面上に生成したＴｉＣやＺｒＣなどの炭化物がインクルージョンの起点となっていることがわかった。そこで本発明者らは，成長初期に種面上に炭化物生成を防ぐため溶媒と種結晶の間にあらかじめＣｕ，Ａｇ，Ａｕ，Ｚｎ，Ｃｄなど，それ自体炭化物を作らず、加えて、ＴｉＣやＺｒＣやＮｂＣなどのIVa族もしくはＶａ族元素の炭化物を分解する働きのなる金属板を配置したところ、種面上にほとんど炭化物を生成しないことを見いだした。その結果，炭化物を起点としたインクル

ージョンの巻き込みを防ぐことができ．このため．従来の2倍以上の早い成長速度でも、良質なIIa結晶が得られることを確認した。

【0006】本発明は温度差法によるダイヤモンド結晶合成において．溶媒金属に．窒素ゲッターとしてTi，Zr、Hf，V、Nb，Taから選ばれる一種もしくは二種以上の金属を添加し．さらに前記溶媒金属と種結晶との間にCu、Ag，Au、Zn，Cdから選ばれる一種もしくは二種以上からなる金属板を配置した状態でダイヤモンドの合成を開始することを特徴とするものである。本発明において溶媒金属と種結晶との間に配置される金属板の厚みは0．01mm以上．1mm以下であることが好ましい。また、窒素ゲッターとして用いられるTi，Zr，Hf，V，Nb，Taから選ばれる一種もしくは二種以上の金属の含有量は、溶媒金属に対して0．2～10重量%であることが好ましい。窒素ゲッターとしてのこれら金属は．他の金属．例えば、Al、Cu．Si、Sn等との合金の形で添加することもできる。また、溶媒金属は、Fe，Co、Ni，Mn、Crの中から選ばれる一種もしくは二種以上からなり．且つ0．1～6．0重量%の炭素を含むことが好ましい。

【0007】図1は本発明の一具体例であってダイヤモンド結晶合成用の試料室構成を示す概略断面図である。溶媒金属2には窒素ゲッターとしてTi，Zr、Hf，V、Nb，Taが添加され．この溶媒金属と種結晶4の間にCu，Ag、Au，Zn，Cdから選ばれる金属板3が配置される。1は炭素源、5は絶縁体、6は黒鉛ヒーター、7は圧力媒体である。この金属板3の厚みは0．01mm未満では効果は不十分で．1mmをこえるとCu，Ag．Au，Zn．Cdなどの金属がダイヤモンドの結晶成長に悪影響を及ぼし、結晶が多結晶化したり．埋め残しのある不良結晶となってしまう。また溶媒2に窒素ゲッターとして添加するTi，Zr，Hf，V、Nb，Taの添加量としては、0．2重量%未満では窒素は十分に除去されず．合成されたダイヤモンドは黄色みを帯びた結晶となる。一方、10重量%をこえると多結晶化や自然核発生が多くなり．良質なダイヤモンド結晶が得られなくなる。

【0008】ここで、2の溶媒金属はFe，Co、Ni，Mn，Crの中から選ばれる一種もしくは二種以上からなる金属であり、種結晶溶解防止のため0．1～6．0重量%の炭素をあらかじめ添加しておくのが好ましい。炭素添加量が0．1重量%未満もしくは炭素を含まない溶媒金属を用いた場合、種結晶上にPtなどの種結晶溶解防止材を配置する必要があるが、このような種結晶溶解防止材を配置することは、多結晶化やインクルージョンの巻き込みの原因となり好ましくない。また、炭素添加量が6重量%をこえると、自然核発生がおこりやすくなり、種結晶以外の部所より結晶成長するため結晶同士が干渉し．良質な結晶が得られなくなる。

【0009】

【作用】本発明ではTi，Zr，Hf、V，Nb、Taなど．窒素との反応性の高い元素を窒素ゲッターとするため．少量の添加でほとんど窒素を含まない無色透明なIIa型のダイヤモンド結晶が得られ．また、溶媒と種結晶の間に、炭化物生成防止のために．Cu，Ag、Au，Zn，Cdの金属板をあらかじめ配置した状態で合成を開始する構成になっているため．インクルージョンの混入を大幅に抑えることができる。その結果．従来よりかなり速い成長速度でも良質なIIa型ダイヤモンド結晶が得られるようになる。また、本発明に用いる種結晶．炭素源等はこの種の技術分野で公知のものを用いることができる。また、温度差法による合成の条件等は適宜選択することができる。

【0010】

【実施例】以下実施例により本発明をさらに詳細に説明する。

実施例1

溶媒の原料として粒径50～100ミクロンの高純度Fe粉末、Co粉末、グラファイト粉末を用い、

Fe：Co：C＝60：40：4．5（重量比）

となるように配合した。これに、さらに窒素ゲッターとして平均粒径50ミクロンのTi粉末を1．5重量%添加し．十分に混合した。この混合粉末を型押し成形し、脱ガス、焼成したもの（直径20mm．厚み10mm）を溶媒とした。図1に示す試料室構成で炭素源1にはダイヤモンドの粉末、種結晶4には直径500ミクロンのダイヤモンド結晶3個を用いた。種結晶4と溶媒2の間に配置する金属板3としては厚み0．2mmのCu板を用いた。そして．炭素源1と種結晶4部に約30℃の温度差がつくように加熱ヒーター6内にセットした。これを超高圧発生装置を用いて．圧力5．5GPa．温度1300℃で70時間保持し．ダイヤモンドの合成を行った。その結果0．7～0．9カラットの無色透明な、インクルージョンのほとんどない良質なIIa型のダイヤモンド結晶が得られた。ESRにより．結晶中の窒素濃度を測定するといずれも0．1ppm以下であった。磁気天秤によりインクルージョン量を測定するといずれも0．3重量%以下であった。

【0011】実施例2

種結晶4と溶媒2の間に配置する金属板3に厚み0．5mmのCu板を用いた他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例3

種結晶4と溶媒2の間に配置する金属板3に厚み0．2mmのAg板を用いた他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例4

種結晶4と溶媒2の間に配置する金属板3に厚み0．3mmのAu板を用いた他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

【0012】実施例5

種結晶4と溶媒2の間に配置する金属板3に厚み0．05mmのAu板を用いた他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例6

種結晶4と溶媒2の間に配置する金属板3に厚み0．2mmのZn板を用いた他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例7

溶媒2に添加する窒素ゲッターに粒径44ミクロン以下（平均10ミクロン）のZr粉末を溶媒に対し3重量%添加した他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

【0013】実施例8

溶媒2に添加する窒素ゲッターに粒径44ミクロン以下（平均10ミクロン）のAlTi合金粉末を溶媒に対し3重量%添加した他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例9

溶媒2に添加する窒素ゲッターとしてAlTi合金粉末の代わりに、CuTi、SnTi又はSi，Ti合金粉末を用いた他は実施例8と同様にしてダイヤモンドの合成を行った。その結果、いずれの場合も、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例10

溶媒の原料として粒径50～100ミクロンの高純度Fe粉末、Ni粉末、Co粉末、グラファイト粉末を用い、

Fe：Ni：Co：C＝60：30：10：4．2（重量比）

となるように配合した他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

【0014】実施例11

溶媒の原料として粒径50～100ミクロンの高純度Fe粉末、Ni粉末、Mn粉末、グラファイト粉末を用い、

Fe：Ni：Mn：C＝60：30：10：4（重量比）

となるように配合した他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど

同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例12

溶媒の原料として粒径50～100ミクロンの高純度Fe粉末、Ni粉末、グラファイト粉末を用い、

Fe：Ni：C＝70：30：3．5（重量比）

となるように配合した他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

実施例13

溶媒の原料として粒径50～100ミクロンの高純度Co粉末、グラファイト粉末を用い、

Co：C＝100：4．7（重量比）

となるように配合した他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

【0015】実施例14

溶媒の原料として粒径50～100ミクロンの高純度Ni粉末、グラファイト粉末を用い、

Ni：C＝100：4．2（重量比）

となるように配合した他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、実施例1とほとんど同じ良質なIIa型ダイヤモンド結晶が得られた。

【0016】比較例1

溶媒と種結晶の間に金属板を配置せずに、他は実施例1と同様にダイヤモンドの合成を試みた。窒素含有量の少ない（約0．1ppm）の結晶が得られたが、インクルージョンの巻き込み量は約1．5重量%と多く、良質な結晶は得られなかった。

実施例15

溶媒と種結晶の間に配置するCu板の厚みを2mmとした他は実施例1と同様にダイヤモンドの合成を試みた。成長したダイヤモンド結晶は表面に埋め残しの多い骸晶状となった。

実施例16

窒素ゲッターとして溶媒に添加するTiの量を15重量%とした他は実施例1と同様にダイヤモンドの合成を試みた。種結晶から成長した結晶は多結晶化していた。

【0017】実施例17

溶媒の原料として粒径50～100ミクロンの高純度Fe粉末、Ni粉末、Co粉末を用い、

Fe：Ni：Co＝60：30：10（重量比）

となるように配合し、グラファイトを添加しなかった他は実施例1と同様にしてダイヤモンドの合成を行った。その結果、種結晶は溶媒中に完全に溶解してしまい、ダイヤモンドの成長は不充分であった。

実施例18

溶媒の原料として粒径50～100ミクロンの高純度Fe粉末、Ni粉末、Co粉末、グラファイト粉末を用い、

Fe：Ni：Co：C＝60：30：10：7（重量

比）

となるように配合した他は実施例１と同様にしてダイヤモンドの合成を行った。その結果、種結晶以外の所よりダイヤモンドが多数自然核発生し、このため結晶同士が干渉し、良質なダイヤモンド結晶はほとんど得られなかった。

【００１８】

【発明の効果】以上説明したように、本発明によれば、無色透明でインクルージョンのほとんどないダイヤモンド結晶を、安価に安定して合成できる。本方法によって合成ダイヤモンドを装飾用途、光学部品などに利用することが可能なものとなる。

＊【図面の簡単な説明】

【図１】図１は本発明の一具体例であって、結晶合成用の試料室構成を示す概略断面図である。

【符号の説明】

１：炭素源

２：溶媒金属（窒素ゲッターを含む）

３：金属板

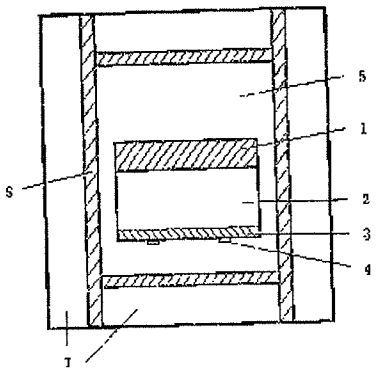
４：種結晶

５：絶縁体

６：黒鉛ヒーター

７：圧力媒体

【図１】



PATENT ABSTRACTS OF JAPAN

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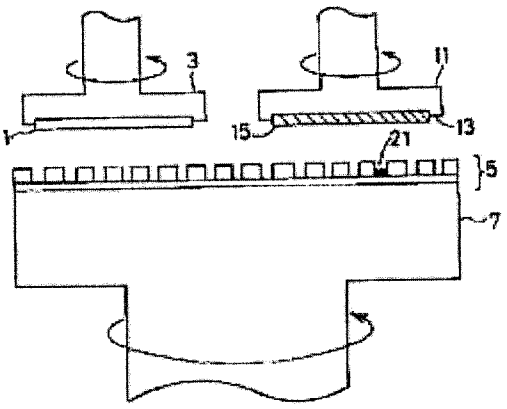
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(54) CMP DEVICE AND ABRASIVE CLOTH CAPABLE OF BEING USED IN THIS CMP DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a CMP device and an abrasive cloth capable of being used in the CMP device, which can suppress deterioration of polishing performance of the abrasive cloth and easily detect a limit of use.
SOLUTION: In a CMP device polishing a semiconductor substrate 1, a diamond dresser 11 is provided with a material 15 capable of mechanically removing a diamond abrasive grain coming off onto an abrasive cloth 5 inside a diamond abrasive grain electrocoating surface 13, and, by the material 15, simultaneously with dressing, the diamond abrasive grain on the cloth 5 is removed. Further, the cloth 5 is provided with a use limit detection part 21 with a work amount of dimple work or the like less than of the other part, and, by polishing the semiconductor substrate 1, the point of time exposing a surface of the use limit detection part 21 is detected as a use limit.



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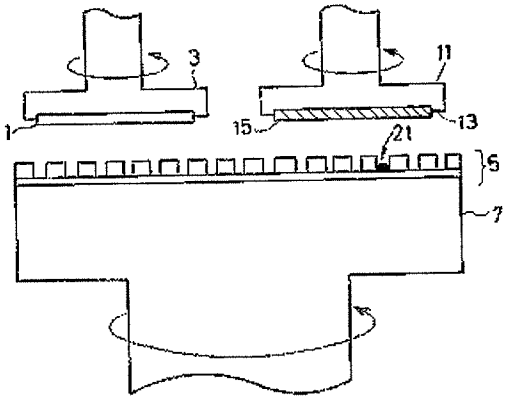
(74)代理人　弁理士　三好　秀和　（外３名）

(54)【発明の名称】　ＣＭＰ装置及び該ＣＭＰ装置に用いることのできる研磨布

(57)【要約】

【課題】　研磨布の研磨性能の劣化を抑制し、かつ、使用限界を容易に検出することができるＣＭＰ装置及び該ＣＭＰ装置に用いることのできる研磨布を提供することを課題とする。

【解決手段】　半導体基板１の研磨を行うＣＭＰ装置で、ダイヤモンドドレッサー１１はダイヤモンド砥粒等着面１３の内側に研磨布５上に脱落したダイヤモンド砥粒を機械的に除去することが可能な材料１５を備え、材料１５によりドレッシングと同時に研磨布５上のダイヤモンド砥粒を除去する。さらに、研磨布５は、ディンプル加工等の加工量が他の部分よりも少ない使用限界検出部２１を備え、半導体基板１の研磨により使用限界検出部２１が表面に露出した時点を使用限界として検出する。



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【特許請求の範囲】

【請求項１】　底面周辺部に設けられたダイヤモンド砥粒電着面により研磨布表面のドレッシングを行うダイヤモンドドレッサーを有するＣＭＰ装置において．

前記ダイヤモンドドレッサーがドレッシングの際に前記ダイヤモンド砥粒電着面から前記研磨布表面に脱落するダイヤモンド砥粒を除去する手段を具備することを特徴とするＣＭＰ装置。

【請求項２】　底面周辺部に設けられたダイヤモンド砥粒電着面により研磨布表面のドレッシングを行うダイヤモンドドレッサーを有するＣＭＰ装置において．

前記ダイヤモンドドレッサーは、前記ダイヤモンド砥粒電着面の内側に前記研磨布上に脱落したダイヤモンド砥粒を機械的に除去することが可能な材料を備え．前記材料によりドレッシングと同時に該ドレッシングの際に前記ダイヤモンド砥粒電着面から前記研磨布上に脱落した前記ダイヤモンド砥粒を除去することを特徴とするＣＭＰ装置。

【請求項３】　前記材料は．ナイロンブラシであることを特徴とする請求項２記載のＣＭＰ装置。

【請求項４】　前記材料は．スポンジであることを特徴とする請求項２記載のＣＭＰ装置。

【請求項５】　前記材料は．モヘアブラシであることを特徴とする請求項２記載のＣＭＰ装置。

【請求項６】　表面に凹部が形成された研磨布により基板の研磨を行うＣＭＰ装置において．

前記研磨布が該研磨布の使用限界を目視により確認することができる使用限界検出手段を具備することを特徴とするＣＭＰ装置。

【請求項７】　表面に凹部が形成された研磨布により基板の研磨を行うＣＭＰ装置において．

前記研磨布は．前記凹部内に使用限界検出部を備え、前記基板の研磨により前記使用限界検出部が前記研磨布表面に露出した時点を使用限界として検出することを特徴とするＣＭＰ装置。

【請求項８】　前記使用限界検出部は．前記凹部内で他の部分よりも浅く加工された部分であることを特徴とする請求項７記載のＣＭＰ装置。

【請求項９】　前記凹部を通じて砥液が研磨布全面に供給されることを特徴とする請求項６乃至請求項８のいずれか１項に記載のＣＭＰ装置。

【請求項１０】　表面に凹部が形成され、基板の研磨に用いられる研磨布において．

前記凹部内に他の部分よりも浅く加工された部分を使用限界検出部として備え、前記基板の研磨により前記使用限界検出部が前記研磨布表面に露出した時点を使用限界と検出することを特徴とする研磨布。

【請求項１１】　前記凹部は、研磨布全面に砥液を供給するために設けられたものであることを特徴とする請求項１０記載の研磨布。

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【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明はＬＳＩ製造工程における平坦化技術として用いられるＣＭＰ装置及び該ＣＭＰ装置に用いることのできる研磨布に関し、特に．研磨布の研磨性能の劣化を抑制し、かつ．使用限界を容易に検出することができるＣＭＰ装置及び該ＣＭＰ装置に用いることのできる研磨布に関する。

【０００２】

【従来の技術】近年、ＬＳＩ（Large Scale Integrated Circuit）の配線が多層化するのに伴い、層間絶縁膜の平坦化技術が非常に重要となってきているが、その技術として現在最も注目されているものが化学的機械研磨（chemical mechanical polishing ：ＣＭＰ）技術である。

【０００３】図５は、上記ＣＭＰ技術を実現する一般的なＣＭＰ装置の構成を示す図である。同図に示すように．このＣＭＰ装置は半導体基板１を固定し、半導体基板１を回転させるトップリング３と．半導体基板１の表面を研磨する研磨布５と．研磨布５を固定し、研磨布５を回転させるターンテーブル７とを少なくとも有し、所定の製造工程を経て凹凸状態となっている半導体基板１の表面を研磨布５に押し付け、砥液９を供給しながらトップリング３とターンテーブル７をそれぞれ回転させ、化学反応を生じさせながら機械的に半導体基板１表面を研磨布５で研磨することにより半導体基板１表面の平坦化を図るものである。

【０００４】上述したようなＣＭＰ装置においては、研磨布の研磨性能維持のためにドレッシング（dressing）と呼ばれる作業が必要である。ドレッシングとは鈍くなった研磨布の目を再び鋭くする目立のことであり．半導体基板の処理枚数の増加に伴って鈍くなっていく研磨布の目を再び鋭くすることにより、研磨布の研磨性能を維持するのである。このドレッシングは例えば次のようなダイヤモンドドレッサーにより実施される。図６は、ドレッシングを行う際のダイヤモンドドレッサーと研磨布を示す図であり．ドレッシングはダイヤモンドドレッサー１１をターンテーブル７に固定された研磨布５の表面に押し付け、ダイヤモンドドレッサー１１とターンテーブル７それぞれを回転させることにより行われる。また．ダイヤモンドドレッサー１１自体を揺動させる場合もある。図７は．上記ダイヤモンドドレッサー１１の拡大図であり、ダイヤモンドドレッサー１１の底面周辺にはダイヤモンド砥粒を電着して形成したダイヤモンド砥粒電着面１３が設けられ．このダイヤモンド砥粒電着面１３を研磨布表面に当てることにより上記ドレッシングが行われる。なお、ドレッシングは上述した半導体基板の研磨と同時に．または．その研磨前．研磨後に行われる。

【０００５】また、図８は．図５と同様に一般的なＣＭ

Ｐ装置の構成を示す図であるが、図８に示すように、ＣＭＰ装置に用いられる研磨布５の表面は実際には砥液９が研磨布５全面に行き渡るようにディンプル加工や格子状の溝加工が施されている。この研磨布５により上述したように半導体基板１の表面を研磨した場合、半導体基板１の処理枚数の増加に伴って研磨布５は摩耗し薄くなるが、研磨布５の使用限界を越えた場合には研磨速度や研磨量の面内均一性の値が悪化してしまう。そのため、実際に上記ＣＭＰ装置により半導体基板１を研磨する場合には、その直前に別途用意された使用限界検出用のテスト基板を予め研磨し、そのテスト基板を評価することにより研磨速度や研磨量の面内均一性の値を算出し、その算出結果に基づいて研磨布５が使用限界に達しているか否かを判断し、使用限界に達していないと判断した場合にのみ本来の半導体基板１の研磨を行い、使用限界に達していると判断した場合には研磨布５の交換が行われる。

【０００６】

【発明が解決しようとする課題】しかしながら、従来のＣＭＰ装置には次のような問題があった。

【０００７】それは、上述したドレッシングの際に、ダイヤモンド砥粒電着面からダイヤモンド砥粒が研磨布表面に脱落し、その脱落したダイヤモンド砥粒がその後の研磨の時に半導体基板表面にキズをつけてしまうということである。図９は、図７のダイヤモンド砥粒電着面１３の断面図であるが、図９（ａ）に示すように、ダイヤモンド砥粒電着面１３は、ダイヤモンド砥粒１７をニッケル膜１９に埋め込み、露出しているダイヤモンド砥粒１７により研磨布のドレッシングを行うものであるが、同図（ｂ）に示すように、ドレッシング時の研磨布との摩擦によりニッケル膜１９からダイヤモンド砥粒１７が剥離し、研磨布に脱落してしまうのである。さらに、ドレッサー１１の使用と共にニッケル膜１９が膜減りし、新たにニッケル膜１９表面に露出するダイヤモンド砥粒１７やニッケル膜１９への埋まり具合が浅くなってくるものもあり、上述したダイヤモンド砥粒１７の脱落は次々と起こり得るのである。

【０００８】また、研磨布の使用限界を検知するために半導体基板の研磨直前にテスト研磨が行われるが、その時用いられるテスト基板は再利用することはできず、廃棄しなければならない。一方、半導体基板の価格は、そのサイズの拡大と共に徐々に上昇している。従って、将来コストの増大を招くのは必至である。さらに、テスト研磨及びテスト基板の評価に要する時間は量産ラインにおいて生産効率を向上させる上で非常に問題である。

【０００９】本発明は上記事情に鑑みて成されたものであり、その目的は、ドレッシングの際にダイヤモンド砥粒電着面から研磨布表面に脱落したダイヤモンド砥粒をその後の研磨の時までに除去することにより半導体基板表面にキズをつけることのないＣＭＰ装置を提供することにある。また、その他の目的は、研磨布の使用限界をテスト研磨することなく容易に判断することができるＣＭＰ装置及び研磨布を提供することにある。

【００１０】

【課題を解決するための手段】上記の目的を達成するために本発明の第１の特徴は、底面周辺部に設けられたダイヤモンド砥粒電着面により研磨布表面のドレッシングを行うダイヤモンドドレッサーを有するＣＭＰ装置において、前記ダイヤモンドドレッサーがドレッシングの際に前記ダイヤモンド砥粒電着面から前記研磨布表面に脱落するダイヤモンド砥粒を除去する手段を具備することである。

【００１１】ここで、前記手段は、具体的には、前記ダイヤモンド砥粒電着面の内側に配置される前記研磨布上に脱落したダイヤモンド砥粒を機械的に除去することが可能な材料であり、例えば、ナイロンブラシ、スポンジである。また、ナイロンブラシに比べて毛先の柔らかいモヘアブラシを用いれば、押し付け圧にあまり影響されることなく良好な除去効果を得ることができる。なお、上記材料の外径は、少なくともＣＭＰ処理を行う基板の外径以上であることが必要である。さらに、ドレッシングの際にダイヤモンドドレッサー自体を揺動させる場合には、少なくとも、研磨布表面の内で研磨に使用される領域全体に上記材料が接触することが可能な外径であることが必要である。

【００１２】上記構成によれば、ダイヤモンドドレッサーとナイロンブラシ等の材料を一体化させることにより、ドレッシングの際にダイヤモンド砥粒電着面から研磨布上に脱落するダイヤモンド砥粒の除去をドレッシングと同時に行うことができる。従って、その後の研磨においてダイヤモンド砥粒による基板表面のキズを無くすことができる。

【００１３】本発明の第２の特徴は、表面に凹部が形成された研磨布により基板の研磨を行うＣＭＰ装置において、前記研磨布が該研磨布の使用限界を目視により確認することができる使用限界検出手段を具備することである。

【００１４】ここで、前記使用限界検出手段は、好ましくは、前記凹部の加工量を調節してその他の部分よりも浅く加工された部分であり、前記基板の研磨により前記浅く加工された部分が表面に露出した時点を使用限界と検出するものである。なお、前記浅く加工された部分の厚みは所望の基板の研磨速度と研磨量の面内均一性の値が悪化する時期に研磨布表面に露出して目視で確認することができるような値とする。

【００１５】上記構成によれば、使用限界検出手段が研磨布の表面に露出し目視で確認できた時点を研磨布の交換時期とするので、従来のようなテスト研磨を行う必要が無くなり、また、その際無駄に消費されていたテスト基板も不要となる。従って、コストの低減を図ることが

できる。

【００１６】

【発明の実施の形態】以下，本発明の実施の形態について図面を用いて説明する。図１は，本発明の実施の形態に係るＣＭＰ装置の構成を示す図である。なお，従来例と同一部分には同一符号が付してある。

【００１７】同図に示すように，このＣＭＰ装置は半導体基板１を固定し，半導体基板１を回転させるトップリング３と，半導体基板１の表面を研磨する研磨布５と，研磨布５を固定し，研磨布５を回転させるターンテーブル７とを有し，所定の製造工程を経て凹凸状態となっている半導体基板１の表面を研磨布５に押し付け，砥液９を供給しながらトップリング３とターンテーブル７をそれぞれ回転させ，化学反応を生じさせながら機械的に半導体基板１表面を研磨布５で研磨することにより半導体基板１表面の平坦化を図るものである。また，ドレッシングを行うダイヤモンドドレッサー１１を有し，ダイヤモンドドレッサー１１をターンテーブル７に固定された研磨布５の表面に押し付け，ダイヤモンドドレッサー１１とターンテーブル７それぞれを回転させることにより，半導体基板１の処理枚数の増加に伴って鈍くなっていく研磨布５の目を再び鋭くし，その研磨性能を維持するものである。

【００１８】図２は，図１に示すダイヤモンドドレッサー１１の拡大図である。なお，従来例と同一部分には同一符号が付してある。

【００１９】図２に示すように，本実施の形態に係るダイヤモンドドレッサー１１は，ダイヤモンド砥粒電着面１３の内側に，研磨布上に脱落したダイヤモンド砥粒を機械的に除去することが可能な材料，例えば，ナイロンブラシを配置することにより，ドレッシング時に研磨布表面上に脱落するダイヤモンド砥粒を研磨布表面から除去し，あるいは，研磨布表面の内で半導体基板の研磨に使用されない領域へ除外することにより従来では問題となったダイヤモンド砥粒による半導体基板表面のキズを無くすことができる。また，かかるダイヤモンド砥粒を上記ナイロンブラシに取り込むことにより除去することも可能である。

【００２０】さらに，ダイヤモンドドレッサー自体にナイロンブラシ等の材料が内蔵されているので，従来と同じドレッシング時間だけでドレッシングと同時にダイヤモンド砥粒の除去も行うことができる。従って，全体の処理時間を短くすることができる。

【００２１】ここで，研磨布上に脱落したダイヤモンド砥粒を機械的に除去することが可能な材料としては，ナイロンブラシ以外にスポンジでも同様な効果を得ることができる。また，ナイロンブラシに比べて毛先の柔らかいモヘアブラシを用いることにより，押し付け圧にあまり影響されることなく良好な除去効果を得ることができる。また，上記材料の外径は，少なくともＣＭＰ処理を行う半導体基板の外径以上であることが必要である。さらに，ドレッシングの際にダイヤモンドドレッサー自体を揺動させる場合には，少なくとも，研磨布表面の内で研磨に使用される領域全体に上記材料が接触することが可能な外径であることが必要である。

【００２２】図３は，図１に示す研磨布５の拡大図であり，図３（ａ）がその平面図，図３（ｂ）がそのＡ－Ａ´における断面図である。なお，従来例と同一部分には同一符号が付してある。

【００２３】図３に示すように，本実施の形態に係る研磨布５は，例えば従来例と同様にディンプル加工あるいは格子状の溝加工をすることで表面に凹部が形成されているが，さらに，その加工量を調節してその他の部分よりも浅く加工された部分を形成し，その浅く加工された部分を研磨布５の使用限界サイン２１として用いる構成としたものである。このような構成とすることにより，この研磨布５で半導体基板１の表面を研磨した場合に半導体基板１の処理枚数の増加に伴って研磨布５は磨耗し薄くなると使用限界サイン２１が徐々に表面に現れることとなるが，その目視確認によって研磨布５の使用限界を容易に検知することができるのである。従って，従来では研磨布５の使用限界を検知するために必要であったテスト研磨が不要となり，その際無駄に消費されていたテスト基板も必要なくなる。なお，使用限界サイン２１は研磨布５の凹部内に別設されてもよいが，上述した通り凹部内で浅く加工された部分を使用限界サイン２１として用いることで使用限界サイン２１を研磨布５の基材と同材質から簡易に得ることができ，好ましい。

【００２４】図４は，図３に示す研磨布５を用いて実際に半導体基板を研磨した結果を示す図であり，図４（ａ）が半導体基板が酸化膜を０．６μｍ堆積したシリコン基板である場合，図４（ｂ）がポリシリコン膜を０．５μｍ堆積したシリコン基板である場合である。また，図４（ａ）及び（ｂ）それぞれの横軸は研磨した半導体基板の枚数であり，縦軸は研磨速度及び研磨量の面内均一性である。なお，ここで用いた研磨布５はポリウレタン材料の研磨布であり，その厚みを約１．３μｍ，使用限界サイン２１の厚みを０．５μｍとしたものである。

【００２５】図４（ａ）に示すように，酸化膜を０．６μｍ堆積したシリコン基板を研磨した場合には，約６００枚研磨した辺りで急激に研磨速度は減少すると共に研磨量の面内均一性が悪化していることが分かる。この時，研磨布５表面には使用限界サイン２１が目視で確認され，それにより，容易に研磨布５が交換時期であることを検知することができた。また，図４（ｂ）に示すように，ポリシリコン膜を０．５μｍ堆積したシリコン基板を研磨した場合には，約９００枚研磨した辺りで急激に研磨速度は減少すると共に研磨量の面内均一性が悪化していることが分かる。この時も同様に，研磨布５表面

には使用限界サイン２１が目視で確認され、それにより、容易に研磨布５が交換時期であることを検知することができた。

【００２６】ここで、研磨布５の材料としてポリウレタンを用いて説明したが、ナイロン、レーヨン等の半導体基板を研磨するために用いられる研磨布材料全てに適用することが可能である。また、使用限界サインの厚みは所望の半導体基板の研磨速度と研磨量の面内均一性の値が悪化する時期に研磨布表面に現れて使用限界サインを目視で確認することができるような厚さに適宜設定する。なお、研磨する半導体基板として酸化膜、ポリシリコン膜を堆積したシリコン基板について説明したが、本実施の形態はこれらの研磨に使用されるのみではなく、一般的にＬＳＩ製造工程で用いられる成膜材料、例えば、高融点金属（Ｓｉ、Ｍｏ、Ｗ、Ｔｉ、Ｔａ等）並びにそれら高融点金属の酸化物、窒化物及びシリサイド、金属配線用材料（Ａｌ、Ｃｕ、Ａｌ－Ｓｉ－Ｃｕ、Ａｌ－Ｃｕ等）の研磨においても適用され得る。

【００２７】

【発明の効果】以上説明したように本発明によれば、ドレッシングを行う際同時に研磨布上に脱落したダイヤモンド砥粒を除去することができるので、従来問題であった脱落したダイヤモンド砥粒による基板表面のキズを無くすことができる。また、ダイヤモンドドレッサーに研磨布上に脱落したダイヤモンド砥粒を除去するナイロンブラシ等の材料を一体化させることにより、ドレッシングとダイヤモンド砥粒の除去を同時に行うことができるので、処理時間の低減を図ることができ、さらに、設備の点からコストの低減を行うことができる。

【００２８】また、研磨布の使用限界を目視で容易に検出することができるので、従来必要であったテスト研磨が不要となり、無駄に消費されていたテスト基板を無くすことができる。従って、全体の処理時間は短縮され、コストの低減にもつながる。

【図面の簡単な説明】

【図１】本発明の実施の形態に係るＣＭＰ装置の構成を示す図である。

【図２】図１に示すダイヤモンドドレッサーの拡大図である。

【図３】図１に示す研磨布の拡大図である。

【図４】図３に示す研磨布を用いて実際に半導体基板を研磨した結果を示す図である。

【図５】一般的なＣＭＰ装置の構成を示す図である。

【図６】ドレッシングを行う際のダイヤモンドドレッサーと研磨布を示す図である。

【図７】図６に示すダイヤモンドドレッサーの拡大図である。

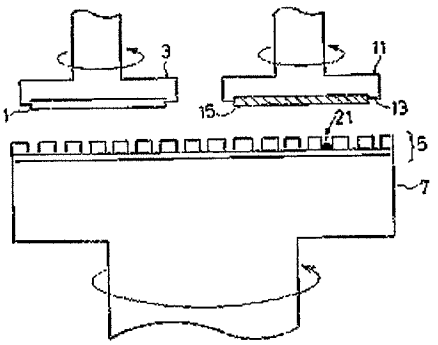
【図８】他の一般的なＣＭＰ装置の構成を示す図である。

【図９】図７に示すダイヤモンド砥粒電着面の断面図である。

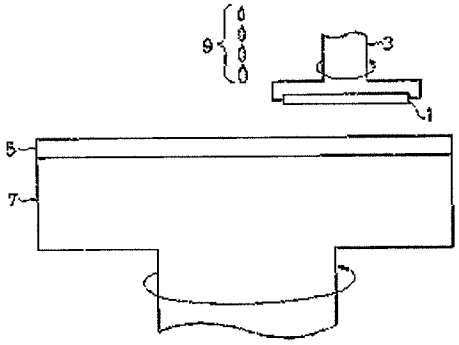
【符号の説明】

１　半導体基板
３　トップリング
５　研磨布
７　ターンテーブル
９　砥液
１１　ダイヤモンドドレッサー
１３　ダイヤモンド砥粒電着面
１５　ナイロンブラシ
１７　ダイヤモンド砥粒
１９　ニッケル膜
２１　使用限界サイン

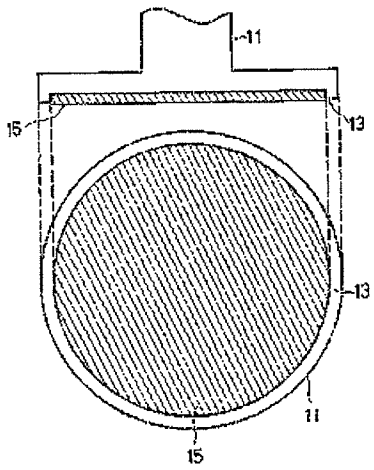
【図１】



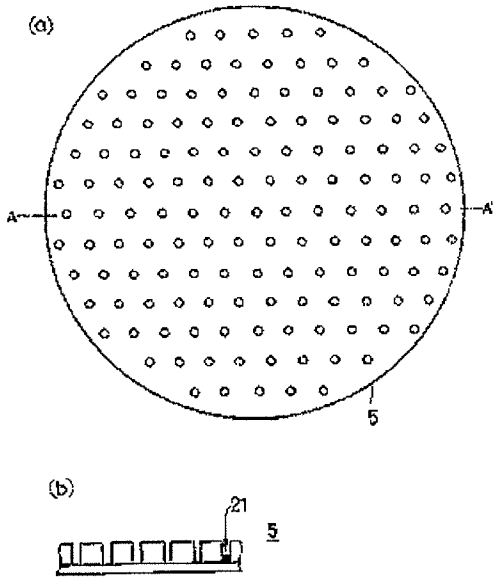
【図５】



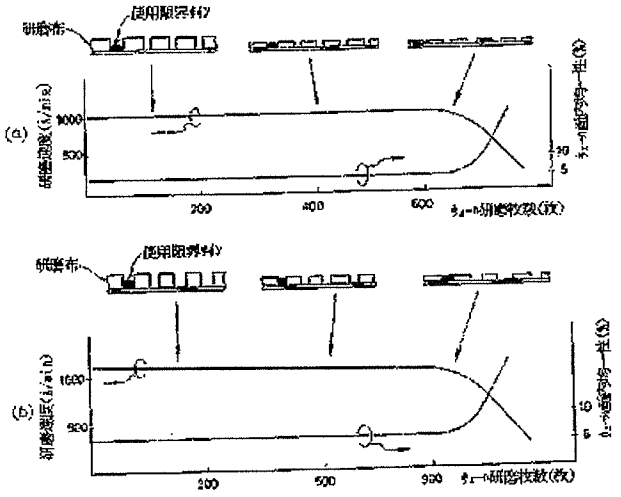
【図2】


11
15
13
13
11
15

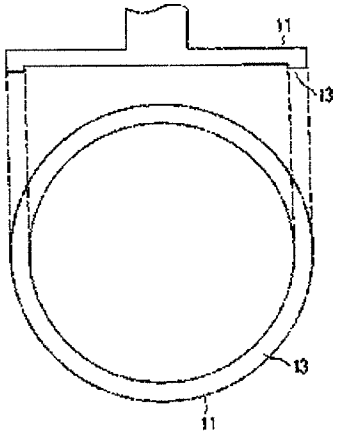
【図3】


(a)
A
A'
5
(b)
21
5

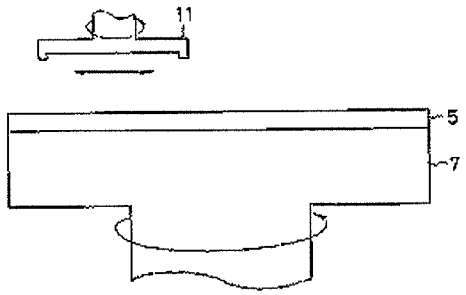
【図4】


研磨布
使用限界47
(a)
1000
500
30
5
200
400
600
研磨枚数(枚)
研磨布
使用限界47
(b)
1000
500
10
5
200
500
900
研磨枚数(枚)

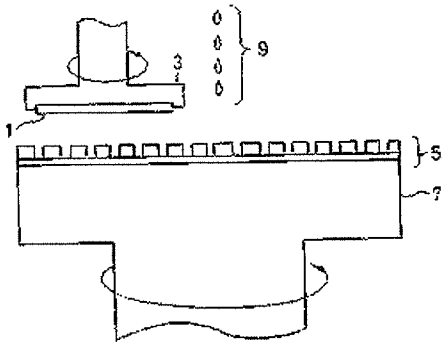
【図7】


11
13
13
11

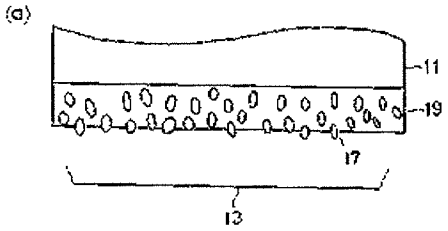
【図6】

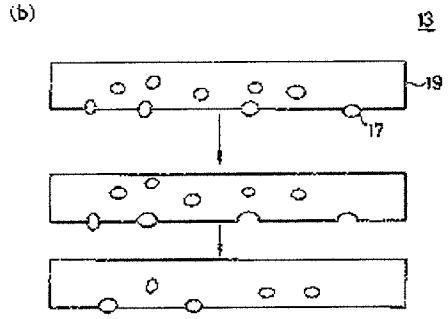


【図8】



【図9】





PATENT ABSTRACTS OF JAPAN

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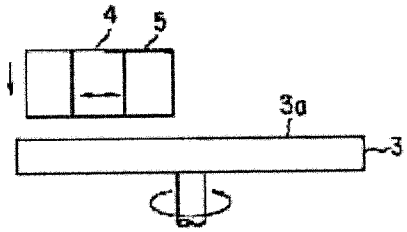
(51)Int.Cl. B24B 37/00
H01L 21/304

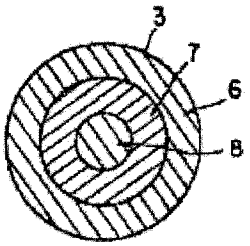
(21)Application number : 08-343567
(22)Date of filing : 24.12.1996

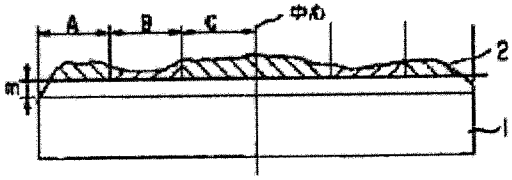
(71)Applicant : NKK CORP
(72)Inventor : TAKEUCHI NOBUYOSHI

(54) GRINDING PAD ADJUSTING METHOD FOR CMP DEVICE

(57)Abstract:
PROBLEM TO BE SOLVED: To maintain the flatness of the device surface of a semiconductor substrate to be ground by dividing the surface of a pad according to the film thickness distribution of the device surface before grinding where the pad surface of the grinding pad is pressed, and adjusting each surface roughness of the pad surface to each different roughness with a plurality of grinding wheels different in hardness.
SOLUTION: The film thickness distribution of a film 2 deposited on the device surface of a semiconductor substrate 1 takes a shape having a doughnut- like recess. According to this film thickness distribution, the inside of a pad surface 3a is divided into, for instance areas A, B and C. A grinding pad 3 needs to adjust surface roughness such that an outer peripheral pad surface part 6 and a center pad surface part 8 for grinding the areas A and C have grinding amounts larger than that of an inner peripheral pad surface part 7 for grinding the area B. Accordingly, a diamond grinding wheel 4 having hardness for reducing a grinding amount more than that of a diamond grinding wheel 5 is loaded, pressed to the pad surface 3a and, then by rotating the grinding pad 3, surface roughness is formed on the pad surface 3a.







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特開平10－180618

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Ｂ２４Ｂ　37/00		Ｂ２４Ｂ　37/00	Ｃ
			Ｆ
Ｈ０１Ｌ　21/304	３４１	Ｈ０１Ｌ　21/304	３４１Ｅ

審査請求　未請求　請求項の数３　ＯＬ　（全５頁）

(21)出願番号　特願平８－343567

(22)出願日　平成８年(1996)12月24日

(71)出願人　000004123
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(72)発明者　竹内　信善
東京都千代田区丸の内一丁目１番２号　日本鋼管株式会社内

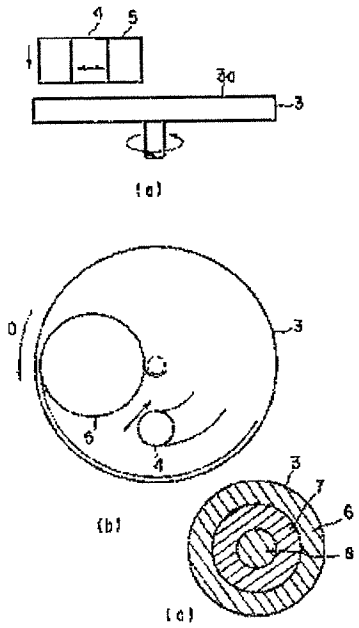
(74)復代理人　弁理士　花輪　義男　（外１名）

(54)【発明の名称】　ＣＭＰ装置の研磨パッドの調整方法

(57)【要約】

【課題】従来の研磨パッドの調整は、パッド面に単一的な表面荒れを形成していたため、半導体装置のデバイス面の凸凹に押し付けられたパッド面が削られ、平坦性がなくなり、表面荒れに研磨の能力の差が生じていた。

【解決手段】本発明は、研磨する半導体基板のデバイス面の膜厚分布を研磨前に測定し、その膜厚分布に対応して、硬度が異なる複数のダイヤモンド砥石を用いて、パッド面内を区分して表面荒れの粗さをそれぞれ調整し、パッド面内での研磨量を変化させることにより、研磨パッドの平坦性を維持させ、研磨される半導体基板のデバイス面の平坦化するＣＭＰ装置の研磨パッドの調整方法である。



1

【特許請求の範囲】

【請求項１】　半導体基板の回路素子を形成するデバイス面を平坦化する化学的機械研磨（ＣＭＰ）装置に用いる研磨パッドの研磨を行うパッド面の調整方法において．

前記研磨パッドのパッド面を研磨前のデバイス面の膜厚分布に応じて．該パッド面内を区分して、硬度の異なる複数の砥石で．該パッド面の表面荒れを異なる粗さにそれぞれ調整することを特徴とするＣＭＰ装置の研磨パッドの調整方法。

【請求項２】　前記ＣＭＰ装置の研磨パッドの調整方法において、

前記デバイス面が平坦化されるまでの研磨量に比例して．そのデバイス面部分に押し付けるパッド面部分の表面荒れが粗くなるように調整することを特徴とする請求項１記載のＣＭＰ装置の研磨パッドの調整方法。

【請求項３】　前記ＣＭＰ装置の研磨パッドの調整方法において、

硬度が異なる砥石を回転する研磨パッドの動径方向にそれぞれ配置して．前記パッド面に押し付け、パッド面を区分してそれぞれ研磨し．異なる粗さの表面荒れに調整することを特徴とする請求項１記載のＣＭＰ装置の研磨パッドの調整方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は．半導体デバイスの製造工程において、半導体基板表面の平坦化を行う化学的機械研磨（ＣＭＰ：Chemical Mechanical Polishing）技術に係り、特にＣＭＰ装置における研磨パッドの調整方法に関する。

【０００２】

【従来の技術】近年、処理時間の高速化や微細化の要求に伴い半導体デバイスの回路素子は積み上げられて多層化し．配線層も多層化されている。

【０００３】このような回路素子等の多層化は．半導体基板上で回路素子を形成した領域と未形成の領域との間に段差を生じさせ、さらに積み上げる毎にそれらの段差が加算される。この結果．上層側では．フォトリソグラフィ工程のマスク露光の際に、焦点深度を越えたり、エッチング困難な場合が生じる。さらに．例えばビアホールにメタル配線を形成した場合、段差によりビアホールの深さに違いが生じ、ビアホール抵抗のばらつきの原因にもなっている。

【０００４】そこで、各層に回路素子を形成する際に、半導体基板表面の平坦化を図る技術が求められていた。

【０００５】従来の平坦化技術としては、エッチバック技術やＳＯＧ（Spin On Glass）技術が知られている。これらの技術は．段差近傍のローカルな平坦化には有用であった。しかし、半導体デバイスの多層化や大型化が進むと半導体基板全体を平坦化する技術が必要である。

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【０００６】エッチバック技術による平坦化は．オーバーエッチングの管理が難しく、半導体基板のデバイス面全体を平坦化させるには．容易でなかった。さらに、層間絶縁膜のような同一材料が全表面を覆った面を平坦化するには問題がないが、例えばＣｕ等を含有する配線のようにエッチングされにくい部材を使用した配線等が含まれる構成であれば、エッチングにより平坦化することは難しい。

【０００７】また、ＳＯＧ技術においては、ＳＯＧ膜をスピンコーティングして塗布し、段差の平坦化を実現していたが、ＳＯＧ膜自体のクラック耐性が乏しく．半導体基板全体を平坦化させる膜厚までは形成できない問題があり、さらに塗布により平坦化させるためには．回路素子の表面形状や配置に工夫を施さねばなかった。このため．多層化された回路素子や多層化配線には．十分な平坦化を提供できる技術ではなくなった。

【０００８】そこで新たな平坦化技術として、インゴットからスライスカットされたシリコンウエハの平面研磨を行うポリッシング研磨技術と化学研磨技術の特徴を併せ持たせ、半導体デバイスの平坦化に応用したＣＭＰ技術が注目されている。

【０００９】このＣＭＰ技術は、図４に示すように、ポリッシング研磨における研磨剤として．アルミナやシリカ等の研磨粒子に過酸化水素水等の化学物質を併せた研磨剤（スラリー液）２１を用いて、定盤２２上に軟質若しくは、粘弾性を有する材料からなる研磨パッド２３を取り付け、化学反応を伴う機械研磨によりデバイス面側を微細に研磨して段差を無くし、表面を平坦化するものである。

【００１０】この構成において、駆動可能なテーブル２４に裏面側から吸着固定された半導体基板２５は．そのデバイス面２５ａを対向し回転する研磨パッド２３に押しつけられ、研磨剤２１が添加されて研磨され．デバイス面が平坦化される。このＣＭＰ技術は、研磨レートが小さいため微細な研磨が可能であり．研磨された面に加工変質を極めてわずかしか与えない特徴がある。

【００１１】

【発明が解決しようとする課題】前述したＣＭＰ技術において、研磨に用いられる研磨パッドの表面は．砥石例えば．ダイヤモンド砥石で削られ、適当な表面荒れが設けられている。この研磨パッドの表面荒れにより．デバイス面上に積層形成された絶縁膜又は金属膜を研磨を行っているが、ダイヤモンド砥石自らの表面も削られるため．表面荒れが削り取られて研磨能力が劣化する。

【００１２】そこで、研磨パッドは．予め定めた処理回数（削った量）毎に、その表面を再度．ダイヤモンド砥石で削り直し．適当な表面荒れが保たれるように調整を行っている。

【００１３】通常、研磨前のデバイス面は、いわゆるａｓ depoの状態にあり、その膜厚分布は下地の平坦さによ

る影響と、成膜装置の特性に依存する面内膜厚分布の凸凹形状があり．ＣＭＰ技術において研磨パッドによる研磨を行った場合．研磨後の研磨パッドもこの凸凹形状に依存して平坦な表面の状態が変化する。つまり．膜なりに削れていくのである。

【００１４】例えば、図５に示すようなデバイス面では．凸形状の部分２５ｂに押しつけられた研磨パッド部分２３ｂは多く削れ、表面荒れの部分も削り取られる。また．凹形状の部分２５ｃを押し付けられた研磨パッド部分２３ｃはあまり削れないため、表面荒れの部分も残っている。

【００１５】この削れ具合の差により．研磨後の研磨パッド表面は、偏った凸凹形状に変化し．且つ研磨パッド内で研磨の能力の差が生じている。従って、このように表面形状が変化していく研磨パッドで．引き続きデバイス面を研磨すると、半導体基板の表面も平坦にならない場合が生じる。

【００１６】また従来の研磨パッドの調整は、研磨パッド表面の平坦化維持を考慮したものではなく、単一的な表面荒れを形成すること目的としているため、研磨パッドの表面全体を１つのダイヤモンド砥石で均一的に削るだけであった。

【００１７】よって、研磨パッドの表面荒れの均一性を持たせる管理を厳しくして．研磨パッドのパッド面の平坦性を維持させ．研磨された半導体基板のデバイス面の平坦化を維持させるために．研磨パッドの交換回数や調整回数が多くなり、作業効率の低下を招き、結果的にコストアップとなる。

【００１８】そこで本発明は、半導体基板のデバイス面の膜厚分布に応じて、研磨パッドのパッド面内を区分して表面荒れの粗さをそれぞれ調整し．研磨面の平坦性と研磨された半導体基板のデバイス面の平坦化を維持させるＣＭＰ研磨パッドの調整方法を提供することを目的とする。

【００１９】

【課題を解決するための手段】本発明は上記目的を達成するために、半導体基板の回路素子を形成するデバイス面を平坦化する化学的機械研磨（ＣＭＰ）装置に用いる研磨パッドの研磨を行うパッド面の調整方法において、前記研磨パッドのパッド面を押し付ける研磨前のデバイス面の膜厚分布に応じて．該パッド面内を区分して、硬度の異なる複数の砥石で．該パッド面の表面荒れを異なる粗さにそれぞれ調整するＣＭＰ装置の研磨パッドの調整方法を提供する。

【００２０】以上のようなＣＭＰ研磨パッドの調整方法は．研磨前の半導体基板のデバイス面の膜厚分布に対応して．硬度が異なる複数の砥石により．デバイス面の膜の研磨量に比例して、そのデバイス面に押し付けられるパッド面の表面荒れが粗くなるように研磨して．パッド面内での研磨量を変化させることにより、研磨される半導体基板のデバイス面の平坦化を維持する。

【００２１】

【発明の実施の形態】以下．図面を参照して本発明の実施形態について詳細に説明する。

【００２２】まず、本発明によるＣＭＰの研磨パッドの調整方法の概要について説明する。図２（ａ）には、半導体基板上に回路素子を形成するための絶縁膜や金属膜をＣＶＤ（Chemical Vaper Deposition）装置やスパッタリング装置を用いて半導体基板上に形成した場合の膜厚分布の一例を示す。

【００２３】この半導体基板１のデバイス面上に堆積された堆積膜２の膜厚分布の形状は、同心円状で．半導体基板１の中心で厚く、エッヂ方向に向かい一旦薄くなるが．次第に厚くなり、再度エッヂで薄くなる。すなわち．ドーナツ形状の凹みを有した形状である。

【００２４】このような膜厚分布を持つ半導体基板をＣＭＰ技術により平坦化させる場合、図２（ｂ）に示すように．斜線で示すＡ領域及びＣ領域の膜厚が近似し、仮に膜厚ｍに平坦化するものとすると．Ａ領域及びＣ領域は．研磨量を多くし、Ｂ領域は、研磨量を少なくすることにより、効率的に平坦化できる。

【００２５】従って、半導体基板１のデバイス面に押し付けられ研磨を行う研磨パッドのパッド面（研磨面）は．膜厚分布と逆の削れ具合の調整が必要となる。つまり後述する図１（ｃ）に示すように．堆積膜の厚いＡ領域及びＣ領域に押し付けられるパッド面部分６及びパッド面部分８は．表面荒れを粗くして研磨レートを上げるように調整し．堆積膜が薄く研磨量が少ないＢ領域に押し付けられるパッド面部分７は、その表面荒れを研磨パッド部分６に比べて、粗くせずに研磨レートを下げるように調整する。

【００２６】このような調整を行うためには研磨パッドのパッド面内を区分して．それぞれの表面荒れの粗さに調整する必要がある。

【００２７】図１（ａ）、（ｂ）に示すように．図２（ｂ）に示したような膜厚分布に対応する、少なくとも硬度が異なる２つのダイヤモンド砥石４、５を研磨パッド３の動径方向Ｏに配置して、研磨パッドのパッド面３ａの表面荒れを調整する。少なくともダイヤモンド砥石４は移動可能に備えられている。

【００２８】この膜厚分布は、予め成膜装置毎に膜厚分布の形状に関するデータを取って、パーソナルコンピュータ等に記録させておき．研磨の際に読み出して利用してもよいし、その都度、半導体基板のデバイス面の膜厚分布を計測してもよい。

【００２９】本実施形態では、図２（ｂ）に示した堆積膜の膜厚分布を例とすると．研磨パッド３は、図１（ｃ）に示すように半導体基板１のＡ領域及びＣ領域を研磨する外周部のパッド面部分６及び中心部のパッド面部分８が、Ｂ領域を研磨する内周部のパッド面部分７よ

りも研磨量が多くなるように、表面荒れの粗さを調整する必要がある。

【００３０】その調整方法は、ダイヤモンド砥石５に比べて、研磨量が異る硬度のダイヤモンド砥石４を装着してパッド面３ａに押し付け、研磨パッド３を回転させて、パッド面３ａに表面荒れを形成する。

【００３１】本実施形態の研磨パッドの調整方法によれば、ＣＭＰ装置に装着して、半導体基板のデバイス面を平坦化する研磨パッド内の表面荒れの粗さを、デバイス面の膜厚分布（研磨すべき量）に基づき、研磨量の多い部分ほど粗くなるように調整することにより、パッド面の平坦化を維持し、且つ同じ膜厚分布の傾向を持つデバイス面を研磨する処理回数（研磨量）を増やすことができる。

【００３２】また、表面荒れの粗さは、研磨量が研磨剤や研磨機構及び研磨を行う堆積膜の材質や成膜方法により異なるため、経験的に求めて決定する。

【００３３】次に図３を参照して、本発明による第２の実施形態としてのＣＭＰ研磨パッドの調整方法について説明する。

【００３４】前述した第１の実施形態では、硬度が異なる２つのダイヤモンド砥石により、研磨パッドを調整したため、２種類の粗さの表面荒れが形成されたが、図２（ｂ）に示した堆積膜２の膜厚分布で、例えば、Ｃ領域の膜厚がＡ領域の膜厚より、さらに厚かった場合には、Ｃ領域の堆積膜の研磨量をＡ領域よりも多くする必要がある。そこで、図３（ａ），（ｂ）に示すように、硬度が異なる３つのダイヤモンド砥石１１，１２，１３を研磨パッド３の動径方向に配置し、研磨パッド３の表面荒れの調整を行う。このダイヤモンド砥石１１，１２，１３の取り付け機構においては、砥石の交換や研磨パッドに対する研磨位置の移動が可能な構成になっているものとする。

【００３５】この調整は、図３（ｃ）に示すような半導体基板１の膜厚分布において、堆積膜２を膜厚ｎに平坦化する際に、Ｃ’領域の研磨量ｑがＡ’領域の研磨量ｐよりも２倍程度ある場合など、半導体基板の外周側と中心部の膜厚に差があり、前述した第１の実施形態による硬度が２種類のダイヤモンド砥石では、十分な平坦化が実現されない膜厚分布に好適する。このような調整において、砥石の配置は、ダイヤモンド砥石１２、ダイヤモンド砥石１１、ダイヤモンド砥石１３の順に研磨量が多くなる硬度ものを配置する。

【００３６】以上のことから本実施形態は、第１の実施形態に比べて、パッド面内の表面荒れの粗さをさらに微

調整でき、研磨する堆積膜の膜厚分布に依らず、平坦化が実現でき、第１の実施形態と同様な効果が得られる。

【００３７】本実施形態では、硬度が異なる２若しくは３個のダイヤモンド砥石を用いて説明したが、これらに限定されるものではなく、半導体基板の径やデバイス面の膜厚分布、膜の材質により、自由に硬度の選択と配置をしてもよく、また、砥石側を回転させてパッド面を押し付け研磨してもよい。

【００３８】尚、従来、ＣＭＰ装置の研磨機構では研磨パッドだけでなく、研磨を施す半導体基板側も回転させ、且つ半導体基板支持体を動径方向に揺動する研磨機構もあり、半導体基板のエッヂ側周辺部は、研磨パッドの外周側と内周側とで研磨されるが半導体基板中心部は揺動中心近くで研磨されている。このような研磨機構では、半導体基板の外周側が中心部分よりも、研磨量が多くなっていたが、本実施形態の調整方法を利用して、研磨パッドの表面荒れを調整し、中心部分の研磨量を多くすることにより、この問題を解決できる。

【００３９】

【発明の効果】以上詳述したように本発明によれば、半導体基板のデバイス面の膜厚分布に応じて、研磨パッドのパッド面内を区分して表面荒れの粗さをそれぞれ調整し、研磨面の平坦性と研磨された半導体基板のデバイス面の平坦化を維持させるＣＭＰ研磨パッドの調整方法を提供することができる。

【図面の簡単な説明】

【図１】本発明による第１の実施形態としてのＣＭＰ研磨パッドの調整方法を実施するための研磨パッドと砥石の配置の構成例を示す図である。

【図２】成膜装置を用いて形成した時の堆積膜の膜厚分布の一例を示す図である。

【図３】本発明による第２の実施形態としてのＣＭＰ研磨パッドの調整方法を実施するための研磨パッドと砥石の配置の構成例を示す図である。

【図４】ＣＭＰ装置の概略的な構成を示す図である。

【図５】従来の半導体基板と研磨パッドの研磨状態を説明するための図である。

【符号の説明】

１…半導体基板

２…堆積膜

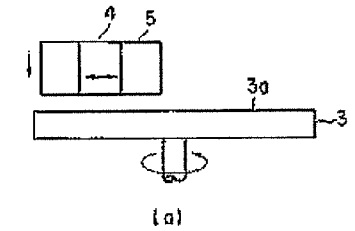
３…研磨パッド

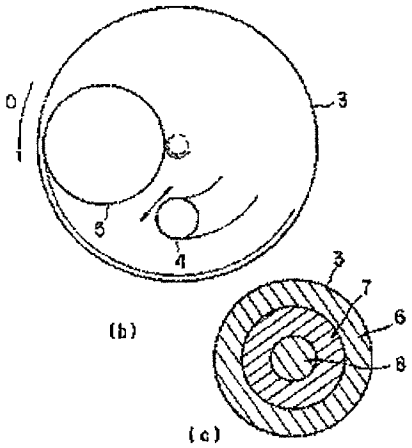
３ａ…パッド面

４、５…ダイヤモンド砥石

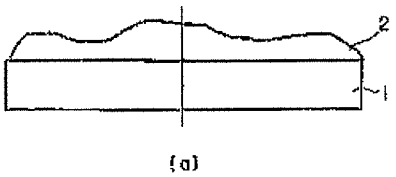
６、７、８…研磨パッド部分

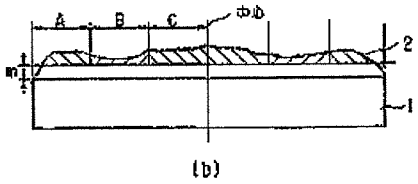
【図1】


4
5
3a
3
(a)

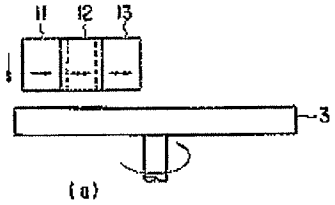

O
3
5
4
(b)
3
7
6
8
(c)

【図2】

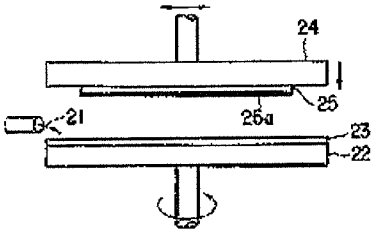

2
1
(a)


A
B
C
中心
2
m
1
(b)

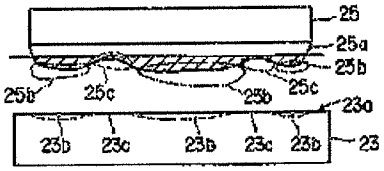
【図3】

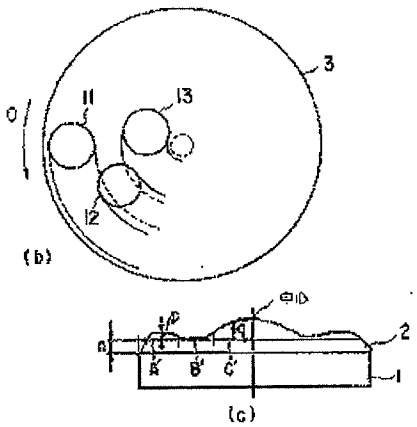

11
12
13
3
(a)

【図4】


24
25
21
25a
23
22

【図5】


25
25a
25b
25b
25c
25c
25b
25c
23a
23b
23c
23b
23c
23b
23


3
O
11
13
12
(b)
中心
2
m
A'
B'
C'
1
(c)

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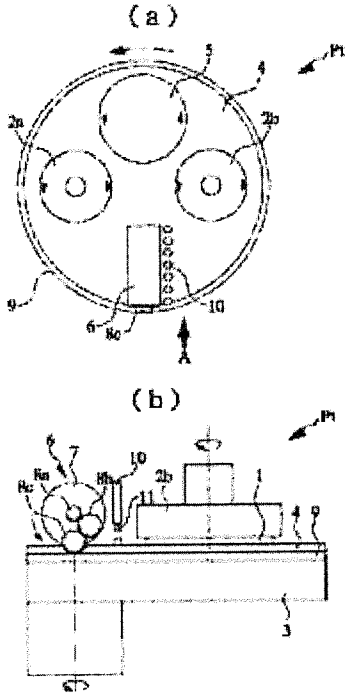
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(54) CHEMICAL-MECHANICAL POLISHING DEVICE, AND MANUFACTURE OF SEMICONDUCTOR INTEGRATED CIRCUIT DEVICE USING SAME

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a polishing pad of long life in a chemical-mechanical polishing(CMP) technique, as well as to polish uniformly a whole surface of a polished film on a semiconductor wafer at stable polishing speed.
SOLUTION: After a surface of a polishing pad 4 is ground by the first dressor 5 with embedded diamond particles to achieve flatness, a surface of a polished film on a semiconductor wafer 1 is polished, and a sodding grain on a surface of the polishing pad 4 is set up simultaneously by the second dressor 6 composed of a cylindrical brush 7 while supplying a polishing abrasive solution through a supplying nozzle 10 so as to restore an original coarse sodding grain.



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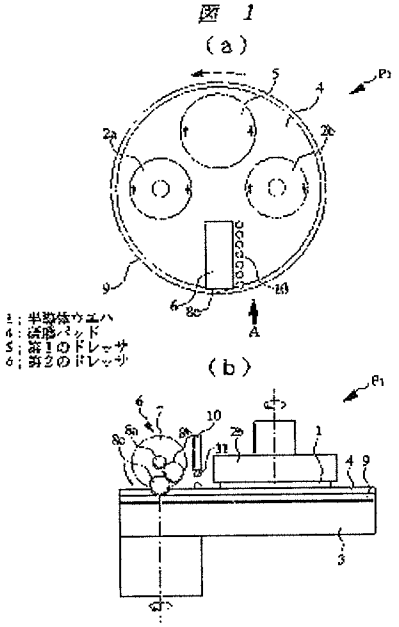
(54)【発明の名称】　化学的機械研磨装置およびこれを用いた半導体集積回路装置の製造方法

(57)【要約】

【課題】　ＣＭＰ技術において、寿命の長い研磨パッドを得ると同時に、安定した研磨速度で半導体ウエハ上の被研磨膜の全面を均一に研磨する。

【解決手段】　ダイヤモンド粒子が埋め込まれた第１のドレッサ５で研磨パッド４の表面を切削して平坦度を出した後、半導体ウエハ１上の被研磨膜の表面を研磨すると同時に、供給ノズル１０から研磨砥粒溶液１１を供給しながら円筒状のブラシ７によって構成される第２のドレッサ６で研磨パッド４の表面の芝めを立たせて、元の荒い芝めを復元する。

図　1



1

【特許請求の範囲】

【請求項１】　研磨定盤上に貼り付けられた研磨パッドに半導体ウエハを押し付けて前記半導体ウエハ上に設けられた各種膜の表面を研磨する化学的機械研磨装置であって、前記研磨パッドの表面を整形するドレッサが、少なくとも２種類設けられていることを特徴とする化学的機械研磨装置。

【請求項２】　請求項１記載の化学的機械研磨装置において、前記研磨パッドの表面を整形するドレッサとして、少なくとも前記研磨パッドの表面を平坦化する第１のドレッサと、前記研磨パッドの表面の荒さを復元させる第２のドレッサとが設けられていることを特徴とする化学的機械研磨装置。

【請求項３】　請求項２記載の化学的機械研磨装置において、前記第１のドレッサはダイヤモンド粒子が埋め込まれたドレッサであり、前記第２のドレッサはポリマ繊維からなるブラシによって構成されたドレッサであることを特徴とする化学的機械研磨装置。

【請求項４】　請求項３記載の化学的機械研磨装置において、前記半導体ウエハ上に設けられた各種膜の表面を研磨すると同時に、前記研磨パッドの表面に研磨砥粒溶液を供給しながら、前記第２のドレッサを前記研磨パッドの表面に押さえ付けて断続的または連続的に摺動させることを特徴とした化学的機械研磨装置。

【請求項５】　請求項４記載の化学的機械研磨装置において、前記第２のドレッサの前記研磨パッドに対する摺動方向が、少なくとも前記半導体ウエハの摺動方向とほぼ逆方向の成分を有していることを特徴とする化学的機械研磨装置。

【請求項６】　請求項４記載の化学的機械研磨装置において、前記研磨砥粒溶液の供給口が前記第２のドレッサに内蔵されていることを特徴とする化学的機械研磨装置。

【請求項７】　請求項２～６のいずれか１項に記載の化学的機械研磨装置において、前記第２のドレッサが前記研磨パッドの研磨面に対して平行な回転軸を有する円筒状のドレッサであることを特徴とする化学的機械研磨装置。

【請求項８】　請求項７記載の化学的機械研磨装置において、前記第２のドレッサが強制的に回転されることを特徴とする化学的研磨装置。

【請求項９】　請求項７項に記載の化学的機械研磨装置において、前記第２のドレッサの円周速度は、前記研磨パッドが貼り付けられた研磨定盤の最外周部の円周速度よりも速いことを特徴とする化学的機械研磨装置。

【請求項１０】　請求項１～９のいずれか１項に記載の化学的機械研磨装置を用いた半導体集積回路装置装置の製造方法であって、前記第１のドレッサおよび前記第２のドレッサで整形される前記研磨パッドによって、半導体ウエハ上に設けられた各種膜の表面を平坦に加工する

2

工程を有することを特徴とする半導体集積回路装置の製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、半導体集積回路装置の製造技術に関し、特に、半導体ウエハ上に堆積された絶縁膜または金属膜の表面の凹凸を化学的機械研磨（Chemcal Mechanical Polishing；ＣＭＰ）装置を用いて平坦に加工する技術に関するものである。

【０００２】

【従来の技術】従来のＣＭＰ装置Ｐ₂の要部断面の模式図を図５に示す。図において、５１は半導体ウエハ、５２は剛性板、５３は低剛性の合成樹脂から成る加圧用パッド、５４は剛性板５２にその厚み方向に複数個設けられた通気孔、５５は剛性板５２に設けられた通気孔５４と一致する如く加圧用パッド５３に配列された通気孔、５６は加圧ヘッド、５７は研磨パッド、５８は研磨パッドが貼り付けられた研磨定盤、５９は半導体ウエハ５１が研磨中に加圧ヘッド５６から外れないように設けられたストッパである。

【０００３】半導体ウエハ５１は、剛性板５２および加圧用パッド５３にそれぞれ設けられた通気孔５４、５５からの真空吸引により加圧ヘッド５６に装着された後、研磨パッド５７上に押し付けられる。研磨時の圧力は加圧ヘッド５６、剛性板５２、加圧用パッド５３を介して半導体ウエハ５１に加えられる。半導体ウエハ５１は加圧ヘッド５６と共に回転し、同じく回転する研磨定盤５８に貼り付けられた研磨パッド５７に押さえつけながら研磨される。

【０００４】次に、前記ＣＭＰ装置Ｐ₂を用い、半導体ウエハ上に堆積された絶縁膜または金属膜の表面の凹凸を平坦化する製造工程の一例を図６（ａ）～（ｆ）を用いて説明する。

【０００５】これらの図において、６０は半導体基板、６１は第１層目の配線、６２は層間絶縁膜、６３は層間絶縁膜６２に開孔されたスルーホール、６４は金属膜、６５は第２層目の配線である。

【０００６】まず、半導体基板６０上に、例えばトランジスタ等の半導体素子、電荷蓄積用容量素子または抵抗素子（いずれも図示せず）などを形成した後、これらを互いに電気的に接続する第１層目の配線６１を形成する（工程（ａ））。この際、半導体基板６０の表面には第１層目の配線６１の厚み分の凸部が生ずる。

【０００７】次に、ＣＶＤ（Chemical Vapor Deposition）法を用いて酸化シリコン膜または窒化シリコン膜などによって構成される層間絶縁膜６２を半導体基板６０上に堆積させて、上記第１層目の配線６１を層間絶縁膜６２で覆う（工程（ｂ））。この際、ほぼ前記第１層目の配線６１の厚み分の段差が層間絶縁膜６２の表面に残留する。次いで、前記ＣＭＰ装置Ｐ₂を用いて、層間絶

縁膜６２の表面を研磨して平坦に加工する（工程（ｃ））。

【０００８】次に、第１層目の配線６１に達するスルーホール６３を層間絶縁膜６２に設けた後、ＣＶＤ法またはスパッタリング法などによって半導体基板６０上に金属膜６４を堆積し（工程（ｄ））、次いで、前記ＣＭＰ装置Ｐ₁を用いて層間絶縁膜６２の表面に積層された金属膜６４を研磨除去する。これによって、スルーホール６３に金属膜６４を埋め込む（工程（ｅ））。

【０００９】次に、半導体基板６０上に金属膜（図示せず）を堆積した後、この金属膜をパターニングすることによって第２層目の配線６５を形成する（工程（ｆ））。第１層目の配線６１と第２層目の配線６５とはスルーホール６３に埋め込まれた金属膜６４を介して電気的に接続される。また、上記工程（ａ）～（ｆ）を同様に繰り返すことにより所望の多層配線を有する半導体集積回路装置を形成することができる。

【００１０】ところで、上記工程（ｃ）での層間絶縁膜６２の表面の平坦化および上記工程（ｅ）での金属膜６４の表面の平坦化で要求される研磨技術の基本的性能としては、被研磨膜の凹凸の平坦度、研磨量の均一性、スループットおよび研磨速度の安定性が挙げられる。これらのうち、被研磨膜の凹凸の平坦度は使用する研磨パッドの機械的材料、研磨量の均一性はウエハ加圧方式によってほぼ決定されるのに対し、スループットおよび研磨速度の安定性は、研磨砥粒の材質、加圧力または揺動速度などの研磨条件に加えて、研磨パッドの表面状態に強く依存する。

【００１１】特に、本発明者の実験により、研磨速度の安定性は研磨パッドの表面の荒さの変化と強い相関関係があることが明らかとなった。図７は、本発明者の実験結果の一例であり、半導体ウエハの処理枚数に対する半導体ウエハ上の被研磨膜の研磨速度の変化および研磨パッドの表面の荒さの変化を示すグラフ図である。

【００１２】図に示すように、半導体ウエハの処理枚数が増加するに従い、研磨速度は初期に急激に低下し、その後、なだらかに低下した後、ほぼ一定の速度に安定する。また、研磨速度の変化と同様に、研磨パッドの表面の荒さも半導体ウエハの処理枚数が増加するに従い減少した後、ほぼ一定の荒さに落ち着く。

【００１３】この現象は、研磨パッドの表面の荒さが減少すると研磨砥粒液の保持力が低下して研磨パッドの表面に供給された研磨砥粒液が半導体ウエハの揺動により半導体ウエハの外周端で掻き出されてしまい、半導体ウエハ上の研磨面と研磨パッド面との間に存在する研磨砥粒の量が減少して、研磨速度が低下するものと考えられる。なお、研磨パッドの表面の荒さが減少する理由は、研磨パッドの表面の芝め構造が、研磨中に繰り返し受ける半導体ウエハの研磨圧力によって倒れてしまうためである。

【００１４】そこで、研磨中における研磨パッドの表面状態の経時変化を防ぎ、半導体ウエハの表面の研磨速度を一定に保つために、半導体ウエハ上の被研磨膜を研磨する加圧ヘッドとは別に、ダイヤモンド粒子を埋め込んだ円盤（以下、ドレッサと称す）を研磨作業後または研磨作業中に研磨パッド上に摺動させて、研磨パッドの表面を整形するドレッシングが研磨パッドに施されている。

【００１５】図８および図９に従来の研磨パッドのドレッシング方法の概略図を示す。図８に示すドレッシング方法は、大型のドレッサ６６に回転と揺動を加えながら研磨パッド５７の表面を整形する方法であり、図９に示すドレッシング方法は、アーム機構６７を用いて小型のドレッサ６８を研磨パッド５７の全面に可変速で揺動させて、研磨パッド５７の表面を整形する方法である。これらのドレッシング方法には、半導体ウエハ上の被研磨膜の研磨と研磨パッドの表面のドレッシングとを同時に行う同時ドレッシング、または半導体ウエハ上の被研磨膜の研磨前後の半導体ウエハを搬送する空き時間に研磨パッドの表面のドレッシングを行う間欠ドレッシングがある。

【００１６】なお、ＣＭＰ装置のドレッシング方法については、例えばソリッド・ステート・テクノロジ（Solid State Technology, 日本版,Dec. 1994, Iqbal Ali et al.,"層間絶縁膜の化学的機械研磨に関する概観"）などに記載されている。

【００１７】

【発明が解決しようとする課題】しかしながら、前記ドレッシング方法には、以下の問題点があることを本発明者は見いだした。

【００１８】すなわち、まず、同時ドレッシングでは、研磨パッドの表面が常にドレッシングされるので安定な研磨速度が得られるが、研磨パッドの表面が常にドレッサによって削り取られるため研磨パッドの寿命が著しく低下する。また、間欠ドレッシングでは、研磨パッドの寿命は長いが、半導体ウエハ上の被研磨膜の研磨中に研磨速度が低下して安定な研磨速度が得られず、さらに、ドレッシングに要する時間が単独で必要なためＣＭＰ装置のスループットが低下する。

【００１９】これらの問題を解決する方法の一つとして、研磨パッドに対するドレッサの押圧力を低下させる方法がある。この方法を採用すれば、研磨速度をある程度安定化させ、研磨パッドの寿命を長くすることができる。

【００２０】しかし、ドレッシングには、研磨パッドの表面の荒さを一定に保ち研磨速度を安定化させる目的の他に、研磨パッドの全面をドレッシングでの切削によって整形し、研磨パッドの表面の平坦度を得ることにより半導体ウエハ上の被研磨膜の全面の均一性を確保する目的があり、研磨パッドに対するドレッサの押圧力を低下

させると研磨パッドの表面の平坦度を確保することが難しく、半導体ウエハ上の被研磨膜の全面を均一に研磨することができない問題がある。

【００２１】本発明の目的は、ＣＭＰ技術において、寿命の長い研磨パッドを得ると同時に、安定した研磨速度で半導体ウエハ上の被研磨膜の全面を均一に研磨することができる技術を提供することにある。

【００２２】本発明の前記ならびにその他の目的と新規な特徴は、本明細書の記述および添付図面から明らかになるであろう。

【００２３】

【課題を解決するための手段】本願において開示される発明のうち、代表的なものの概要を簡単に説明すれば、次のとおりである。

【００２４】すなわち、本発明のＣＭＰ装置は、研磨定盤上に貼り付けられた研磨パッドの表面を整形するドレッサとして、少なくとも、ダイヤモンド粒子が埋め込まれ、研磨パッドの表面を平坦化する第１のドレッサと、ポリマ繊維からなるブラシによって構成され、研磨パッドの表面の荒さを復元させる第２のドレッサとを有しており、上記第１のドレッサにより研磨パッドの表面を切削した後、第１のドレッサを後退させ、次いで、加圧ヘッドに装着された半導体ウエハを研磨パッドの表面に押さえ付けて半導体ウエハ上の被研磨膜の表面を研磨すると同時に、研磨パッドの表面に研磨砥粒溶液を供給しながら上記第２のドレッサを断続的または連続的に研磨パッドの表面に押さえ付けて、研磨パッドの表面の芝めを立たせる方向に摺動させるものである。

【００２５】上記した手段によれば、第２のドレッサによるドレッシングによって、研磨パッドの表面を切削することなく、半導体ウエハ上の被研磨膜の表面を研磨することによって倒れた研磨パッドの表面の芝めを立たせて、比較的容易に元の荒い芝めに復元できるので、研磨パッドの寿命を大幅に長くできると同時に、半導体ウエハ上の被研磨膜の研磨速度を安定化することができる。さらに、研磨パッドに対する第１のドレッサの押圧力を低下させる必要がないので、研磨パッドの表面の平坦度が確保できて、半導体ウエハ上の被研磨膜の全面を均一に研磨することができる。

【００２６】

【発明の実施の形態】以下、本発明の実施の形態を図面に基づいて詳細に説明する。

【００２７】なお、実施の形態を説明するための全図において同一機能を有するものは同一の符号を付し、その繰り返しの説明は省略する。

【００２８】本発明の一実施の形態であるＣＭＰ装置Ｐ，が有する研磨パッドのドレッシング方法を図１に示す模式図を用いて説明する。図１（ａ）は、ＣＭＰ装置Ｐ，の上面図であり、図１（ｂ）は、図１（ａ）中に記載のＡ方向から見たＣＭＰ装置Ｐ，の側面図である。１は半導体ウエハ、２ａ，２ｂは加圧ヘッド、３は研磨定盤、４は研磨パッド、５は第１のドレッサ、６は第２のドレッサ、７はブラシ、８ａ，８ｂ，８ｃは歯車、９はギア、１０は供給ノズル、１１は研磨砥粒溶液である。

【００２９】被研磨材料である半導体ウエハ１は、加圧ヘッド２ａ，２ｂに装着され、回転する研磨定盤３上に張り付けられた研磨パッド４の表面に加圧ヘッド２ａ，２ｂを介して押さえ付けられて、その表面は研磨される。なお、研磨時の加圧ヘッド２ａ、２ｂおよび研磨定盤３の回転数は、例えば共に３０回／分であり、半導体ウエハ１および研磨定盤３の直径は、例えばそれぞれ８インチおよび６００ｎｍである。半導体ウエハ１は、例えば３００ｇｒ／ｃｍ² の圧力で研磨パッド４の表面に押さえ付けられている。

【００３０】研磨パッド４の表面は、第１のドレッサ５および第２のドレッサ６を用いてドレッシングされる。第１のドレッサ５にはダイヤモンド粒子が埋め込まれており、第１のドレッサ５は研磨パッド４の表面を切削して平坦度を出すために用いられる。第２のドレッサ６は研磨パッドの研磨面に対して平行な回転軸を有する円筒状のブラシ７と歯車８ａ，８ｂ，８ｃとによって構成されており、研磨パッド４の表面の芝めを立たせて元の荒い芝めを復元するために用いられる。

【００３１】第２のドレッサ６の歯車８ｃを研磨定盤３の外周壁面に形成したギア９と噛み合わせて研磨定盤３を回転させることにより、歯車８ｂを介して歯車８ａと一体のブラシ７を強制的に回転駆動させる。この際、第２のドレッサ６の研磨パッド４に対する摺動方向は、半導体ウエハ１の摺動方向とほぼ逆方向の成分を有している。また、ブラシ７の円周速度は研磨定盤３の最外周部の円周速度より約1.5倍速くなるように、歯車８ｃのギア比とブラシ７の径は選ばれる。ブラシ７には、例えば線径１００μｍ、長さ５ｍｍのナイロンブラシを使用した。

【００３２】まず、第１のドレッサ５を用いて研磨パッド４の表面を切削した後、第１のドレッサ５を後退させ、次いで、半導体ウエハ１上の被研磨膜の表面を研磨すると同時に、第２のドレッサ６を断続的または連続的に研磨パッド４上で摺動させて、研磨パッド４の表面を整形する。この際、第２のドレッサ６の近傍に設置した供給ノズル１０から研磨砥粒溶液１１が約２００ｍｌ／分の速度で研磨パッド４上に供給される。研磨砥粒溶液１１の供給口は第２のドレッサ６に内蔵してもよい。

【００３３】図２に、本実施の形態である前記ＣＭＰ装置Ｐ，を用いて、半導体ウエハ上にプラズマＣＶＤ法で堆積された酸化シリコン膜の表面を研磨した際の酸化シリコン膜の研磨速度と半導体ウエハの研磨枚数との関係を示す。図において、四角印は前記本実施の形態のドレッシング、白丸印は従来の同時ドレッシング、黒丸印は従来の間欠ドレッシングを採用した際のそれぞれの酸化

シリコン膜の研磨速度を示す。

【００３４】いずれの場合も一つの研磨定盤に対して２つの加圧ヘッドを有し、２枚の半導体ウエハを同時に研磨した結果であり、図中には２枚の半導体ウエハで得られたそれぞれの酸化シリコン膜の研磨速度の平均値を１点で示してある。半導体ウエハ上の酸化シリコン膜の研磨時間は５分である。

【００３５】本実施の形態のドレッシングでは、半導体ウエハ１上の酸化シリコン膜の研磨前の第１のドレッサ５によるドレッシング時間は３分であり、半導体ウエハ１上の酸化シリコン膜の研磨中は第２のドレッサ６でドレッシングを行っている。研磨パッドには厚さが1.2ｍｍの発泡ポリウレタン性のＩＣ１０００（米国ロデール社）を用いた。なお、従来の間欠ドレッシングのドレッシング時間は２分である。

【００３６】図から明らかなように、従来の間欠ドレッシングの研磨速度は他のドレッシングの研磨速度と比べて約１０％低く、また、±５％以上の研磨速度の変動がある。しかし、本実施の形態のドレッシングでは半導体ウエハの研磨枚数が２５枚まで従来の同時ドレッシングとほぼ同じ研磨速度が得られ、また、±２％以下の研磨量の均一性（図示せず）が得られる。

【００３７】図３に、本実施の形態である前記ＣＭＰ装置P_1を用いて、半導体ウエハ上に堆積された酸化シリコン膜を研磨した際の研磨パッドの厚さと半導体ウエハの研磨枚数との関係を示す。図において、四角印は前記本実施の形態のドレッシング、白丸印は従来の同時ドレッシング、黒丸印は従来の間欠ドレッシングを採用した際のそれぞれの研磨パッドの厚さを示す。

【００３８】なお、本発明者の実験から、研磨パッドをその厚さが初期の厚さ（例えば1.2ｍｍ）の約半分になるまで研磨すると、半導体ウエハ上の被研磨膜の研磨速度の安定性または半導体ウエハ上の被研磨膜の研磨量均一性に顕著な劣化が認められることが明らかになっており、このことから、研磨パッドの厚さが半分となった時点を研磨パッドの寿命と称す。

【００３９】図に示すように、従来の同時ドレッシングでは約１００枚の半導体ウエハを研磨するだけで研磨パッドは寿命に達し、従来の間欠ドレッシングでも約２５０枚の半導体ウエハを研磨すると研磨パッドは寿命に達する。これに対し、本実施の形態のドレッシングでは、約４０００枚の半導体ウエハを研磨すると研磨パッドが寿命に達する。

【００４０】次に、本実施の形態の前記ＣＭＰ装置P_1を用いたＤＲＡＭ（Dynamic RandomAccess Memory）の多層配線の製造方法を図４を用いて説明する。なお、ＤＲＡＭの周辺回路部はｎチャネル型ＭＩＳＦＥＴ（Metal Insulator SemiconductorField Effect Transistor）Q_sの製造方法のみを記載する。

【００４１】まず、p^-型シリコン単結晶からなる半導体基板１２の主面上に周知の方法でｐ型ウエル１３、フィールド絶縁膜１４およびゲート絶縁膜１５を順次形成する。

【００４２】次に、図示はしないが、半導体基板１２上に堆積された窒化シリコン膜、タングステンシリサイド（WSi_x）膜および多結晶シリコン膜からなる積層膜を順次エッチングすることにより、WSi_x膜および多結晶シリコン膜からなるメモリセルのメモリセル選択用ＭＩＳＦＥＴのゲート電極１６および周辺回路部のｎチャネル型ＭＩＳＦＥＴQ_sのゲート電極１６を形成する。

【００４３】なお、上記ゲート電極１６を構成するメタルシリサイド膜にWSi_x膜を用いたが、その他のメタルシリサイド膜、例えばモリブデンシリサイド（$MoSi_x$）膜、チタンシリサイド（$TiSi_x$）膜、タンタルシリサイド（$TaSi_x$）膜などを用いてもよい。

【００４４】次に、レジストパターンならびに上記窒化シリコン膜、WSi_x膜および多結晶シリコン膜からなる積層膜をマスクにして、周辺回路部のｐ型ウエル１３にｎ型不純物、例えばリン（Ｐ）をイオン注入し、ｎチャネル型ＭＩＳＦＥＴQ_sのｎ型半導体領域（ソース領域、ドレイン領域）１７を、ゲート電極１６に対して自己整合で形成する。

【００４５】その後、半導体基板１２上に堆積された窒化シリコン膜をＲＩＥ（Reactive Ion Etching）法などの異方性エッチングで加工することによって、ゲート電極１６の側壁にサイドウォールスペーサを形成し、ゲート電極１６を窒化シリコン膜からなる絶縁膜１８で覆う。

【００４６】なお、上記サイドウォールスペーサを形成した後、周辺回路部のｐ型ウエル１３に高濃度のｎ型不純物、例えば砒素（Ａｓ）をイオン注入することにより、ｎチャネル型ＭＩＳＦＥＴQ_sのソース領域、ドレイン領域をＬＤＤ（Lightly Doped Drain）構造としてもよい。

【００４７】次に、半導体基板１２上に酸化シリコン膜１９および第１のＢＰＳＧ（Boron-doped Phospho Silicate Glass）膜２０をＣＶＤ法によって堆積した後、９００～９５０℃のリフロー処理により上記第１のＢＰＳＧ膜２０の表面を平坦化する。

【００４８】その後、レジストパターンをマスクにして第１のＢＰＳＧ膜２０、酸化シリコン膜１９およびゲート絶縁膜１５と同一層の絶縁膜を順次エッチングすることにより、メモリセル選択用ＭＩＳＦＥＴの一方の後に形成されるｎ型半導体領域２１上に第１のコンタクトホール２２を形成する。

【００４９】次いで、上記第１のコンタクトホール２２内にＰが導入された多結晶シリコン膜２３からなる第１プラグ電極を形成する。なお、この多結晶シリコン膜２３に導入されたＰの拡散によってメモリセル選択用ＭＩ

ＳＦＥＴの一方のｎ型半導体領域２１が形成される。

【００５０】次に、半導体基板１２上に酸化シリコン膜２４をＣＶＤ法によって堆積する。次いで、図示はしないが、レジストパターンをマスクにして酸化シリコン膜２３、第１のＢＰＳＧ膜２０、酸化シリコン膜１９およびゲート絶縁膜１５と同一層の絶縁膜を順次エッチングすることにより、メモリセル選択用ＭＩＳＦＥＴの他方の後に形成されるｎ型半導体領域上に第２のコンタクトホールを形成する。この際、後に形成されるビット線を周辺回路部に延在し、周辺回路部の半導体基板１２に接続するための第２のコンタクトホール（周辺回路部）２５を形成してもよい。

【００５１】次いで、半導体基板１２上にＰが導入された多結晶シリコン膜２６およびWSi_x膜２７をＣＶＤ法によって順次堆積した後、レジストパターンをマスクにしてWSi_x膜２７および多結晶シリコン膜２６を順次エッチングすることにより、WSi_x膜２７および多結晶シリコン膜２６からなるビット線を形成する。

【００５２】また、多結晶シリコン膜２６に導入されたＰの拡散によってメモリセル選択用ＭＩＳＦＥＴの他方のｎ型半導体領域（図示せず）は形成され、ビット線は第２のコンタクトホールを通して、このメモリセル選択用ＭＩＳＦＥＴの他方のｎ型半導体領域に接続される。この際、多結晶シリコン膜２６に導入されたＰの拡散によって周辺回路部のｐ型ウエル１３にもｎ型半導体領域（周辺回路部）２８が形成され、第２のコンタクトホール（周辺回路部）２５を通して、ビット線が上記ｎ型半導体領域（周辺回路部）２８に接続される。

【００５３】次に、半導体基板１２上に酸化シリコン膜２９、窒化シリコン膜３０および第２のＢＰＳＧ膜（図示せず）をＣＶＤ法によって順次堆積した後、９００～９５０℃のリフロー処理により上記第２のＢＰＳＧ膜の表面を平坦化する。

【００５４】次に、半導体基板１２上にＰが導入された多結晶シリコン膜３１をＣＶＤ法によって堆積した後、レジストパターンをマスクにして多結晶シリコン膜３１をエッチングする。次いで、半導体基板１２上にＣＶＤ法によって堆積されたＰが導入された多結晶シリコン膜３２をＲＩＥ法などの異方性エッチングによって加工し、上記多結晶シリコン膜３１の側壁に多結晶シリコン膜３２からなるサイドウォールスペーサを形成する。

【００５５】次いで、レジストパターンをマスクにしてメモリセルの第２のＢＰＳＧ膜、窒化シリコン膜３０、酸化シリコン膜２９および酸化シリコン膜２４を順次エッチングすることにより、第１のコンタクトホール２２内に設けられた第１プラグ電極上に第３のコンタクトホール３３を形成した後、半導体基板１２上にＰが導入された多結晶シリコン膜３４および第３のＢＰＳＧ膜（図示せず）をＣＶＤ法によって順次堆積する。

【００５６】次に、レジストパターンをマスクにして上記第３のＢＰＳＧ膜および多結晶シリコン膜３４，３１を順次エッチングした後、半導体基板１２上にＰが導入された多結晶シリコン膜３５をＣＶＤ法によって堆積する。次いで、この多結晶シリコン膜３５をＲＩＥ法などの異方性エッチングによって加工し、メモリセルの第３のＢＰＳＧ膜および多結晶シリコン膜３４，３１の側壁に多結晶シリコン膜３５を残す。

【００５７】次に、例えば、フッ酸溶液を用いたウエットエッチングによって、第３のＢＰＳＧ膜および第２のＢＰＳＧ膜を除去し、メモリセルに多結晶シリコン膜３１，３２，３４，３５からなる円筒型の蓄積電極を形成する。

【００５８】次に、半導体基板１２上に厚さ約２ｎｍの窒化シリコン膜（図示せず）をＣＶＤ法によって堆積し、続いて、厚さ約３０ｎｍの非晶質の酸化タンタル（Ta_2O_5）膜（図示せず）をＣＶＤ法によって堆積した後、半導体基板１２に熱酸化処理を施すことによって、上記Ta_2O_5膜を結晶化する。その後、半導体基板１２上にＴｉＮ膜３６をＣＶＤ法によって堆積し、次いで、フォトレジストをマスクにしてこのＴｉＮ膜３６をエッチングすることにより、ＴｉＮ膜３６からなるプレート電極を形成する。

【００５９】なお、容量絶縁膜にTa_2O_5膜を用いたが、その他の酸化メタル膜（例えば、（Ｂａ，Ｓｒ）ＴｉＯ膜またはＰｂ（Ｚｒ，Ｔｉ）O_3膜）などを用いてもよく、また、上記プレート電極にＴｉＮ膜を用いたが、その他のメタルナイトライド膜（例えば、ＷＮ膜）またはメタル膜（例えば、Ｗ膜）などを用いてもよい。

【００６０】次に、半導体基板１２上に酸化シリコン膜３７および第４のＢＰＳＧ膜３８をＣＶＤ法によって順次堆積した後、９００～９５０℃のリフロー処理により上記第４のＢＰＳＧ膜３８の表面を平坦化する。

【００６１】次いで、レジストパターンをマスクにして第４のＢＰＳＧ膜３８および酸化シリコン膜３７を順次エッチングすることにより、ＴｉＮ膜３６からなるプレート電極上に第４のコンタクトホール３９ａを形成し、同時に、第４のＢＰＳＧ膜３８、酸化シリコン膜３７および酸化シリコン膜２９を順次エッチングすることにより、WSi_x膜２７および多結晶シリコン膜２６からなるビット線上に第４のコンタクトホール３９ｂを形成する。

【００６２】さらに、同時に、第４のＢＰＳＧ膜３８、酸化シリコン膜３７、酸化シリコン膜２９、酸化シリコン膜２４、第１のＢＰＳＧ膜２０、酸化シリコン膜１９およびゲート絶縁膜１５と同一層の絶縁膜を順次エッチングすることにより、ｎチャネル型ＭＩＳＦＥＴQ_sのｎ型半導体領域１７上に第４のコンタクトホール３９ｃを形成する。

【００６３】次に、半導体基板１２上に金属膜（図示せず）を堆積した後、レジストパターンをマスクにして上

記金属膜をエッチングすることにより、第１層目のメタル配線M_1が形成される。次いで、半導体基板１２上にＥＣＲ（Electron CyclotronResonance：電子サイクロトロン共鳴）プラズマＣＶＤ法によって酸化シリコン膜を堆積した後、この酸化シリコン膜の表面を本実施の形態である前記ＣＭＰ装置P_1を用いて研磨することによって、その表面が平坦化された酸化シリコン膜によって構成される第１の層間絶縁膜４０を設ける。

【００６４】次に、レジストパターンをマスクにして上記第１の層間絶縁膜４０をエッチングすることにより、第１層目のメタル配線M_1に達するスルーホール４１を形成した後、半導体基板１２上に金属膜（図示せず）を堆積し、次いで、この金属膜をレジストパターンをマスクにしてエッチングすることにより、第２層目のメタル配線M_2を形成する。

【００６５】ここで、第１の層間絶縁膜４０の表面が平坦化されているので、第２層目のメタル配線M_2を形成する際のフォトリソグラフィ工程において、マスクパターン転写における焦点深度に余裕が生じ、高解像度のレジストパターンが形成される。これによって、レジストパターンをマスクとして加工、形成される第２層目のメタル配線M_2の欠損または隣接する第２層目のメタル配線M_2間の接触を防ぐことができる。

【００６６】さらに、上記第１の層間絶縁膜４０と同様に、半導体基板１２上にＥＣＲプラズマＣＶＤ法によって酸化シリコン膜を堆積した後、この酸化シリコン膜の表面を本実施の形態である前記ＣＭＰ装置P_1を用いて研磨することによって、その表面が平坦化された酸化シリコン膜によって構成される第２の層間絶縁膜４２を設ける。

【００６７】次に、レジストパターンをマスクにして上記第２の層間絶縁膜４２をエッチングすることにより、第２層目のメタル配線M_2に達するスルーホール４２を形成した後、半導体基板１２上に金属膜（図示せず）を堆積し、次いで、この金属膜をレジストパターンをマスクにしてエッチングすることにより、第３層目のメタル配線M_3を形成する。

【００６８】最後に、半導体基板１２の表面をパッシベーション（図示せず）で被覆することにより、本実施の形態のＣＭＰ装置P_1を用いて加工された第１の層間絶縁膜４０および第２の層間絶縁膜４２を有するＤＲＡＭが完成する。

【００６９】このように、本実施の形態では、研磨パッド４の寿命が、従来の同時ドレッシングを採用した研磨パッドの寿命の約４０倍以上、また、従来の間欠ドレッシングを採用した研磨パッドの寿命の約１６倍以上長くなり、例えば、従来の同時ドレッシングでは４～５時間毎に必要があった研磨パッドの交換を週に１度の頻度とすることができる。さらに、第２のドレッサ６のブラシ７を研磨パッド４の表面の芝めを立たせる方向に摺動させることによって、研磨パッド４の表面の倒れた芝めを立たせて、比較的容易に元の荒い芝めに復元することができるので、研磨速度を安定化することができる。さらに、研磨パッド４に対する第１のドレッサ５の押圧力を低下させる必要がないので、研磨パッド４の表面の平坦度が確保できて、半導体ウエハ１上の被研磨膜の全面を均一に研磨することができる。

【００７０】以上、本発明者によってなされた発明を発明の実施の形態に基づき具体的に説明したが、本発明は前記実施の形態に限定されるものではなく、その要旨を逸脱しない範囲で種々変更可能であることはいうまでもない。

【００７１】

【発明の効果】本願によって開示される発明のうち、代表的なものによって得られる効果を簡単に説明すれば、以下のとおりである。

【００７２】本発明によれば、ブラシによって構成された第２のドレッサによるドレッシングによって、研磨パッドの表面を切削することなく、比較的容易に研磨パッドの表面の芝めを荒い芝めに復元することができるので、研磨パッドの寿命を大幅に長くできると同時に、半導体ウエハ上の被研磨膜の表面の研磨速度を安定化することができ、さらに、ダイヤモンド粒子を埋め込んだ第１のドレッサの研磨パッドに対する押圧力を低下させる必要がないので、研磨パッドの表面の平坦度が確保できて、半導体ウエハ上の被研磨膜の全面を均一に研磨することができる。

【００７３】また、本発明によれば、研磨パッドの寿命が長くなるので、半導体製造装置としての生産能力、稼働率が大幅に向上し、また、高価な研磨パッドの消費量が減少する。

【図面の簡単な説明】

【図１】本発明の一実施の形態であるＣＭＰ装置の模式図であり、（ａ）は上面図、（ｂ）は要部側面図である。

【図２】本発明の一実施の形態であるドレッシング、従来の同時ドレッシングまたは従来の間欠ドレッシングをそれぞれ採用した研磨パッドを有するＣＭＰ装置を用いて、半導体ウエハ上の酸化シリコン膜の表面を研磨した際の酸化シリコン膜の研磨速度の経時変化を示すグラフ図である。

【図３】本発明の一実施の形態であるドレッシング、従来の同時ドレッシングまたは従来の間欠ドレッシングをそれぞれ採用した研磨パッドを有するＣＭＰ装置を用いて、半導体ウエハ上の酸化シリコン膜の表面を研磨した際の研磨パッドの厚さの経時変化を示すグラフ図である。

【図４】本発明の一実施の形態であるドレッシングを採用した研磨パッドを有するＣＭＰ装置を用いて平坦化される層間絶縁膜を有するＤＲＡＭを示す半導体基板の要

部断面図である。

【図５】従来のＣＭＰ装置の要部側面の模式図である。

【図６】（ａ）～（ｆ）はそれぞれ従来のドレッシングを採用した研磨パッドを有するＣＭＰ装置を用いて平坦化される絶縁膜または金属膜を有する半導体基板の要部断面図である。

【図７】従来のドレッシングを採用した研磨パッドを有するＣＭＰ装置を用いて研磨された半導体ウエハ上の被研磨膜の研磨速度と研磨パッドの荒さの経時変化を示すグラフ図である。

【図８】従来の研磨パッドのドレッシング方法を説明するための概略図である。

【図９】従来の研磨パッドのドレッシング方法を説明するための概略図である。

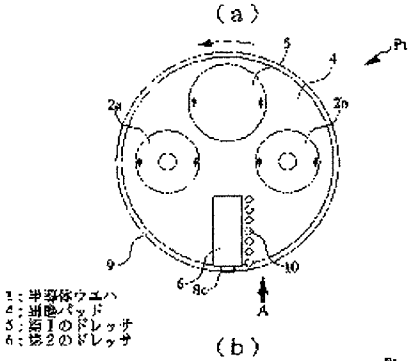
【符号の説明】

１　半導体ウエハ
２ａ　加圧ヘッド
２ｂ　加圧ヘッド
３　研磨定盤
４　研磨パッド
５　第１のドレッサ
６　第２のドレッサ
７　ブラシ
８ａ　歯車
８ｂ　歯車
８ｃ　歯車
９　ギア
１０　供給ノズル
１１　研磨砥粒溶液
１２　半導体基板
１３　ｐ型ウエル
１４　フィールド絶縁膜
１５　ゲート絶縁膜
１６　ゲート電極
１７　ｎ型半導体領域（ソース領域，ドレイン領域）
１８　絶縁膜
１９　酸化シリコン膜
２０　第１のＢＰＳＧ膜
２１　ｎ型半導体領域
２２　第１のコンタクトホール
２３　多結晶シリコン膜
２４　酸化シリコン膜
２５　第２のコンタクトホール（周辺回路部）
２６　多結晶シリコン膜

２７　タングステンシリサイド膜
２８　ｎ型半導体領域（周辺回路部）
２９　酸化シリコン膜
３０　窒化シリコン膜
３１　多結晶シリコン膜
３２　多結晶シリコン膜
３３　第３のコンタクトホール
３４　多結晶シリコン膜
３５　多結晶シリコン膜
３６　窒化チタン膜
３７　酸化シリコン膜
３８　第４のＢＰＳＧ膜
３９ａ　第４のコンタクトホール
３９ｂ　第４のコンタクトホール
３９ｃ　第４のコンタクトホール
４０　第１の層間絶縁膜
４１　スルーホール
４２　第２の層間絶縁膜
４３　スルーホール
５１　半導体ウエハ
５２　剛性板
５３　加圧用パッド
５４　通気孔
５５　通気孔
５６　加圧ヘッド
５７　研磨パッド
５８　研磨定盤
５９　ストッパ
６０　半導体基板
６１　第１層目の配線
６２　層間絶縁膜
６３　スルーホール
６４　金属膜
６５　第２層目の配線
６６　大型のドレッサ
６７　アーム機構
６８　小型のドレッサ
P_1　本発明の実施の形態のＣＭＰ装置
P_2　従来のＣＭＰ装置
Q_5　ｎチャネル型ＭＩＳＦＥＴ
M_1　第１層目のメタル配線
M_2　第２層目のメタル配線
M_3　第３層目のメタル配線

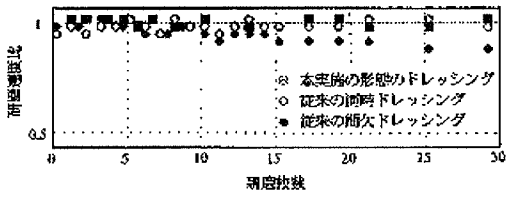
【図１】

図 1



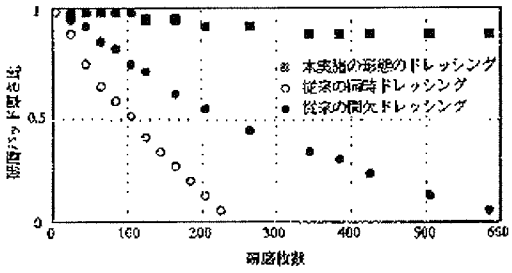
【図２】

図 2



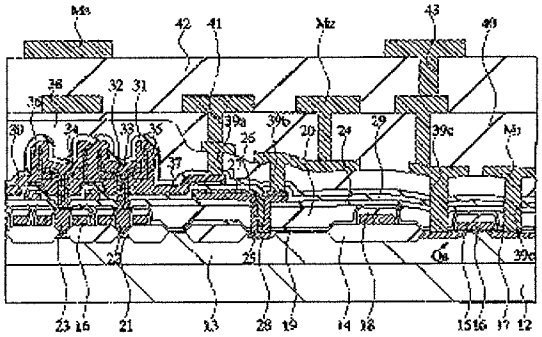
【図３】

図 3



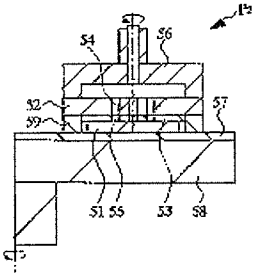
【図４】

図 4



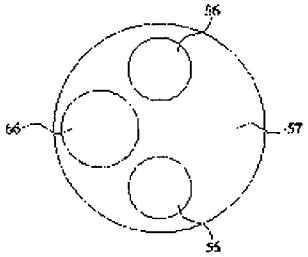
【図５】

図 5



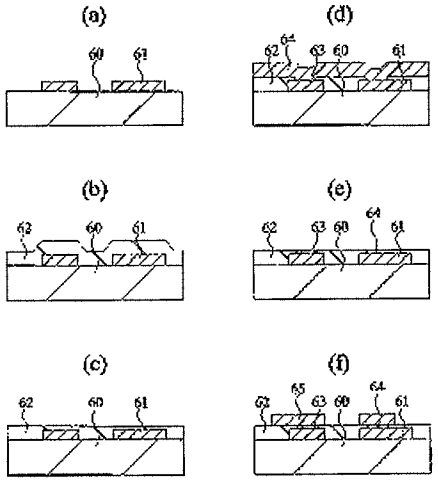
【図８】

図 8



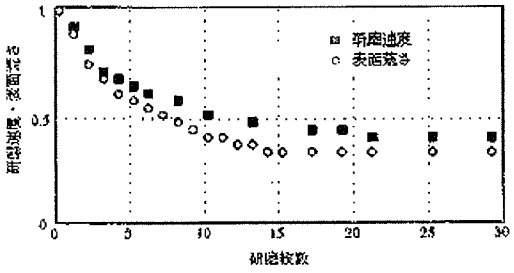
【図６】

図 6



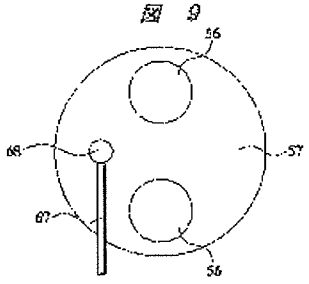
【図７】

図 7



【図９】

図 9



フロントページの続き

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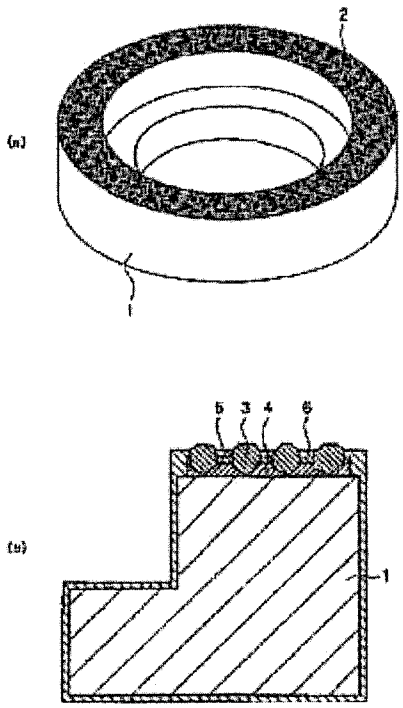
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(71)Applicant : ASAHI DIAMOND IND CO LTD
(72)Inventor : HARA TOMOYOSHI

(54) CONDITIONER FOR CMP AND ITS MANUFACTURE

(57)Abstract:
PROBLEM TO BE SOLVED: To prevent a plated layer fixing diamond abrasive grains from being corroded even by highly acidic polishing liquid and to prevent contamination caused by metallic elution, and falling off of diamond abrasive grains.
SOLUTION: This CPM conditioner has diamond abrasive grains 3 fixed by a plated layer 4, and is applied with nitric acid resistant plating to the plated layer 4; coated its surface with a synthetic resin, and having action tip parts of the diamond abrasive grains projected out of the synthetic resin layer 6. The CPM conditioner is manufactured by fixing the diamond abrasive grains 3 to an action surface by an electrodeposition or a reversible electroforming followed by nitric acid resistant plating 5 and covering with synthetic resin its action surface.



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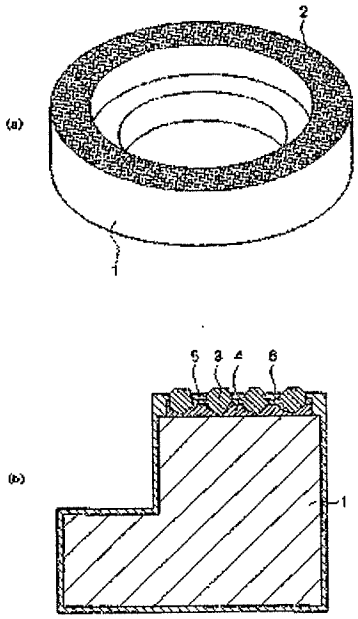
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(54)【発明の名称】　ＣＭＰ用コンディショナ及びその製造方法

(57)【要約】
【課題】半導体ウェーハ研磨用のポリッシングマットのコンディショニングにおいて、酸性の高い研磨液によってもダイヤモンド砥粒を固着するメッキ層が侵されるおそれがなく、金属の溶出によるコンタミネーションやダイヤモンド砥粒の脱落を生じないＣＭＰ用コンディショナ及びその製造方法を提供する。
【解決手段】ダイヤモンド砥粒がメッキ層により固着されたコンディショナにおいて、メッキ層上に耐硝酸性のメッキが施され、その表面がさらに合成樹脂により被覆され、ダイヤモンド砥粒の先端作用部が合成樹脂層より突出してなることを特徴とするＣＭＰ用コンディショナ、及び、作用面にダイヤモンド砥粒を電着法又は反転電鋳法によって固着したのち、さらに耐硝酸性のメッキを施し、その表面を合成樹脂により被覆することを特徴とする該ＣＭＰ用コンディショナの製造方法。



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【特許請求の範囲】

【請求項１】ダイヤモンド砥粒がメッキ層により固着されたコンディショナにおいて、メッキ層上に耐硝酸性のメッキが施され、その表面がさらに合成樹脂により被覆され、ダイヤモンド砥粒の先端作用部が合成樹脂層より突出してなることを特徴とするＣＭＰ用コンディショナ。

【請求項２】耐硝酸性のメッキが、アルミニウム、クロム、金、ロジウム、錫又はこれらの合金のメッキである請求項１記載のＣＭＰ用コンディショナ。

【請求項３】作用面にダイヤモンド砥粒を電着法又は反転電鋳法によって固着したのち、さらに耐硝酸性のメッキを施し、その表面を合成樹脂により被覆することを特徴とする請求項１又は請求項２記載のＣＭＰ用コンディショナの製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は、ＣＭＰ用コンディショナ及びその製造方法に関する。さらに詳しくは、本発明は、半導体ウェーハ研磨用のポリッシングマットのコンディショニングにおいて、酸性の高い研磨液によってもダイヤモンド砥粒を固着するメッキ層が侵され、ダイヤモンド砥粒が脱落するおそれのないＣＭＰ用コンディショナ及びその製造方法に関する。

【０００２】

【従来の技術】一般に半導体ウェーハの表面を研磨するウェーハ加工装置では、円盤状の定盤の上に研磨用ポリッシングマットを貼り付け、定盤上面に１枚又は複数枚のウェーハを載置し、これらウェーハをポリッシングマット上でキャリアにより強制回転させつつポリッシングマットとウェーハの間に微細な研磨粒子と研磨液を供給して、界面の化学的機械的作用によりケミカルメカニカルポリッシング（ＣＭＰ）を行っている。ポリッシングマットとしては、ポリエステル不織布にポリウレタン樹脂を含浸させたベロアタイプマット、ポリエステル不織布を基材としてその上に発泡ポリウレタン層を形成したスエードタイプマット、あるいは独立気泡を有する発泡ポリウレタンのマットなどや、さらにこれらの多層構造体などが使用されている。また、研磨粒子としては、酸化鉄、アルミナ、炭酸バリウム、酸化セリウム、コロイダルシリカなどが用いられ、研磨液には水酸化カリウム溶液、希塩酸、過酸化水素水、硝酸鉄水溶液など、それぞれの場合に応じて使い分けられる。このようなウェーハの研磨を繰り返すうちに、研磨粒子や研磨屑などがポリッシングマットの微細な孔に入り込んで目詰まりを起こしたり、研磨粒子と研磨液の化学反応熱によってポリッシングマットの表面が鏡面化して、研磨速度が低下してしまう。このため、ポリッシングマットの表面を再生して研磨速度を回復させる、いわゆるコンディショニングと呼ばれる操作を常時又は定期的に行う必要があり、

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このような操作にはＣＭＰ用コンディショナと呼ばれる工具が使用される。ダイヤモンド砥粒は優れたコンディショニング材料であり、ダイヤモンド砥粒を利用した半導体ウェーハ研磨用のポリッシングマットのコンディショニングが検討されている。例えば、特開昭６４－７１６６１号公報には、ダイヤモンド砥粒と合金粉末を混合し、加熱焼結したダイヤモンドペレットを端面に貼り付けるか、あるいは、端面にダイヤモンド砥粒を均一に分布するように載せて電着した修正リングを用い、ポリッシングマットと修正リングを相対移動させることによりポリッシングマットの表面を研削して平坦度を高める方法が提案されている。しかし、合金粉末を用いて焼結したダイヤモンドペレットからは、コンディショニングの際に合金が溶出してウェーハの研磨時にウェーハを汚染するおそれがある。また、特開平４－３６４７３０号公報には、ウェーハ研磨装置の定盤に貼り付けられたポリッシングマットのコンディショニングに、ダイヤモンド砥粒をエポキシ樹脂に電着したペレットを用いる方法が提案されている。しかし、ペレットがメタルボンドの場合、金属が研磨液によって溶解され、半導体ウェーハに残存して悪影響を及ぼすおそれがある。特に、一般にメタルボンドの主成分として使用される銅は悪影響が著しい。本発明者らは、先に半導体デバイスの層間絶縁膜及び金属配線などのＣＭＰ用のポリッシングマットのコンディショニングに際して、金属分による汚染を生じないコンディショナとして、台金作用面にメッキにより固着されたダイヤモンド砥粒層を有し、メッキされた金属が合成樹脂層により被覆され、ダイヤモンド砥粒の先端作用部が合成樹脂層より突出してなるコンディショナを提案した。このコンディショナは、ＣＭＰ用ポリッシングマットのコンディショニングに好適に使用されているが、さらに強い酸性条件下でのＣＭＰ加工においても、金属の溶出やダイヤモンド砥粒の脱落のおそれのないＣＭＰ用コンディショナが求められるようになった。

【０００３】

【発明が解決しようとする課題】本発明は、半導体ウェーハ研磨用のポリッシングマットのコンディショニングにおいて、酸性の高い研磨液によってもダイヤモンド砥粒を固着するメッキ層が侵されるおそれがなく、金属の溶出によるコンタミネーションやダイヤモンド砥粒の脱落を生じないＣＭＰ用コンディショナ及びその製造方法を提供することを目的としてなされたものである。

【０００４】

【課題を解決するための手段】本発明者は、上記の課題を解決すべく鋭意研究を重ねた結果、ダイヤモンド砥粒がメッキ層により固着されたコンディショナにおいて、メッキ層上に耐硝酸性のメッキを施し、さらにその表面を合成樹脂で被覆することにより、強い酸性条件下でのＣＭＰ加工の際にも、金属の溶出によるコンタミネーションやダイヤモンド砥粒の脱落を生ずることがなく、ま

た．このようなコンディショナは、作用面にダイヤモンド砥粒を電着法又は反転電鋳法によって固着したのち、その表面に耐硝酸性のメッキを施し．さらに合成樹脂で被覆することにより、容易に製造し得ることを見いだし．この知見に基づいて本発明を完成するに至った。すなわち、本発明は、（１）ダイヤモンド砥粒がメッキ層により固着されたコンディショナにおいて、メッキ層上に耐硝酸性のメッキが施され、その表面がさらに合成樹脂により被覆され、ダイヤモンド砥粒の先端作用部が合成樹脂層より突出してなることを特徴とするＣＭＰ用コンディショナ．（２）耐硝酸性のメッキが、アルミニウム．クロム、金．ロジウム．銀又はこれらの合金のメッキである第(１)項記載のＣＭＰ用コンディショナ．及び．（３）作用面にダイヤモンド砥粒を電着法又は反転電鋳法によって固着したのち、さらに耐硝酸性のメッキを施し、その表面を合成樹脂により被覆することを特徴とする第(１)項又は第(２)項記載のＣＭＰ用コンディショナの製造方法．を提供するものである。さらに．本発明の好ましい態様として．（４）耐硝酸性のメッキが、金メッキである第(２)項記載のＣＭＰ用コンディショナ．（５）金メッキの厚さが２～１０μｍである第(４)項記載のＣＭＰ用コンディショナ．を挙げることができる。

【０００５】

【発明の実施の形態】本発明のＣＭＰ用コンディショナは．台金作用面にダイヤモンド砥粒がメッキ層により固着され、メッキ層上に耐硝酸性のメッキが施され．その表面がさらに合成樹脂層により被覆され、ダイヤモンド砥粒の先端作用部が合成樹脂層より突出してなるものである。図１(ａ)は、本発明のＣＭＰ用コンディショナの一態様の斜視図であり、図１(ｂ)は．図１(ａ)のコンディショナを中心軸を通る平面で切断したときの切断部端面図である。図１に示すＣＭＰ用コンディショナは、カップ型の台金１の作用面にダイヤモンド砥粒がメッキにより固着されて．ダイヤモンド砥粒層２を形成している。ダイヤモンド砥粒３は．メッキ層４により台金１に固着され、メッキ層上に耐硝酸性のメッキ５が施され、その表面が合成樹脂層６により被覆され、ダイヤモンド砥粒の先端作用部が合成樹脂層より突出している。本発明において、耐硝酸性のメッキとは．２０㎜×２０㎜×０．２～２㎜の金属試験片を５重量%硝酸５０mlに２４時間浸漬したのち、ＪＩＳ Ｋ ０１２１にしたがって硝酸をフレーム原子吸光分析して、金属の溶出量が５μｇ／ml以下である金属のメッキをいう。このような金属としては、例えば．アルミニウム、クロム、金、ロジウム．錫などや．これらの金属の合金を挙げることができる。本発明のコンディショナは、ダイヤモンド砥粒がすべてメッキにより台金に強固に固着され、メッキ層上に耐硝酸性のメッキが施され．その表面がさらに合成樹脂層により被覆されているので、pHが２以下であるような強い酸性の研磨液を用いた場合でも．研磨液が合成樹脂層に浸透してダイヤモンド砥粒を固着しているメッキ層と直接接触することがなく．金属分の溶出やダイヤモンド砥粒の脱落を生ずるおそれがない。そのため．本発明のＣＭＰ用コンディショナは、半導体デバイスの層間絶縁膜及び金属配線などのＣＭＰ用のポリッシングマットのコンディショニングに使用したとき．脱落したダイヤモンド砥粒によるウェーハの損傷を生ずることがなく、ＣＭＰ加工後のウェーハの洗浄工程を簡略化することができる。

【０００６】図２及び図３は、本発明のＣＭＰ用コンディショナの製造方法の一態様の説明図である。本態様においては、台金作用面にダイヤモンド砥粒をメッキにより仮固定し、次いでダイヤモンド砥粒をメッキ層により固着してダイヤモンド砥粒層を形成し．メッキ層上に耐硝酸性のメッキを施し、その表面をさらに合成樹脂により被覆し、ダイヤモンド砥粒の先端作用部を突出させる。ダイヤモンド砥粒をメッキにより仮固定する場合は．図２(ａ)に示すように．台金１のダイヤモンド砥粒固定面７を残して、絶縁性のマスキング材８で被覆する。台金をメッキ浴に浸漬し、ダイヤモンド砥粒固定面にダイヤモンド砥粒３を載置し、台金に陰極を接続し、メッキ液に陽極を接続して．電気メッキを行う。使用するダイヤモンド砥粒に特に制限はないが、ＪＩＳ Ｂ ４１３０に規定する粒度１００／１２０～３０／４０の粒径を有する砥粒であることが好ましく．粒度６０／８０程度の粒径を有する砥粒であることがより好ましい。ダイヤモンド砥粒の粒径が．粒度１００／１２０に相当する粒径未満であると、被覆する合成樹脂層の厚さが薄くなって、耐硝酸性のメッキの表面を完全に被覆しきれなくなるおそれがある。ダイヤモンド砥粒の粒径が．粒度３０／４０に相当する粒径を超えると．ダイヤモンド砥粒が高価になって経済的に不利であるばかりでなく、コンディショニングの際にポリッシングマットが粗面化するおそれがある。メッキする金属は．ダイヤモンド砥粒を仮固定することができるものであれば特に制限はなく．例えば、ニッケル、クロムなどを好適に使用することができる。ダイヤモンド砥粒が仮固定され、ダイヤモンド砥粒固定面から脱落しない状態になれば、余剰のダイヤモンド砥粒を除去する。図２(ｂ)は、ダイヤモンド砥粒が、ダイヤモンド砥粒固定面に仮固定された状態を示す断面図である。ダイヤモンド砥粒を仮固定したとき．大部分のダイヤモンド砥粒はその一部が台金のダイヤモンド砥粒固定面に接した状態で仮固定されるが、台金のダイヤモンド砥粒固定面に接しない状態で付着し、浮き石９となっているダイヤモンド砥粒が存在する場合もあるので、仮固定を終了したのち．ダイヤモンド砥粒層面の表面をアルミナ砥石．シリコンカーバイド砥石などを用いて軽く研磨することにより．浮き石を除去することが好ましい。図２(ｃ)は、浮き石を除去した状態を

示す断面図である。

【０００７】浮き石を除去したのち、台金をふたたびメッキ浴に浸漬し、台金に陰極を接続し、メッキ液に陽極を接続して、ダイヤモンド砥粒固定面のメッキを行い、ダイヤモンド砥粒をメッキ層４により固着してダイヤモンド砥粒層を形成し、図２(d)に示す状態とする。メッキする金属は、ダイヤモンド砥粒を固定することができるものであれば特に制限はなく、例えば、ニッケル、クロムなどを使用することができるが、特にニッケルが好ましい。ニッケルメッキによりダイヤモンド砥粒を固着する場合、添加剤を加えたスルファミン酸ニッケル浴を使用すると、ニッケルの硬度はＨＶ４００～６００、伸び率は１～５％となり、ニッケル固着層は十分な靭性を有する。ダイヤモンド砥粒を固着するメッキ層の厚さは、ダイヤモンド砥粒の粒径の４０％以上であることが好ましく、５０％以上であることがより好ましい。メッキ層の厚さがダイヤモンド砥粒の粒径の４０％未満であると、ダイヤモンド砥粒を保持する力が不足するおそれがある。ダイヤモンド砥粒をメッキ層により固着してダイヤモンド砥粒層を形成したのち、さらにメッキ層上に耐硝酸性のメッキを施す。耐硝酸性のメッキを施す方法には特に制限はなく、メッキする金属に応じてそれぞれ公知の方法を適宜選択することができる。例えば、耐硝酸性のメッキが金メッキである場合は、金シアン化カリウムを用いるシアン化物メッキ浴法や塩化金を用いるリン酸塩浴法などを挙げることができる。金は最も貴な金属であるので、台金をメッキ浴に浸漬するだけで置換によって表面に金が析出する。このような析出物は素地金属との密着力が弱く剥離しやすいので、台金に陰極を空気中で接続し、通電を始めてから手早くメッキ浴に浸漬することが好ましい。使用する陽極の材質には特に制限はなく、例えば、硬質炭素、ステンレス鋼、ニクロム鋼などを使用することができる。金のメッキを続けると、時間の経過にしたがって析出結晶が粗雑になるので、時々台金をメッキ浴から取り出して刷毛で摩擦し、ふたたびメッキを繰り返すことにより、平滑なメッキ面を得ることができる。金メッキの厚さは、２～１０μｍであることが好ましく、３～６μｍであることがより好ましい。金メッキの厚さが２μｍ未満であると、強い酸性条件下でダイヤモンド砥粒を固着するメッキ層が侵されるおそれがある。金メッキの厚さは１０μｍで十分であり、１０μｍを超える金メッキは通常は必要はない。図３(a)は、メッキ層上に耐硝酸性のメッキ５が施された状態を示す断面図である。メッキ層上に耐硝酸性のメッキを施したのち、台金よりマスキング材を外して洗浄、乾燥し、合成樹脂層により耐硝酸性のメッキの表面を被覆する。使用する合成樹脂には特に制限はなく、熱硬化性樹脂及び熱可塑性樹脂のいずれをも使用することができる。熱硬化性樹脂としては、例えば、エポキシ樹脂、ポリウレタン樹脂、不飽和ポリエステル樹脂、フッ素樹脂などを挙げることができる。熱可塑性樹脂としては、例えば、フッ素樹脂、ポリアミド樹脂、ポリイミド樹脂などを挙げることができる。また、本発明においては、樹脂の機械的強度を向上させるために、非導電性の無機化合物粒子やファイバーを加えることもできる。熱硬化性樹脂としては、加熱硬化型のほかに常温硬化型の樹脂も使用することができ、さらに、熱硬化性樹脂に代えて光硬化性樹脂も使用することができる。

【０００８】図３(b)は、耐硝酸性のメッキの表面を、さらに合成樹脂層で被覆した状態を示す断面図である。合成樹脂層６で被覆したのち合成樹脂層の表面部分を除去することにより、ダイヤモンド砥粒３の先端作用部を突出させる。ダイヤモンド砥粒の先端作用部を突出させる方法に特に制限はなく、例えば、ダイヤモンド砥粒の最突出部が見えるまで研削盤などを用いて合成樹脂層を除去したのち、一般砥石などによるドレッシング、鋳鉄などの定盤上でのシリコンカーバイドやアルミナなどの遊離砥粒を用いたドレッシング、ショットブラストなどにより、ダイヤモンド砥粒の突出量を容易に所定の値とすることができる。ダイヤモンド砥粒は、メッキによって強固に台金に固着されているので、ダイヤモンド砥粒に強い力がかかっても、コンディショナからダイヤモンド砥粒が脱落するおそれがない。図３(c)は、合成樹脂層の表面部分を除去してダイヤモンド砥粒の先端作用部が合成樹脂層６より突出し、かつ耐硝酸性のメッキの表面が合成樹脂層に覆われて露出しない状態を示す断面図である。

【０００９】図４及び図５は、本発明のＣＭＰ用コンディショナの製造方法の他の態様の説明図である。本態様においては、反転型のダイヤモンド砥粒固定面にダイヤモンド砥粒をメッキにより仮固定し、さらにダイヤモンド砥粒をメッキ層により埋め込んだのち、必要に応じてメッキ層を平坦化し台金の作用面に接合する。その後、反転型を除去し、メッキ層の表面部分を除去してダイヤモンド砥粒を露出させ、メッキ層上に耐硝酸性のメッキを施し、その表面をさらに合成樹脂により被覆し、ダイヤモンド砥粒の先端作用部を突出させる。ダイヤモンド砥粒をメッキにより仮固定する場合は、図４(a)に示すように、反転型１０のダイヤモンド砥粒固定面７を残して、絶縁性のマスキング材８で被覆する。反転型をメッキ浴に浸漬し、ダイヤモンド砥粒固定面にダイヤモンド砥粒３を載置し、反転型に陰極を接続し、メッキ液に陽極を接続して、電気メッキを行う。使用するダイヤモンド砥粒に特に制限はないが、ＪＩＳ Ｂ ４１３０に規定する粒度１００／１２０～３０／４０の粒径を有する砥粒であることが好ましく、粒度６０／８０程度の粒径を有する砥粒であることがより好ましい。ダイヤモンド砥粒の粒径が、粒度１００／１２０に相当する粒径より小さいと、被覆する合成樹脂層の厚さが薄くなって、耐硝酸性のメッキの表面を完全に被覆しきれなくなるおそれ

がある。ダイヤモンド砥粒の粒径が、粒度３０／４０に相当する粒径より大きいと、ダイヤモンド砥粒が高価になって経済的に不利であるばかりでなく、コンディショニングの際にポリッシングマットが組面化するおそれがある。メッキする金属は、ダイヤモンド砥粒を仮固定することができるものであれば特に制限はなく、例えば、ニッケル、クロムなどを好適に使用することができる。ダイヤモンド砥粒が仮固定され、ダイヤモンド砥粒固定面から脱落しない状態になれば、余剰のダイヤモンド砥粒を除去する。図４（ｂ）は、ダイヤモンド砥粒が、ダイヤモンド砥粒固定面に仮固定された状態を示す断面図である。

【００１０】余剰のダイヤモンド砥粒を除去したのち、反転型をふたたびメッキ浴に浸漬し、反転型に陰極を接続し、メッキ液に陽極を接続して、ダイヤモンド砥粒固定面のメッキを行い、ダイヤモンド砥粒をメッキ層４により埋め込んでダイヤモンド砥粒層を形成し、図４（ｃ）に示す状態とする。メッキする金属は、ダイヤモンド砥粒を埋め込んで固着することができるものであれば特に制限はなく、例えば、ニッケル、クロムなどを使用することができるが、特にニッケルが好ましい。ニッケルメッキによりダイヤモンド砥粒を埋め込む場合、添加剤を加えたスルファミン酸ニッケル浴を使用すると、ニッケルの硬度はＨＶ４００～６００、伸び率は１～５％となり、ニッケル固着層は十分な靭性を有する。ダイヤモンド砥粒をメッキにより埋め込んでダイヤモンド砥粒層を形成した反転型は、マスキング材を外して洗浄、乾燥し、必要に応じて、反転型上のメッキ層の表面を平坦に加工する。次いで、図４（ｄ）に示すように、反転型１０上のメッキ層４を台金１に接合する。反転型上のメッキ層４若しくは台金１のダイヤモンド砥粒層接合面又はその双方に接着剤を塗付し、メッキ層とダイヤモンド砥粒層接合面を合わせて固定し、メッキ層を台金に接合する。使用する接着剤は、コンディショナの使用に十分な強度を有するものであれば特に制限はなく、例えば、エポキシ接着剤などを好適に使用することができる。必要に応じて、接着剤に無機充填材、例えば、アルミニウム粉末などを配合することができる。メッキ層４を台金１に接合したのち、反転型１０を除去する。反転型を除去する方法には特に制限はなく、例えば、旋盤加工、フライス盤加工などを挙げることができるが、旋盤加工を特に好適に使用することができる。図５（ａ）は、メッキ層４を台金１に接合し、反転型を除去した状態を示す。

【００１１】台金に接合したメッキ層は、金属の表面部分を除去してダイヤモンド砥粒を露出させる。ダイヤモンド砥粒を露出させる方法には特に制限はなく、例えば、一般砥石などによるドレッシング、鋳鉄などの定盤上でのシリコンカーバイドやアルミナなどの遊離砥粒によるドレッシング、ショットブラスト、金属剥離剤による化学エッチング、電解エッチングなどにより行うことができる。化学エッチング処理は、台金及びダイヤモンド砥粒層を形成する材料のうち、メッキされた金属のみを溶解する薬剤に浸漬することにより行うものである。このような薬剤としては、金属がニッケルである場合はエンストリップＮＰ［メルテックス(株)製］、金属がクロムである場合はエンストリップＣＲ－５［メルテックス(株)製］などの市販されている薬剤を使用することができる。図５（ｂ）は、メッキ層４の表面部分を除去して、ダイヤモンド砥粒３を露出させた状態を示す。ダイヤモンド砥粒を露出させたメッキ層は、次いでその上に耐硝酸性のメッキを施す。耐硝酸性のメッキを必要としない台金の部分は、あらかじめマスキング材により保護することができる。耐硝酸性のメッキを施す方法には特に制限はなく、メッキする金属に応じてそれぞれ公知の方法を適宜選択することができる。例えば、耐硝酸性のメッキが金メッキである場合は、金シアン化カリウムを用いるシアン化物メッキ浴法や塩化金を用いるリン酸塩浴法などを挙げることができる。金は最も貴な金属であるので、台金をメッキ浴に浸漬するだけで置換によって表面に金が析出する。このような析出物は素地金属との密着力が弱く剥離しやすいので、台金に陰極を空気中で接続し、通電を始めてから手早くメッキ浴に浸漬することが好ましい。使用する陽極の材質には特に制限はなく、例えば、硬質炭素、ステンレス鋼、ニクロム鋼などを使用することができる。金のメッキを続けると、時間の経過にしたがって析出結晶が粗雑になるので、時々台金をメッキ浴から取り出して刷毛で摩擦し、ふたたびメッキを繰り返すことにより、平滑なメッキ面を得ることができる。金メッキの厚さは、２～１０μｍであることが好ましく、３～６μｍであることがより好ましい。金メッキの厚さが２μｍ未満であると、強い酸性条件下でダイヤモンド砥粒を固着するメッキ層が侵されるおそれがある。金メッキの厚さは１０μｍで十分であり、１０μｍを超える金メッキは通常は必要はない。図５（ｃ）は、メッキ層４上に耐硝酸性のメッキ５が施された状態を示す断面図である。メッキ層上に耐硝酸性のメッキを施したのち、洗浄、乾燥し、合成樹脂層により耐硝酸性のメッキの表面を被覆する。使用する合成樹脂には特に制限はなく、熱硬化性樹脂及び熱可塑性樹脂のいずれをも使用することができる。熱硬化性樹脂としては、例えば、エポキシ樹脂、ポリウレタン樹脂、不飽和ポリエステル樹脂、フッ素樹脂などを挙げることができる。熱可塑性樹脂としては、例えば、フッ素樹脂、ポリアミド樹脂、ポリイミド樹脂などを挙げることができる。また、本発明においては、樹脂の機械的強度を向上させるために、非導電性の無機化合物粒子やファイバーを加えることもできる。熱硬化性樹脂としては、加熱硬化型のほかに常温硬化型の樹脂も使用することができ、さらに、熱硬化性樹脂に代えて光硬化性樹脂も使用することができる。

【００１２】図５(ｄ)は、耐硝酸性のメッキの表面を、さらに合成樹脂層で被覆した状態を示す断面図である。合成樹脂層６で被覆したのち合成樹脂層の表面部分を除去することにより、ダイヤモンド砥粒の先端作用部を突出させる。ダイヤモンド砥粒の先端作用部を突出させる方法に特に制限はなく、例えば、ダイヤモンド砥粒の最突出部が見えるまで研削盤などを用いて合成樹脂層を除去したのち、一般砥石などによるドレッシング、鋳鉄などの定盤上でのシリコンカーバイドやアルミナなどの遊離砥粒を用いたドレッシング、ショットブラストなどにより、ダイヤモンド砥粒の突出量を容易に所定の値とすることができる。ダイヤモンド砥粒は、メッキによって強固に固着されているので、ダイヤモンド砥粒に強い力がかかっても、コンディショナからダイヤモンド砥粒が脱落するおそれがない。図５(ｅ)は、合成樹脂層の表面部分を除去してダイヤモンド砥粒の先端作用部が合成樹脂層より突出し、かつ耐硝酸性のメッキの表面が合成樹脂層に覆われて露出しない状態を示す断面図である。本態様により製造されたコンディショナは、ダイヤモンド砥粒の仮固定の際に、ダイヤモンド砥粒が反転型のダイヤモンド砥粒固定面に接して固定され、ダイヤモンド砥粒層を台金に接合したとき、ダイヤモンド砥粒の最突出部は反転型のダイヤモンド砥粒固定面に接した部分であるので、コンディショナにおいて、各ダイヤモンド砥粒の最突出部が完全に同一平面上に存在する構造となる。また、ダイヤモンド砥粒層と台金の接合後の基準面転写により、ダイヤモンド砥粒層面の振れ精度は数μｍである。ニッケルの電鋳によりダイヤモンド砥粒を固着する場合、添加剤を加えたスルファミン酸ニッケル浴を使用すると、ニッケルの硬度はＨＶ４００～６００、伸び率は１～５％となり、ニッケル固着層は十分な靭性を有する。このために、ポリッシングマットのコンディショニングを精度よく能率よく行うことができ、ダイヤモンド砥粒の脱落が長期にわたって生じない。

【００１３】合成樹脂によりダイヤモンド砥粒層を覆う方法によれば、数ミリ程度の厚さの合成樹脂層も短時間で形成することができ、研削盤や遊離砥粒による合成樹脂の除去も短時間で精度よく行うことができる。本発明のＣＭＰ用コンディショナにおいて、ダイヤモンド砥粒の突出量は、ダイヤモンド砥粒の平均粒径の５～５０％であることが好ましく、平均粒径の２０～３０％であることがより好ましい。ダイヤモンド砥粒の突出量が平均粒径の５％未満であると、コンディショナのコンディショニング作用が微弱になるおそれがある。ダイヤモンド砥粒の突出量が平均粒径の５０％を超えると、コンディショニング作用が強すぎてポリッシングマットを損傷し、ダイヤモンド砥粒が脱落するおそれがある。本発明方法においては、必要に応じてさらにラップ加工を行うことができる。ラップ加工は、ダイヤモンド砥石を用いて突出したダイヤモンド砥粒の先端部をカットするものであり、ラップ加工を行うことにより、コンディショナに、使用当初から安定した優れた性能を発揮させることができる。本発明のＣＭＰ用コンディショナによれば、耐硝酸性のメッキがバリアとなって、ｐＨの低い酸性の強い研磨液を用いても、メッキ層の金属と研磨液が接触することがないので、ダイヤモンド砥粒が脱落してウェーハを傷つけたり、金属分が溶出してウェーハを汚染することがない。さらに、本発明のコンディショナはダイヤモンド砥粒の最突出部の平坦性に優れるので、ポリッシングマットの平坦度が向上し、ポリッシングマットの切れ味が向上する。

【００１４】

【実施例】以下に、実施例を挙げて本発明をさらに詳細に説明するが、本発明はこれらの実施例によりなんら限定されるものではない。

実施例１

寸法が１２７Ｄ－６Ｗ－２０Ｔ－３０Ｈの台金を、ステンレス鋼（ＳＵＳ３０４）を旋盤加工することにより作製した。次に、ダイヤモンド砥粒固定面を残して、表面を絶縁テープ及び塗料によりマスキングした。台金のアルカリ脱脂処理を行い、塩化ニッケル２４０ｇ／リットル及び塩酸１００ｇ／リットルを含有する前処理液に浸漬し、電流密度１０Ａ／ｄｍ²で常温にて陽極側に台金をセットし２分間電解エッチングしたのち、陰極側に台金をセットしてストライクメッキを３分間行った。次いで、スルファミン酸ニッケルメッキ浴で電流密度１Ａ／ｄｍ²で１５分間メッキを行い、下地メッキ層を３μｍ形成した。次に、ダイヤモンド砥粒固定面に粒度＃６０／８０、平均粒径２５０μｍのダイヤモンド砥粒を載置し、メッキ応力と硬度調節のための添加剤を加えたスルファミン酸ニッケルメッキ浴を用い、電流密度０．５Ａ／ｄｍ²で３時間メッキを行い、ダイヤモンド砥粒一層分を仮固定した。余剰のダイヤモンド砥粒を払い落とし、電流密度１Ａ／ｄｍ²で１時間埋め込みメッキを行ったのち、＃１００アルミナ砥石を当て、浮き石となっているダイヤモンド砥粒を除去した。次いで、塩化ニッケル２４０ｇ／リットル及び塩酸１００ｇ／リットルを含有する前処理液に浸漬して陽極側に台金をセットし、電流密度１０Ａ／ｄｍ²で常温にて３０秒電解エッチングしたのち、陰極側に台金をセットしてストライクメッキを２分間行った。次に、スルファミン酸ニッケルメッキ浴で電流密度１Ａ／ｄｍ²で１５分間メッキを行い、さらに同じスルファミン酸ニッケルメッキ浴で、電流密度１Ａ／ｄｍ²で５時間メッキを行い、ダイヤモンド砥粒を固着するよう厚さ約１２５μｍのメッキを施した。ダイヤモンド砥粒固定面及び台金を洗浄したのち、シアン化金２．５ｇ／リットル、シアン化カリウム３０．０ｇ／リットル、第二リン酸ナトリウム１５．０ｇ／リットル及びシアン化コバルト１０．０ｇ／リットルを含むメッキ浴に浸漬し、ステンレス鋼を陽極とし、浴温５０℃、電流密

度０．２Ａ／dm²．電圧２Ｖの条件で２０時間メッキを行い．厚さ４μｍの金合金層を形成した。金合金の組成は．金９９．７重量%．コバルト０．３重量%であった。マスキングをすべて外し．ダイヤモンド砥粒層が形成された台金を洗浄．乾燥したのち、フッ素樹脂塗料［日建塗装工業(株)．ＰＦＡ］を．塗膜厚さが１００μｍとなるように塗付して、３３０℃で３０分間焼き付けた。その後．アルミナ砥粒＃８００を用いてスエードタイプの研磨マットで．ダイヤモンド砥粒先端部が５０μｍ露出するまでラップ加工を行った。得られたＣＭＰ用コンディショナを５重量%硝酸に２４時間浸漬したが．金属分の溶出は全く認められなかった。また．このＣＭＰ用コンディショナと研磨マット（ｉＣ１０００）を用い、スラリー（硝酸鉄＋硝酸＋アルミナ）でＣＭＰ加工を行ったところ、金属膜ウェーハの研磨レート１，８７０Å／分という良好な結果が得られた。

実施例２

寸法が２８０Ｄ－６Ｗ－２０Ｔ－１４０Ｈの反転型（Ｓ４５Ｃ）を、旋盤加工により作製した。ダイヤモンド砥粒固定面をマスキングテープで囲い．さらにその他のダイヤモンド砥粒層非形成部分のマスキング処理を行った。アルカリ脱脂処理したのち、反転型を、メッキ応力と硬度調節のため添加剤を加えたスルファミン酸ニッケル浴に浸め、粒度＃６０／８０のダイヤモンド砥粒をダイヤモンド砥粒固定面に載置した。電流密度１Ａ／dm²で２時間メッキを行い、ダイヤモンド砥粒の仮固定を行ったのち、余剰のダイヤモンド砥粒を除去し、さらに電流密度２Ａ／dm²で９６時間メッキを行い．３mmの厚みのニッケル固着層を形成してダイヤモンド砥粒を完全に埋め込んだ。次いで、反転型上のニッケル固着層面を、旋盤加工により平坦に加工した。寸法２８６Ｄ－１２Ｗ－３５Ｔ－１６０Ｈの台金（ＳＵＳ３０４）を．旋盤加工により作製した。２液型エポキシ接着剤１０重量部にアルミニウム粉末５重量部を混合し．反転型上のニッケル固着層面と台金のダイヤモンド砥粒層接着部分に塗布し接合した。接合層が十分に硬化したのち、旋盤で反転型を正にして台金の裏面を切削して基準面転写した。さらに．台金を旋盤にくわえ．反転型を切除した。その後．ニッケル剥離剤エンストリップＮＰ［メルテックス(株)］を用いて．ダイヤモンド砥粒層面のニッケルを約１２５μｍ溶解除去した。ダイヤモンド砥粒層が形成された台金を洗浄．乾燥したのち、ダイヤモンド砥粒層以外の部分をマスキング処理し、シアン化金２．５ｇ／リットル、シアン化カリウム３０．０ｇ／リットル、第二リン酸ナトリウム１５．０ｇ／リットル及びシアン化コバルト１０．０ｇ／リットルを含むメッキ浴に浸漬し．ステンレス鋼を陽極とし．浴温５０℃．電流密度０．２Ａ／dm²．電圧２Ｖの条件で２５時間メッキを行い、厚さ５μｍの金合金層を形成した。金合金の組成は．金９９．７重量%、コバルト０．３重量%であった。次いで、エポキシ塗料を塗膜厚さが１１０μｍとなるように塗付し．焼き付けた。その後．シリコンカーバイド＃８００を用いてエポキシ樹脂層約５０μｍを削り出し．ダイヤモンド砥粒の先端作用部をエポキシ樹脂層から突出させて．ＣＭＰ用コンディショナを得た。得られたＣＭＰ用コンディショナを５重量%硝酸に２４時間浸漬したが、金属分の溶出は全く認められなかった。また、このＣＭＰ用コンディショナを用いて、ポリエステル不織布を基剤とし、その上に発泡ポリウレタン層を形成したスエードタイプのポリッシングマットのコンデショニングを行った。平坦性に優れたコンデショニングを、効率よく行うことができた。

【００１５】

【発明の効果】本発明のＣＭＰ用コンディショナは、ｐＨ２以下のような強い酸性条件下でのＣＭＰ加工に使用しても．メッキ層から金属が溶出したり．ダイヤモンド砥粒が脱落するおそれがなく．安定してコンディショニングを行うことができる。

【図面の簡単な説明】

【図１】図１は．本発明のＣＭＰ用コンディショナの一態様の斜視図及び切断部端面図である。

【図２】図２は．本発明のＣＭＰ用コンディショナの製造方法の一態様の説明図である。

【図３】図３は．本発明のＣＭＰ用コンディショナの製造方法の一態様の説明図である。

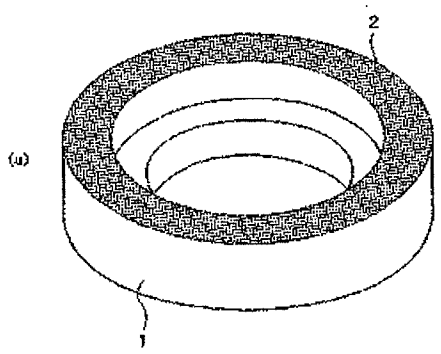
【図４】図４は．本発明のＣＭＰ用コンディショナの製造方法の他の態様の説明図である。

【図５】図５は．本発明のＣＭＰ用コンディショナの製造方法の他の態様の説明図である。

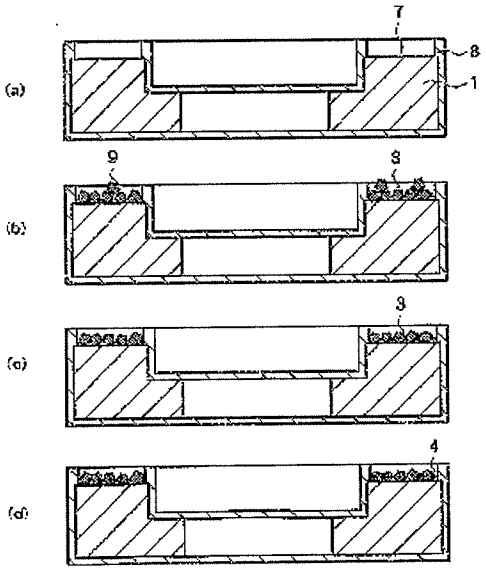
【符号の説明】

１　台金
２　ダイヤモンド砥粒層
３　ダイヤモンド砥粒
４　メッキ層
５　耐硝酸性のメッキ
６　合成樹脂層
７　ダイヤモンド砥粒固定面
８　マスキング材
９　浮き石
１０　反転型

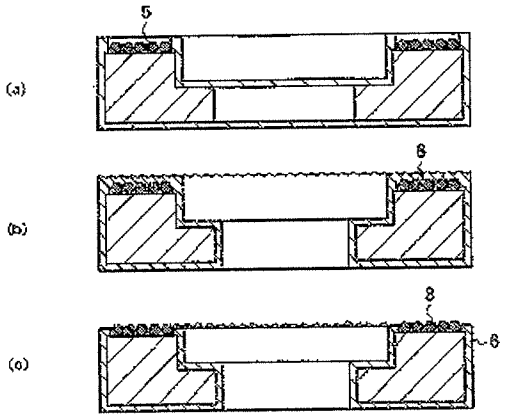
【図1】



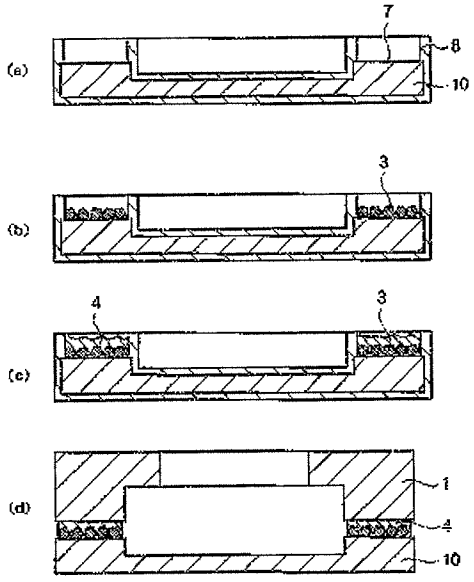
【図2】



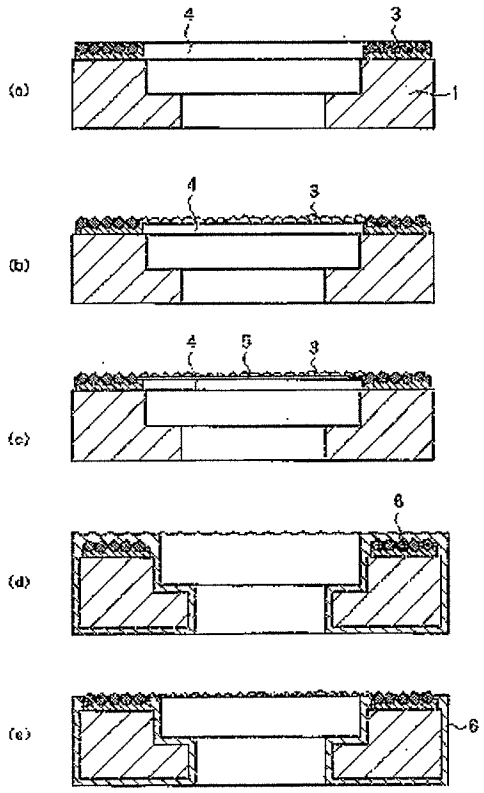
【図3】



【図4】



【図５】



PATENT ABSTRACTS OF JAPAN

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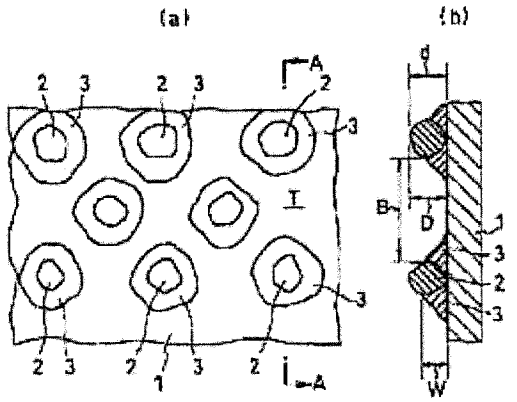
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(71)Applicant : NORITAKE DIAMOND IND CO LTD
NORITAKE CO LTD
(72)Inventor : TOGE NAOKI
NONOSHITA TETSUYA

(54) GRINDING WHEEL AND MANUFACTURE THEREOF

(57)Abstract:
PROBLEM TO BE SOLVED: To obtain long-term stable cutting quality through the excellent supply of a polishing solution and discharge of chips while obtaining the holding force and necessary protruding height of abrasive grains by setting wax material thickness to be specific times as large as an abrasive grain diameter, and forming a chip pocket with base metal matrix exposed with a width specific times as large as the abrasive grain diameter between the abrasive grains.
SOLUTION: In arranging abrasive grains 2 in one layer on a base metal 2 for brazing, the abrasive grains 2 are held with a wax material thickness W of about 1/3-1/2 times as large as an abrasive grain diameter(d),and a chip pocket T with the matrix of the base metal 1 exposed with a width about 2/3-2.5 times as large as the abrasive grain diameter(d) between the adjacent abrasive grains 2 is regularly formed. Such a wax material thickness W can ensure the protruding height of the abrasive grains 2 required to exhibit excellent cutting quality while ensuring the holding force of the abrasive grains 2, and the regular formation of the chip pocket T with the exposed matrix of the base metal 1 permits the uniform distribution of the abrasive grains 2 and excellent supply of a polishing solution and discharge of chips.



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					３１０Ｂ
		３２０			３２０Ｂ
		３４０			３４０
	3/02			3/02	Ａ

審査請求　未請求　請求項の数３　ＯＬ　（全４頁）　最終頁に続く

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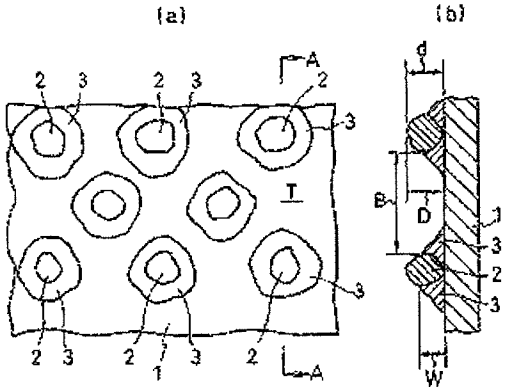
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最終頁に続く

(54)【発明の名称】　研削砥石およびその製造方法

(57)【要約】
【課題】　超砥粒を台金に一層配列してろう付けした研削砥石において，砥粒層の全面に砥粒を均一に分布させ，良好な切れ味と切粉の排出を安定的に維持する。
【解決手段】　砥粒粒径ｄの１／３～１／２倍の厚さのろう材３で砥粒２を保持するとともに，隣り合う砥粒２との間に砥粒粒径の２／３～２．５倍の幅で台金１の素地を露出させた部分を含むチップポケットＴを規則的に形成した。



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【特許請求の範囲】

【請求項１】　ダイヤモンド、ＣＢＮなどの超砥粒を台金に一層配列してろう付けした研削砥石において．砥粒粒径の１／３～１／２倍のろう材厚さで砥粒を保持するとともに、隣り合う砥粒との間に砥粒粒径の２／３～２．５倍の幅で台金素地を露出させた部分を含むチップポケットを規則的に形成した研削砥石。

【請求項２】　前記チップポケットの深さを砥粒粒径の２／３～１倍の深さとした請求項１記載の研削砥石。

【請求項３】　ダイヤモンド、ＣＢＮなどの超砥粒を台金に一層配列してろう付けする研削砥石の製造方法において．所定の間隔で規則的に孔を開けたスクリーンを用いて台金上に有機接着剤を塗布し、この有機接着剤の上に砥粒を配置した状態で乾燥炉中で乾燥させた後．接着部にのみろう材とバインダーの混合物を塗布し加熱、ろう付けすることにより、砥粒を台金上に所定の間隔で配列させることを特徴とする研削砥石の製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明はダイヤモンド．ＣＢＮなどの超砥粒を用いた研削砥石にかかり、とくに砥石の切れ味を向上させた研削砥石およびその製造方法に関する。

【０００２】

【従来の技術】従来より．ダイヤモンド砥粒やＣＢＮ砥粒などの超砥粒をろう付け法により単層に固着した研削砥石が研削・研磨用砥石として使用されている。このような研削砥石には、切れ味に優れ、しかもその切れ味が長期にわたって安定的に持続することが要求される。ところが、ダイヤモンド砥粒にしろ、ＣＢＮ砥粒にしろ、研削作業の進行に伴い切れ味と寿命が低下する。

【０００３】その主な原因として、台金への砥粒の固着状態が不安定で砥粒が脱落しやすいこと、チップポケットが小さいこと．砥粒間隔のコントロールが不十分なために研削作業中に切粉によって目詰まりが生じることが挙げられる。とくに砥粒間隔に関しては、台金の表面に砥粒を均一に分散させるのが難しく．砥粒どうしが近接した状態にある部分においては、研削液が充分に供給されにくく、また切粉が排出されにくく．切れ味の低下につながる。

【０００４】ろう付け法による砥石の製造において、砥粒を均一に分散させるための方策として、特開平９－１９８６７号公報には、金属被覆したダイヤモンド砥粒を砥石台金と金型の間隙に充填し、砥石台金と金型を加熱しながら銀ろうを間隙に溶浸させる砥石の製造方法が開示されている。また特開平１０－３４５４０号公報には．台金の表面に複数本のＶ溝を平行にかつ等間隔に設け．このＶ溝に砥粒をろう付けする方法が開示されている。

【０００５】

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【発明が解決しようとする課題】上記の公開公報に記載の方法によれば．砥粒が所定の間隔をもって一様に分布した砥石が得られる。しかし、特開平９－１９８６７号公報に記載の方法により製造された砥石は、台金と金型の間隙によって決まる一定厚さの砥粒層が形成され、砥粒と砥粒の間に砥粒の金属被覆成分と銀ろうとが充填されたかたちであるので、いわゆるチップポケットが形成されず、充分な切れ味と切粉の排出が得られないという欠点がある。

【０００６】また特開平１０－３４５４０号公報に記載の方法により製造された砥石は、砥粒の一部がＶ溝に埋設されたかたちであるので．砥粒の突出量が小さく、切れ味が不十分となり、また．Ｖ溝内に配列される個々の砥粒どうしの間隔をコントロールすることができないため．Ｖ溝内の砥粒間隔が小さい部分では部分的に目詰まりが生じるという欠点がある。

【０００７】本発明が解決すべき課題は、超砥粒を台金に一層配列してろう付けした研削砥石において．砥粒層の全面に砥粒を均一に分布させ、良好な切れ味と切粉の排出を安定的に維持することにある。

【０００８】

【課題を解決するための手段】本発明の研削砥石は、ダイヤモンド、ＣＢＮなどの超砥粒を台金に一層配列してろう付けした研削砥石であって、砥粒粒径の１／３～１／２倍のろう材厚さで砥粒を保持するとともに．隣り合う砥粒との間に砥粒粒径の２／３～２．５倍の幅で台金素地を露出させた部分を含むチップポケットを規則的に形成したことを特徴とする。

【０００９】本発明の研削砥石においては、ろう材の厚さを砥粒粒径の１／３～１／２倍とすることによって、砥粒の保持力を確保したうえで、良好な切れ味を発揮するのに必要な砥粒の突出高さを確保することができる。ろう材の厚さが砥粒粒径の１／３倍より小さいと．ろう材による砥粒の保持力が低下し、砥粒が脱落しやすくなる。砥粒粒径の１／２倍より大きくなると、砥粒の切削に寄与する部分が小さいため切削量が少なく、切れ味が悪くなり、また．切粉が排出されにくく、ろう材が摩耗しやすくなる。ろう材の厚さが上記の範囲内にあるとき．砥粒が被研削材に十分に食い込んで研削され．また．切粉が効率よく排出され、目詰まりや焼付きが発生せず．安定した切れ味が得られる。

【００１０】また、個々の砥粒どうしの間に砥粒粒径の２／３～２．５倍の幅で台金素地を露出させた部分を含むチップポケットを規則的に形成させることによって、砥粒層の全面にわたって砥粒の分布を均一にするとともに．研削液の供給と切粉の排出を良好にして切れ味を向上させることができる。チップポケットの幅が砥粒粒径の２／３倍より小さいと．研削液の供給と切粉の排出が不十分となり．砥粒粒径の２．５倍より大きくすると、砥粒の総量が少なくなって砥石全体としての研削能力が

低下し、砥石の寿命も短くなる。

【００１１】ここで、前記チップポケットの深さを砥粒粒径の２／３～１倍の深さとするのが望ましい。チップポケットの深さをこの範囲とすることにより、研削液の供給と切粉の排出がより良好となり、切れ味がより向上する。

【００１２】上記のように個々の砥粒どうしの間に所定の範囲内の幅のチップポケットが形成されるように砥粒を配列させた砥石は、つぎのいずれかの方法により製造することができる。第１の方法は、所定の間隔で規則的に孔を開けたスクリーンを用いて、台金上に有機接着剤を塗布し、この有機接着剤の上に砥粒を配置した状態で乾燥炉中で乾燥させて砥粒を仮固定した後、接着部にのみろう材とバインダーの混合物を塗布し、加熱．ろう付けして本固定することにより、砥粒を台金上に所定の間隔で配列させる方法である。第２の方法は、スクリーンを用いてろう材とバインダーの混合体を塗布し、砥粒を配置した状態で加熱することにより．仮固定なしで本固定する方法である。砥粒の確実な保持と所定の範囲内の幅のチップポケットの形成のためにろう材とバインダーの混合物の塗布量をコントロールするという点からは、砥粒の仮固定後に砥粒一粒ずつに対して確実に塗布することのできる前記第１の方法が適している。

【００１３】

【発明の実施の形態】図１は本発明の実施形態における研削砥石の台金上の砥粒の配列を示す模式図であり、（ａ）は平面図、（ｂ）はＡ－Ａ線断面図である。

【００１４】本実施形態は．ＡＤＣ（アルミダイキャスト）合金、鋳鉄などの粗研削用の砥石に本発明を適用した例である。図１は砥石の砥粒層形成部分の一部を示す＊図であり、１は台金、２は砥粒、３はろう材である。この砥石の製造手順はつぎの通りである。

①台金１として外径１００ｍｍ、厚さ１０ｍｍの鉄製台金を準備する。

②砥粒２として平均粒径約４００μｍのダイヤモンド砥粒を準備する。

③直径０．２ｍｍの孔を１．２ｍｍ間隔で千鳥状に配列したスクリーンを用いて．台金１上に有機接着剤を塗布する。

④この有機接着剤の上に砥粒を配置する。この状態で砥粒は台金上に１．２ｍｍ間隔で千鳥状に配列されたかたちとなる。

⑤これを乾燥炉中で１２０℃、１時間乾燥させ．砥粒を仮固定する。

⑥三次元移動が可能なアプリケータ（吐出機）を用いて．接着部にろう材とバインダーの混合物を砥粒粒径の１／２の高さに塗布する。

⑦これを非酸化性雰囲気中で１０００℃、１時間加熱し．砥粒を台金に本固定する。

【００１５】このようにして、ろう材３の厚さＷが砥粒粒径ｄ（４００μｍ）の１／２で、砥粒２のまわりに幅Ｂ．深さＤともに砥粒粒径ｄに相当するチップポケットＴを形成した研削砥石を製造した。この砥石（発明品）と．同じ砥粒と台金を用いて前述した特開平１０－３４５４０号公報記載の方法によって製造した砥石（比較品）について研削試験を行った。両砥石の仕様のうち数値の異なる項目を表１に示す。

【００１６】

【表１】

	発明品	比較品
砥粒ピッチ	１．２ｍｍ	溝間隔０．８ｍｍ、溝内ピッチ不定
砥粒突出高さ	０．４ｍｍ	０．２ｍｍ
チップポケット幅	０．４ｍｍ	０～０．４ｍｍ
チップポケット深さ	０．４ｍｍ	０．２ｍｍ

【００１７】〔試験条件〕

研削機械　：工具研削盤

砥石周速度：１２００ｍ／ｍｉｎ

被研削材　：ハイシリコンアルミ（ＡＤＣ－１４）

切り込み量：０．１ｍｍ／ｐａｓｓ

【００１８】図２に試験結果を示す。同図は、比較品の砥石の切断速度および砥石寿命を１００としたときの本発明品の切断速度および砥石寿命を示すものである。同図からわかるように、Ｖ溝に砥粒を配列した比較品の砥石に比べて、全面に砥粒を一様に分布させ、かつ適正なチップポケットを形成した発明品は．切断速度は１．５倍程度、砥石寿命は１．７倍程度向上している。

【００１９】

【発明の効果】本発明によって以下の効果を奏する。

【００２０】（１）ろう材の厚さを砥粒粒径の１／３～１／２倍とし．さらに個々の砥粒どうしの間に砥粒粒径の２／３～２．５倍の幅で台金素地を露出させた部分を含むチップポケットを形成させることによって．砥粒の保持力を確保したうえで．良好な切れ味を発揮するのに必要な砥粒の突出高さを確保することができ、また、研削液の供給と切粉の排出を良好にして目詰まりや縁付きが発生せず、長期にわたって安定した切れ味が得られ、砥石の寿命も延長する。

【００２１】（２）チップポケットの深さを砥粒粒径の２／３～１倍の深さとすることにより．研削液の供給と切粉の排出がより良好となり、切れ味がより向上する。

【００２２】（３）所定の間隔で規則的に孔を開けたスクリーンを用いて台金上に有機接着剤を塗布し．この有

機接着剤の上に砥粒を配置した状態で乾燥炉中で乾燥させた後、接着部にのみろう材とバインダーの混合物を塗布し加熱、ろう付けすることにより、砥粒を台金上に所定の間隔で配列させることができる。

【図面の簡単な説明】

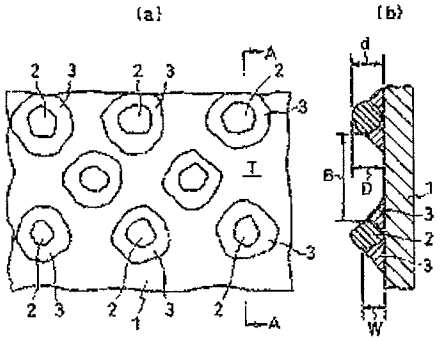
【図１】　発明の実施形態における研削砥石の台金上の砥粒の配列を示す模式図であり、（ａ）は平面図、（ｂ）はＡ－Ａ線断面図である。

【図２】　研削試験結果を示すグラフである。

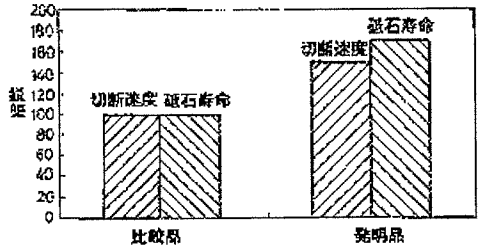
＊【符号の説明】

1　台金
2　砥粒
3　ろう材
d　砥粒粒径
W　ろう材厚さ
T　チップポケット
B　チップポケット幅
D　チップポケット深さ

【図１】



【図２】



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	3/28		3/28	
	5/00		5/00	P

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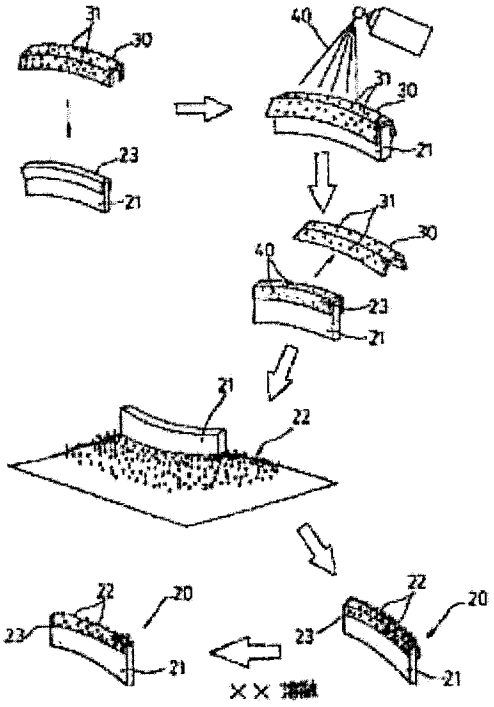
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(72)Inventor : YOSHIDA TAKUMA
FUKADA NOBUO

(54) MANUFACTURE OF DIAMOND CUTTER AND DIAMOND CUTTER AND DIAMOND CUTTER MANUFACTURING JIG

(57)Abstract:
PROBLEM TO BE SOLVED: To increase fixation strength of diamond particles to prevent diamond particles from falling out by fixing diamond particles forming a diamond layer on the diamond layer at a predetermined interval mutually.
SOLUTION: A manufacturing method of a diamond cutter includes a bond paste fixation process in which bond (registered trademark) paste in which binder and bond powders are blended is attached on a substrate, a screen covering process in which a screen 30 in which holes are drilled to a desired manner after the bond paste fixation process is covered in a bond paste fixation scope, an application process in which viscous substance 40 is applied from above the screen 30 on which the bond paste is covered, a screen removing process in which the screen 30 is removed after the application process, and a diamond abrasive grain adhesion process in which diamond abrasive grains 22 come into contact with a bond paste face on which the viscous substance 40 adheres from a hole drilled part 31 of the screen 30 to form the substrate and the diamond layer integrally with each other by melting the bond after binder removing treatment.



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		３２０			３２０Ｂ	
	5/12			5/12	Ｚ	

審査請求　未請求　請求項の数３　ＦＤ　（全８頁）

(21)出願番号　特願平10－301722

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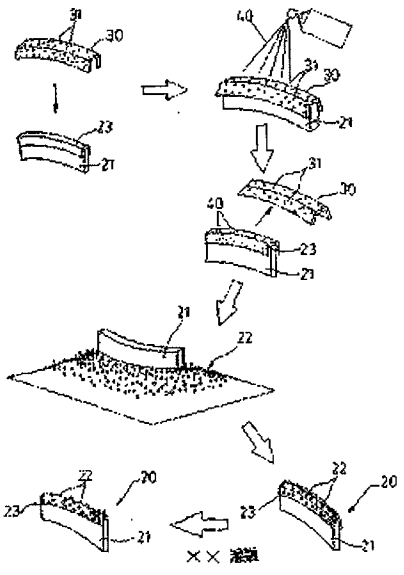
特許法第64条第２項ただし書の規定により図面第１図，４図，５図及び選択図の一部は不掲載とした。

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最終頁に続く

(54)【発明の名称】　ダイヤモンドカッターの製造方法及びダイヤモンドカッター並びにダイヤモンドカッター製造治具

(57)【要約】
【課題】　本発明の目的はダイヤモンド層を形成するダイヤモンド粒子が互いに所定間隔をもってダイヤモンド層に固着され、ダイヤモンド粒子の固着強度を高めてダイヤモンド粒子の脱落を防止できるダイヤモンドカッターの製造方法及びダイヤモンドカッター並びにダイヤモンドカッター製造治具を提供する。
【解決手段】　ダイヤモンドカッターＣの製造方法は、基板１０にバインダとボンド粉とを混練したボンド（登録商標）ペーストを取着させるボンドペースト取着工程と、ボンドペースト取着工程の後で所望に穿孔されたスクリーン３０をボンドペースト取着範囲に被覆するスクリーン被覆工程と、ボンドペーストを被覆したスクリーン３０上から粘性物質４０を塗布する塗布工程と、塗布工程の後でスクリーン３０を取り除くスクリーン除去工程と、スクリーン３０の穿孔部分３１から粘性物質４０が付着したボンドペースト面にダイヤモンド砥粒２２を接触させるダイヤモンド砥粒付着工程と、脱バインダ処理後ボンドを溶融させることによって基板１０とダイヤモンド層を一体に形成する。



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【特許請求の範囲】

【請求項１】　取付部が形成された基板と、該基板の外周端面に取着されたダイヤモンド層と、を備えたダイヤモンドカッターの製造方法において、前記基板にバインダとボンド粉とを混練したボンドペーストを取着させるボンドペースト取着工程と、該ボンドペースト取着工程の後で所望に穿孔されたスクリーンを前記ボンドペースト取着範囲に被覆するスクリーン被覆工程と、前記ボンドペーストを被覆したスクリーン上から粘性物質を塗布する塗布工程と、該塗布工程の後で前記スクリーンを取り除くスクリーン除去工程と、前記スクリーンの穿孔部分から粘性物質が付着した前記ボンドペースト面にダイヤモンド砥粒を接触させるダイヤモンド砥粒付着工程と、脱バインダ処理後前記ボンドを溶融させることによって基板とダイヤモンド層を一体に形成してなることを特徴とするダイヤモンドカッターの製造方法。

【請求項２】　取付部が形成された基板と、該基板の外周端面に取着されたダイヤモンド層と、を備えたダイヤモンドカッターであって、前記ダイヤモンド層はボンド材料により所定間隔でダイヤモンド砥粒が配列されて前記基板に固定されていることを特徴とするダイヤモンドカッター。

【請求項３】　取付部が形成された基板と、該基板の外周端面に取着されたダイヤモンド層と、を備えたダイヤモンドカッターの製造過程で用いられるダイヤモンドカッター製造治具であって、ダイヤモンド層となる部分を被覆するカバー部材と、該カバー部材に所望間隔で形成された多数の小孔とから形成されていることを特徴とするダイヤモンドカッター製造治具。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明はダイヤモンドカッターの製造方法及びダイヤモンドカッター並びにダイヤモンドカッター製造治具に係り、特に石材、コンクリートなどの切断に用いるのに好適なダイヤモンドカッターの製造方法及びダイヤモンドカッター並びにダイヤモンドカッター製造治具に関するものである。

【０００２】

【従来の技術】従来、取り付け部を有する基板の外周にダイヤモンド層が形成されたダイヤモンドカッターは公知である。そして、このようなダイヤモンドカッターとしては、例えば特公昭５５－２２１９４号公報で示されているように、「一時的な結合剤を使用して金属基材表面にダイヤモンド結晶とろう付け用合金の粒子を附着させて組立てたものを造る工程と、該組合せを還元性雰囲気または真空中で約１３００℃以下の温度迄に加熱してろう付け用合金を熔融する工程、該組合せを冷却して該ろう付け用合金を固化させダイヤモンドを基材に結合する工程よりなり、ここに該ろう付け用合金はニッケルおよびコバルトからなる群から選ばれた１種または２種の

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金属の少なくとも５０重量％、クロムの２～２６重量％、および硼素、珪素、燐より成る群より選ばれた１種または２種以上の元素の合計１２重量％以下よりなる、金属基材にダイヤモンド結晶を結合する」技術が知られている。

【０００３】また特開平９－２７２０６０号公報で示されているように、「化学的または物理的に表面処理された前記砥石刃取付部に、有機溶剤と結合材として自溶合金粉末の混合物を塗布し、その後乾燥させ、さらに有機溶剤を塗布し、砥粒を散布し、乾燥させ次いで、非酸化性雰囲気中において９００～１１５０°Ｃの加熱温度に加熱し、前記自溶合金の融着により前記砥石刃取付部に前記砥粒を固定し、前記加熱温度から徐々に冷却する」技術が知られている。

【０００４】上記従来技術では、基板等に取着させたボンドペーストにダイヤモンド砥粒を附着させるときに篩を利用したり、直接散布することにより、ダイヤモンド層を形成している。

【０００５】

【発明が解決しようとする課題】上述のように、ダイヤモンド砥粒を篩や散布することによっているため、ダイヤモンド層を形成するボンドペーストにダイヤモンド粒子が、一部分に団塊となって附着したり、ダイヤモンド粒子同士が隣接して結合することになり、ダイヤモンド粒子の固着が弱くなるという不都合があった。すなわち、このようにダイヤモンド粒子が団塊になったり、ダイヤモンド粒子が隣接した状態は、ダイヤモンド粒子を固定するためのボンドペーストが、ダイヤモンド粒子の周りに少ない状態となり、ダイヤモンド粒子の固着力の低下を意味するものである。

【０００６】本発明の目的は、ダイヤモンド層を形成するダイヤモンド粒子が互いに所定間隔をもってダイヤモンド層に固着され、ダイヤモンド粒子の固着強度を高めてダイヤモンド粒子の脱落を防止できるダイヤモンドカッターの製造方法及びダイヤモンドカッター並びにダイヤモンドカッター製造治具を提供することにある。

【０００７】

【課題を解決するための手段】上記課題は、請求項１のダイヤモンドカッターの製造方法によれば、取付部が形成された基板と、該基板の外周端面に取着されたダイヤモンド層と、を備えたダイヤモンドカッターの製造方法において、前記基板にバインダとボンド粉とを混練したボンドペーストを取着させるボンドペースト取着工程と、該ボンドペースト取着工程の後で所望に穿孔されたスクリーンを前記ボンドペースト取着範囲に被覆するスクリーン被覆工程と、前記ボンドペーストを被覆したスクリーン上から粘性物質を塗布する塗布工程と、該塗布工程の後で前記スクリーンを取り除くスクリーン除去工程と、前記スクリーンの穿孔部分から粘性物質が付着した前記ボンドペースト面にダイヤモンド砥粒を接触させ

るダイヤモンド砥粒付着工程と、脱バインダ処理後前記ボンドを溶融させることによって基板とダイヤモンド層を一体に形成してなる構成とすることにより、解決される。

【０００８】上記のように、ボンドペースト取着工程の後で所望に穿孔されたスクリーンを前記ボンドペースト取着箇所に被覆するスクリーン被覆工程と、前記ボンドペーストを被覆したスクリーン上から粘性物質を塗布する塗布工程を行なうことにより、ボンドペーストに塗布される粘性物質は、スクリーンを除去すると、スクリーンの小孔が形成された範囲だけとなる。したがって、スクリーンを除去した後でダイヤモンド砥粒を接触させると、ダイヤモンド粒子は、粘性物質が塗布された個所、すなわちスクリーンに形成された小孔の位置に付着することになる。このようにしてスクリーンに形成された小孔にしたがって、ダイヤモンド粒子を所定間隔で付着させたダイヤモンド層を形成することができる。

【０００９】また、上記課題は、請求項２に係るダイヤモンドカッターによれば、取付部が形成された基板と、該基板の外周端面に取着されたダイヤモンド層と、を備えたダイヤモンドカッターであって、前記ダイヤモンド層はボンドペーストにより所定間隔でダイヤモンド砥粒が配列されて前記基板に固定されている構成とすることにより、解決される。

【００１０】このようなダイヤモンド層はボンドペーストにより所定間隔でダイヤモンド砥粒が配列されて前記基板に固定されているダイヤモンドカッターによれば、ダイヤモンド粒子が所定間隔で配置されているために、ダイヤモンド粒子の固着強度が高まる。そして、ダイヤモンド層に均一にダイヤモンド粒子を配置して固着されているために、被切削材に対して均一な切り口となり、切削がスムーズに行なわれることになる。

【００１１】さらに、上記課題は、請求項３に係るダイヤモンドカッター製造治具によれば、取付部が形成された基板と、該基板の外周端面に取着されたダイヤモンド層と、を備えたダイヤモンドカッターの製造過程で用いられるダイヤモンドカッター製造治具であって、ダイヤモンド層となる部分を被覆するスクリーン部材と、該スクリーン部材に所望間隔で形成された多数の小孔とから形成されている構成とすることにより、解決される。

【００１２】このようなスクリーン部材によれば、スクリーン部材に形成する小孔の間隔や数を調整することにより、ダイヤモンド粒子を一定間隔で所望数配置することが可能となり、ダイヤモンドカッターにおけるダイヤモンド粒子の配置調整が可能となる。またダイヤモンド粒子が団塊になったり、隣接して配置されることがないために、各ダイヤモンド粒子が溶融ボンドによって確実に基板に固定できることになる。

【００１３】

【発明の実施の形態】ここでは、ダイヤモンドカッター

としてダイヤモンドチップを用いた例を示すが、これに限定されるものではなく、基板に直接ダイヤモンド層を形成してもよい。本発明のダイヤモンドカッターＣは、基板１０にダイヤモンドチップ２０を取着しており、このダイヤモンドチップは、基台にバインダペーストとボンド粉とを混練したボンドペーストを取着させ、ボンドペースト取着箇所に所望に穿孔されたスクリーンを被覆し、このスクリーン上から粘性物質を塗布し、塗布工程の後でスクリーンを取り除き、スクリーンの穿孔部分から粘性物質が付着したボンドペースト面にダイヤモンド砥粒を接触させ、脱バインダ処理後ボンドを溶融させることによって基板とダイヤモンド層を一体に形成することにより製造することが可能となる。

【００１４】以上のように、ダイヤモンド砥粒のばらつきがなく、均等に配置することが可能となり、ダイヤモンド層の全ての部分で切削が均等に行うことが可能となる。

【００１５】

【実施例】以下、本発明の一実施形態について、図を参照して説明する。なお、以下に説明する部材、配置等は、本発明を限定するものではなく、本発明の趣旨に沿って各種改変することができることは勿論である。

【００１６】図１乃至図６は本発明に係る実施例を示すものであり、図１はダイヤモンドカッターの一例としてダイヤモンドチップとして適用したときの製造工程を示す説明図、図２乃至図４は製造工程の拡大説明図、図５は製造工程のブロック図、図６はダイヤモンドカッターの一例を示す正面図である。また図７はダイヤモンドカッター製造治具としてのスクリーンの例を示す説明図である。

【００１７】本例のダイヤモンドカッターＣは、図６で示すように、基板１０と、ダイヤモンドチップ２０と、ダイヤモンド粒子（砥粒）２２と、を主要構成要素としており、ダイヤモンドチップ２０は、基台２１とダイヤモンド粒子（砥粒）２２とを固定するボンドペースト層２３から構成されている。そして上記円形基板１０の外周に、ダイヤモンド粒子（砥粒）２２が取着されたダイヤモンドチップ２０を焼結等により固着している。

【００１８】本例の基板１０は、鋼製であり、この鋼製基板１０は中心に取付孔１１が形成され、円形形状として形成されている。本例の基板１０は、冷間プレスで成形されている。また、本例の基板１０は、外周端面が同一円の面に形成され、所定間隔で冷却用溝等が形成されているものを用いている。このとき、基板１０の外周端面に若干の凹凸等が形成されている場合には、基台２１を基板外周端面と整合するような形状に成形する。しかし、外周端面に若干の凹凸等が形成されたり、溝を設けていないものを用いても良い。

【００１９】次に本発明に係るダイヤモンドカッターＣの製造方法について、図１乃至５を参照して説明する。

本発明のダイヤモンドカッターＣは，基板１０にダイヤモンドチップ２０を取着しており，このダイヤモンドチップ２０は，基台２１にバインダペーストとボンド粉とを混練したボンドペースト２３を取着させ，ボンドペースト取着範囲に所望に穿孔されたスクリーン３０を被覆し，このスクリーン３０上から粘性物質４０を塗布し，塗布工程の後でスクリーン３０を取り除き，スクリーン３０の穿孔部分から粘性物質４０が付着したボンドペースト面にダイヤモンド砥粒２２を接触させ，少なくともボンドペースト２３中のバインダを除去した後，ダイヤモンド砥粒２２の周辺部分のボンドを溶融させて基板１０とダイヤモンド層を一体に形成することにより製造する。これをさらに詳細に説明する。

【００２０】はじめにペースト用バインダとボンド粉とを混練してボンドペースト２３を作成する。ボンドペースト２３を構成するペースト用バインダとボンド粉は，公知の材料を使用するものであり，本例で使用するボンドペースト２３としては，ダイヤとの化学的親和力の高いＴｉ，Ｃｒ等を含むボンドであり，ダイヤに対するボンドの濡れが良く，ダイヤ保持力がかなり強化されている。基台２１（基板１０）との接着力は，ボンドと基台２１（基板１０）が化学的に結合され，溶融に伴う拡散もあるので，接着力は比較的強固となる。具体的にはＣｕ－Ｓｎ－Ｔｉ系や、Ｎｉロウ系のボンドと，各種のバインダ用ペーストを用いてボンドペーストを形成している。

【００２１】本例で用いる粘性物質４０としては，例えば，市販の水溶性メチルセルロースを約３．３倍量の水で希釈した有機糊剤，その他糊材等の粘着のある物質を使用する。

【００２２】なお溶融のボンド合金化は９４０℃～９８０℃が適正温度範囲であり，ボンドとダイヤの濡れ具合が良好となる。また適正脱脂条件について説明すると，脱脂の昇温速度が速すぎると急激なバインダの分解ガスでボンドとダイヤの飛散が生じる。そこで，真空脱脂はバインダ熱分解温度まで５℃／ｍｉｎで昇温し２０ｍｉｎ保持の条件が有効である。使用金属粉としては，ブロンズ粉が溶融温度が低めで溶融状態が安定している。またＣｕＰの添加をすることにより，濡れ性を改善することができる。

【００２３】次に図１に示すように，上記混練されたペースト用バインダとボンド粉からなるボンドペースト２３を，ディスペンサなどの射出機や刷毛を使用して，ダイヤモンドチップ２０を構成する基台２１に塗布等により取着する。そして，次に述べるスクリーン３０を固着させないように，若干の所定時間を経過させて，乾燥させる。

【００２４】次いで，基台２１のボンドペースト２３の取着範囲にスクリーン３０を被覆する。本例のスクリーン３０は，断面コ字状の枠体であり，ボンドペースト２３が取着された基台端部に嵌合可能に形成されている。スクリーン３０はボンドペースト２３の取り付けを考慮して，基台２１より若干大き目で基台２１と略同形状に形成されている。そして，基台２１にスクリーン３０を被覆するように嵌合させる。

【００２５】なおスクリーン３０は基台端部を連続して被覆するように形成しても良く，或いは所定長さに形成し，この所定長さに形成された複数のスクリーン３０を用いて基台端部を被覆するように構成しても良い。スクリーン３０には，所望箇所に多数の小孔３１が穿孔されており，この小孔３１を介して，粘性物質４０が基台２１に塗布されるように構成されている。

【００２６】本例のスクリーン３０は，アルミ等の金属から形成されている。このようにスクリーン３０を金属製とすることにより，表面や小孔３１に付着した粘性物質４０を取り除いて再使用することが可能となり，低コスト化を実現するとともに，廃棄物を減少させて環境への影響を抑えることができる。またスクリーン３０を単一金属で形成することにより，リサイクルが可能となり資源の有効利用を図ることが可能となる。

【００２７】上記スクリーン３０の形状は，上記形状に限定されるものではなく，基台２１（基板１０）の端部形状に合わせて，各種形成するものである。例えば図７（ａ）に示すスクリーン３０は，端部側が薄く中心部に向けて厚みが増した形状の基台２１（基板１０）に用いられるものであり，図７（ｂ）に示すスクリーン３０は，端部がアール形状の基台２１（基板１０）に用いられるものである。さらに図７（ｃ）に示すスクリーン３０は端部側が薄く，且つ端部がアール形状の基台２１（基板１０）に用いられるものである。

【００２８】また，スクリーン３０は上記金属製に限らず，紙製或いは樹脂フィルム製とすることもできる。紙製や樹脂フィルム製のスクリーン３０とすれば，製造時において，各基台２１（基板１０）に常に新しいスクリーン３０を使用することが可能となり，生産効率の向上を図ることができる。

【００２９】そして基台２１に配設されたスクリーン３０に，粘性物質４０をディスペンサなどの射出機や刷毛を使用して塗布する。塗布された粘性物質４０は，スクリーン３０の小孔３１を介して基台２１に付着する。

【００３０】粘性物質４０を塗布後，基台２１からスクリーン３０を取り外す。スクリーン３０が取り外された基台２１表面には，図３に示すように，スクリーン３０の小孔３１と同様のパターンで粘性物質４０が付着している。

【００３１】次に基台２１にダイヤモンド砥粒２２を付着させる。ダイヤモンド砥粒２２としては通常４０～５０メッシュのダイヤモンド粒子を使用する。ダイヤモンド砥粒２２は，図１及び図３に示すように，予め作業台等の上に所定量が載せられており，このダイヤモンド砥

粒２２中に前記基台２１の粘性物質４０が付着した側を接触させ、基台２１にダイヤモンド砥粒２２を付着させる。

【００３２】次に基台２１にダイヤモンド砥粒２２を一体に形成するため、加熱炉の炉内にセットし、排気を行う。処理は、乾燥、昇温、減圧脱脂、溶融、炉冷（真空冷却）、取り出しの順で行なう。なお製造における加熱条件としては、温度１２０℃で乾燥し、５℃／ｍｉｎで昇温し、脱脂は、１８０℃２０ｍｉｎ保持～３８０℃２０ｍｉｎ保持で行なうと好適である。次に溶融について昇温を３０℃／ｍｉｎで行い、９００℃～１１００℃で１５ｍｉｎ保持する。次に、炉冷（真空冷却）を行なうが、約７℃／ｍｉｎで行なう。さらに外熱炉体移動を６００℃で行ない、その後取り出す。なお上記では、溶融接合時の炉内真空度１０－５～１０－６Ｔｏｒｒとしている。

【００３３】上記製造工程により、基台２１にダイヤモンド粒子を単一層に保持したダイヤモンドチップ２０を得ることができる。そしてこのダイヤモンドチップ２０を基板１０に取着してダイヤモンドカッターＣが形成される。なお上記実施例では複数の基台２１にダイヤモンド砥粒２２を取着させ、基台２１を基板１０に貼着した構成例を示したが、基板１０に直接ダイヤモンド砥粒２２を取着させた構成としても良い。またダイヤモンドカッターＣとしては、円形基板の外周にダイヤモンド層が形成されたダイヤモンドホイール、筒状の一方端面側にダイヤモンドチップを取りつけたコアビット、皿状のダイヤモンドカッター等各種形態のものとすることが可能である。

【００３４】上記各種形態のダイヤモンドカッターを製造するときも、スクリーンとしては、上記各ダイヤモンド層を形成する構成に合わせて、各種形成するものである。スクリーンの形状をダイヤモンドチップの形状に合わせて構成することにより、所望形状のダイヤモンド砥粒層を取着することができる。

【００３５】

【発明の効果】以上のように本発明に係るダイヤモンドカッターの製造方法によれば、ボンドペースト取着工程の後で所望に穿孔されたスクリーンを前記ボンドペースト取着範囲に被覆するスクリーン被覆工程と、前記ボンドペーストを被覆したスクリーン上から粘性物質を塗布する塗布工程を行なうことにより、ボンドペーストに塗布される粘性物質は、スクリーンを除去すると、スクリーンの小孔が形成された範囲だけとなる。したがって、

スクリーンを除去した後でダイヤモンド砥粒を接触させると、ダイヤモンド粒子は、粘性物質が塗布された個所、すなわちスクリーンに形成された小孔の位置に付着することになる。このようにしてスクリーンに形成された小孔にしたがって、ダイヤモンド粒子を所定間隔で付着させたダイヤモンド層を形成することができる。

【００３６】また、本発明のダイヤモンドカッターによれば、ダイヤモンド粒子が所定間隔で配置されているために、ダイヤモンド粒子の固着強度が高まる。そして、ダイヤモンド層に均一にダイヤモンド粒子を配置して固着されているために、被切削材に対して均一な切り口となり、切削がスムーズに行なわれることになる。

【００３７】さらに、本発明のダイヤモンドカッター製造治具としてのスクリーン部材によれば、スクリーン部材に形成する小孔の間隔や数を調整することにより、ダイヤモンド粒子を一定間隔で所望数配置することが可能となり、ダイヤモンドカッターにおけるダイヤモンド粒子の配置調整が可能となる。またダイヤモンド粒子が団塊になったり、隣接して配置されることがないために、各ダイヤモンド粒子が溶融ボンドによって確実に基板に固定できることになる。

【図面の簡単な説明】

【図１】本発明をダイヤモンドカッターの一例としてダイヤモンドチップとして適用したときの製造工程を示す説明図である。

【図２】図１の製造工程の拡大説明図である。

【図３】図１の製造工程の拡大説明図である。

【図４】図１の製造工程の拡大説明図である。

【図５】製造工程のブロック図である。

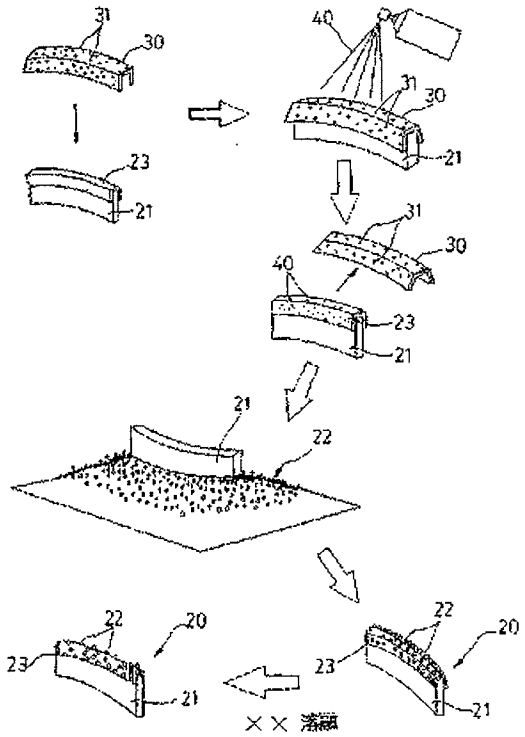
【図６】ダイヤモンドカッターの一例を示す正面図である。

【図７】ダイヤモンドカッター製造治具としてのスクリーンの例を示す説明図である。

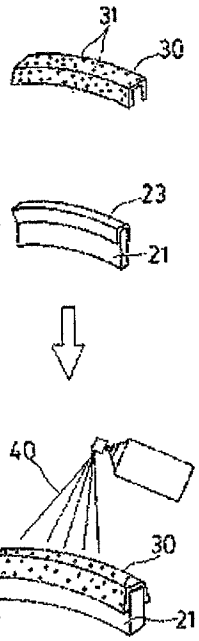
【符号の説明】

１０　基板
１１　取付孔
２０　ダイヤモンドチップ
２１　基台
２２　ダイヤモンド砥粒
２３　ボンドペースト
３０　スクリーン
３１　小孔
４０　粘性物質
Ｃ　ダイヤモンドカッター

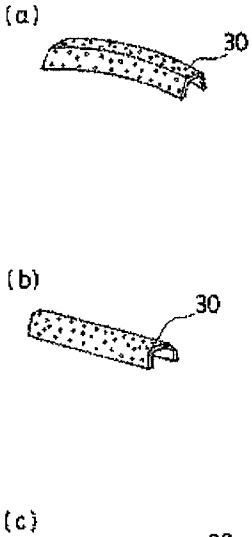
【図１】


31
30
40
23
21
22
20
××溶融

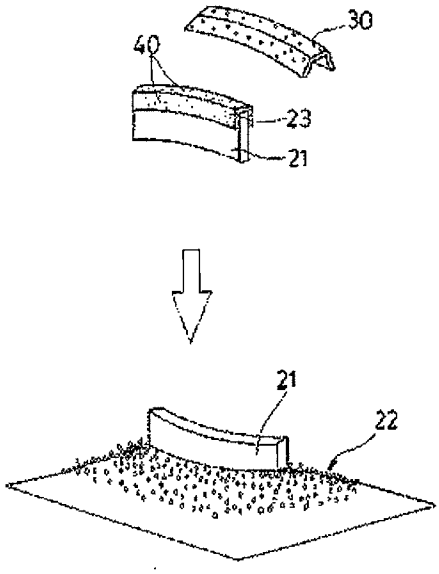
【図２】


31
30
23
21
40

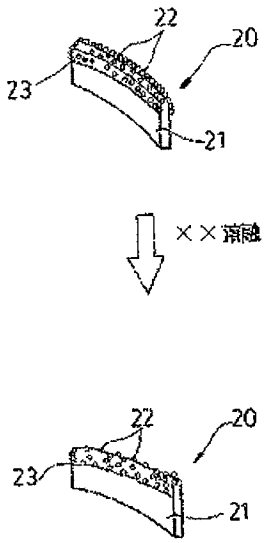
【図７】


(a)
30
(b)
30
(c)
30

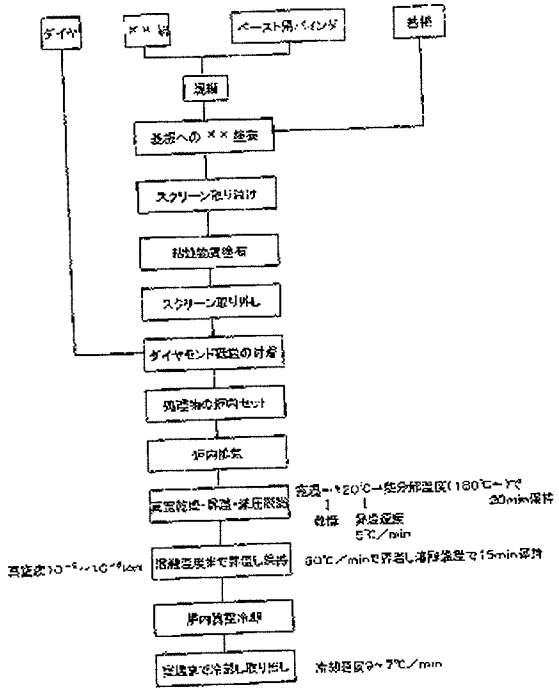
【図３】


30
40
23
21
22

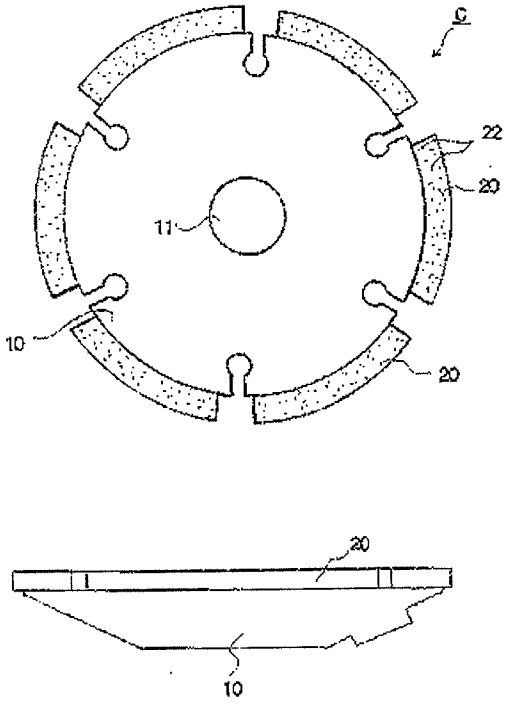
【図４】


22
20
23
21
××溶融

【図５】


ダイヤ
××粉
ペースト用バインダ
基板
混練
基板への××塗布
スクリーン抜り設計
粉粒物質塗布
スクリーン取り外し
ダイヤモンド微粒の付着
処理物の炉内セット
炉内排気
減圧雰囲気-昇温-減圧保持
1
1
数種
昇温速度
5℃／min
20min保持
高速度10⁻⁵～10⁻⁶Torr
溶融温度未満で昇温し保持
50℃／minで昇温し溶融温度で15min保持
炉内管理冷却
室温まで冷却し取り出し
冷却速度3～7℃／min

【図６】



フロントページの続き

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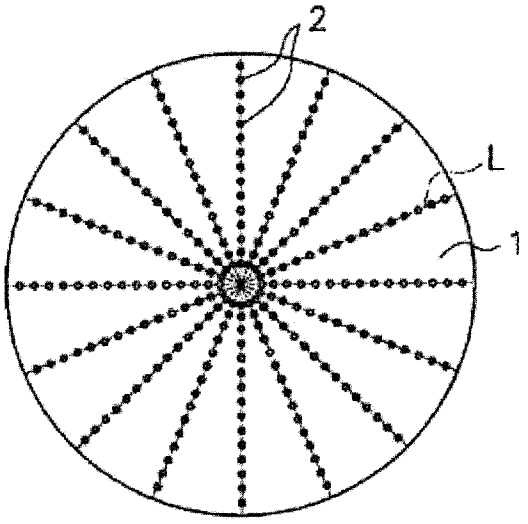
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(54) CMP CONDITIONER, METHOD FOR ARRANGING HARD ABRASIVE GRAIN USED IN CMP CONDITIONER AND METHOD FOR MANUFACTURING CMP CONDITIONER

(57)Abstract:
PROBLEM TO BE SOLVED: To provide stable CMP conditioner characteristics and to relieve slurry or the like in polishing without forming relief groove or the like on a support member.
SOLUTION: This CMP conditioner of polishing cloth for a semiconductor substrate is composed of the support member 1 and plural diamond grains 2 brazed on a surface of the supporting member 1. Plural straight lines or curved lines radially extending from a center of the support member 1 are laid out on the surface of the disk-shaped support member 1 and the diamond grains 2 are arranged on the straight lines or the curved lines. The diamond grains 2 are arranged in such a manner that density of the diamond grains 2 at edge parts is smaller than that at a center par of the support member 1. Since area where no diamond grain 2 exists is secured in radial shape on the surface of the support member 1, slurry can be relieved outward from the support member 1 in polishing.



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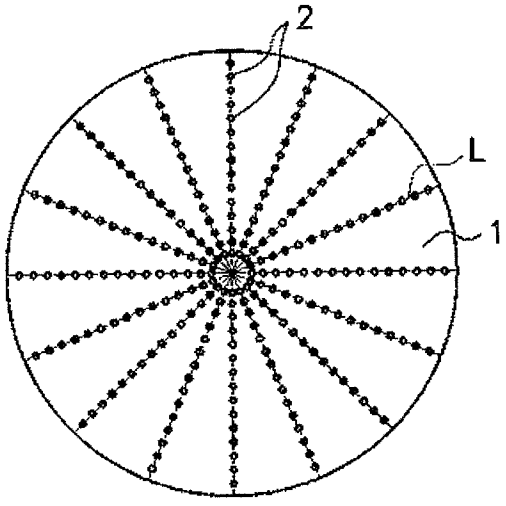
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弁理士　國分　孝悦

最終頁に続く

(54)【発明の名称】　ＣＭＰコンディショナー，ＣＭＰコンディショナーに使用する硬質砥粒の配列方法、及びＣＭＰコンディショナー製造方法

(57)【要約】
【課題】　安定したＣＭＰコンディショナー特性が得られるとともに，支持部材に逃し溝等を形成しなくとも研磨時にスラリー等を逃すことができるようにする。
【解決手段】　半導体基盤用研磨布のＣＭＰコンディショナーは，支持部材１と，支持部材１の面上にろう付けされた複数のダイヤモンド粒２とからなり，円板状の支持部材１の表面において，支持部材１の中心から放射状に伸びる複数の直線或いは曲線を考え，それら直線或いは曲線上にダイヤモンド粒２を配置するようにしている。このようにしたＣＭＰコンディショナーでは，ダイヤモンド粒２が支持部材１の中央部分に比べて縁部分における密度が小さくなるよう配列されており、支持部材１の表面上には，ダイヤモンド粒２が存在しない領域が放射状に確保されることになるので，研磨時にスラリーを支持部材１の外側に向けて逃すことができる。



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【特許請求の範囲】

【請求項１】　支持部材と．前記支持部材の面上に設けられた複数の硬質砥粒とを備えたＣＭＰコンディショナーであって、

前記支持部材の面上に、前記複数の硬質砥粒を規則的に．かつ、前記支持部材の内側から外側にかけて密度が減少するように配列させたことを特徴とするＣＭＰコンディショナー。

【請求項２】　前記硬質砥粒を、前記支持部材の中心から略放射状に配列させていることを特徴とする請求項１に記載のＣＭＰコンディショナー。

【請求項３】　支持部材と．前記支持部材の面上に設けられた複数の硬質砥粒とを備えたＣＭＰコンディショナーであって、

前記支持部材の面上に、前記複数の硬質砥粒が存在しない領域を略放射状に確保していることを特徴とするＣＭＰコンディショナー。

【請求項４】　前記硬質砥粒はダイヤモンド粒であることを特徴とする請求項１～３のいずれか１項に記載のＣＭＰコンディショナー。

【請求項５】　チタン、クロム、又はジルコニウムより選ばれた１種以上を０．５～２０ｗｔ％含む融点６５０℃～１２００℃の合金を用いて、前記ダイヤモンド粒を金属及び／又は合金からなる前記支持部材に、単層、ろう付けし、前記ダイヤモンド粒と前記合金との界面にチタン．クロム．又はジルコニウムより選ばれた金属の炭化物層が形成されていることを特徴とする請求項４に記載のＣＭＰコンディショナー。

【請求項６】　前記融点６５０℃～１２００℃の合金がニッケル基合金であることを特徴とする請求項５に記載のＣＭＰコンディショナー。

【請求項７】　規則的に．かつ、内側から外側にかけて密度が減少するように配列させた複数の貫通穴が形成された薄板状の配列部材を被配列面上に位置させる手順と．

前記配列部材の各貫通穴に硬質砥粒を入れ込む手順とを有することを特徴とするＣＭＰコンディショナーに使用する硬質砥粒の配列方法。

【請求項８】　複数の貫通穴の存在しない領域が略放射状に確保された薄板状の配列部材を被配列面上に位置させる手順と、

前記配列部材の各貫通穴に硬質砥粒を入れ込む手順とを有することを特徴とするＣＭＰコンディショナーに使用する硬質砥粒の配列方法。

【請求項９】　前記被配列面は、ＣＭＰコンディショナーを構成する支持部材の表面であることを特徴とする請求項７又は８に記載のＣＭＰコンディショナーに使用する硬質砥粒の配列方法。

【請求項１０】　複数の硬質砥粒を規則的に、かつ、内側から外側にかけて密度が減少するように配列させた状態で保持部材に保持する手順と、

前記保持部材により保持された硬質砥粒を、ＣＭＰコンディショナーを構成する支持部材の表面に転写する手順とを有することを特徴とするＣＭＰコンディショナーに使用する硬質砥粒の配列方法。

【請求項１１】　複数の硬質砥粒の存在しない領域が略放射状に確保された状態で前記複数の硬質砥粒を保持部材に保持する手順と、

前記保持部材により保持された硬質砥粒を、ＣＭＰコンディショナーを構成する支持部材の表面に転写する手順とを有することを特徴とするＣＭＰコンディショナーに使用する硬質砥粒の配列方法。

【請求項１２】　前記保持部材には前記硬質砥粒を保持するための第１の接着手段を設け．前記支持部材の表面には第２の接着手段を設け．これら第１、２の接着手段の性質に差を持たせたことを特徴とする請求項１０又は１１に記載のＣＭＰコンディショナーに使用する硬質砥粒の配列方法。

【請求項１３】　請求項７～１２のいずれか１項に記載のＣＭＰコンディショナーに使用する硬質砥粒の配列方法を利用して前記硬質砥粒を前記支持部材の表面上に配列させた後、前記硬質砥粒を前記支持部材の表面に固着することを特徴とするＣＭＰコンディショナー製造方法。

【発明の詳細な説明】

【０００１】

【発明の属する技術分野】本発明は．半導体基板用の研磨布の目詰まりを解消し．異物を除去するのに使用されるＣＭＰコンディショナー．ＣＭＰコンディショナーに使用する硬質砥粒の配列方法、及びＣＭＰコンディショナー製造方法に関する。

【０００２】

【従来の技術】ウェハのポリッシングにおいては．ＣＭＰ(Chemical Mechanical Polishing)と呼ばれる研磨方法が提案されている。ＣＭＰは、機械的研磨作用に化学的研磨作用を重畳して働かせることにより、研磨速度の確保と被研磨材が無欠陥であることの両立を可能としたものであり、シリコンウェハの仕上げポリッシング工程で広く使用されている。

【０００３】また、近年ではデバイスの高集積化に伴い．集積回路を製造する所定の段階で．ウェハ表面やウェハ表面に導電体・誘電体層が形成された半導体基板表面を研磨することが必要になってきた。半導体基板は、研磨されて、高い隆起、引っかき傷．粗さ等の表面欠陥が除去される。通常、この工程は、ウェハ上に種々の素子及び集積回路を形成する間に行われる。この研磨工程では．シリコンウェハの仕上げポリッシング工程と同様に．研磨速度と無欠陥であることの両立が必要である。化学スラリーを導入することにより．半導体表面により大きな研磨除去速度及び無欠陥性が与えられる化学的か

つ機械的平坦化が行われる。

【０００４】ＣＭＰ工程の一例としては、図８に示すように、例えば５～３００ｎｍ程度の粒径を有するシリカ粒子を苛性ソーダ、アンモニア及びアミン等のアルカリ溶液に懸濁させてＰＨ９～１２程度に化学スラリー１０１と、ポリウレタン樹脂等からなる研磨布１０２とが用いられる。研磨時には、化学スラリー１０１を流布しながら、半導体基板１０３を研磨布１０２に適当な圧力で当接させ、同図の矢印に示すように相対回転させることにより研磨が行われる。

【０００５】そして、前記研磨布１０２のコンディショニング法としては、研磨布１０２に水又は化学スラリー１０１を流しながら、ＣＭＰコンディショナーを用いたコンディショニングを行って、研磨布１０２の目詰まりを解消し、異物を除去していた。ＣＭＰコンディショナーを用いたコンディショニングは、半導体基板１０３の研磨が終わった後に、ＣＭＰコンディショナーを研磨布１０２に当接させるか、或いは、半導体基板１０３の研磨と同時に、半導体基板１０３が当接する位置とは別の位置でＣＭＰコンディショナーを研磨布１０２に当接させるかして行われる。

【０００６】

【発明が解決しようとする課題】従来の研磨布のコンディショニングに用いられるＣＭＰコンディショナーでは、図９に示すように、円板状の支持部材２０１の表面に、硬質砥粒としてダイヤモンド粒２０２を入手で撒く等して適当に均一に分布させた後、これらダイヤモンド粒２０２を固着させていた。しかし、この場合、いかに丁寧にダイヤモンド粒２０２を散布したとしても、ダイヤモンド粒２０２は不均一に分布し、ＣＭＰコンディショナー個体間での相違の原因となり、安定したＣＭＰコンディショナー特性の発現が妨げられていた。

【０００７】また、従来のＣＭＰコンディショナーでは、スラルーの逃げが悪いため、マイクロスクラッチが多くなった。また、スラリーの逃げを改良するためには、図１０に示すように、支持部材２０１に化学スラリー１０１を逃すための逃し溝２０３等を形成しておき、研磨時に、この逃し溝２０３を介して化学スラリー１０１を逃すことがなされていた。しかし、支持部材２０１に逃し溝２０３を形成するのでは、ＣＭＰコンディショナー特性に悪影響を与えるおそれがあり、また、その逃し溝の加工に手間がかかり、コストアップの要因となってしまう。

【０００８】本発明は前記のような点に鑑みてなされたものであり、安定したＣＭＰコンディショナー特性が得られるとともに、逃し溝等を形成しなくとも研磨時にスラリー等を逃すことができ、マイクロスクラッチを減らすようにすることを目的とする。

【０００９】

【課題を解決するための手段】本発明のＣＭＰコンディショナーは、支持部材と、前記支持部材の面上に設けられた複数の硬質砥粒とを備えたＣＭＰコンディショナーであって、前記支持部材の面上に、前記複数の硬質砥粒を規則的に、かつ、前記支持部材の内側から外側にかけて密度が減少するように配列させた点に特徴を有する。

【００１０】本発明の他のＣＭＰコンディショナーは、支持部材と、前記支持部材の面上に設けられた複数の硬質砥粒とを備えたＣＭＰコンディショナーであって、前記支持部材の面上に、前記複数の硬質砥粒が存在しない領域を略放射状に確保している点に特徴を有する。

【００１１】本発明のＣＭＰコンディショナーに使用する硬質砥粒の配列方法は、規則的に、かつ、内側から外側にかけて密度が減少するように配列させた複数の貫通穴が形成された薄板状の配列部材を被配列面上に位置させる手順と、前記配列部材の各貫通穴に硬質砥粒を入れ込む手順とを有する点に特徴を有する。

【００１２】本発明の他のＣＭＰコンディショナーに使用する硬質砥粒の配列方法は、複数の貫通穴の存在しない領域が略放射状に確保された薄板状の配列部材を被配列面上に位置させる手順と、前記配列部材の各貫通穴に硬質砥粒を入れ込む手順とを有する点に特徴を有する。

【００１３】本発明の他のＣＭＰコンディショナーに使用する硬質砥粒の配列方法は、複数の硬質砥粒を規則的に、かつ、内側から外側にかけて密度が減少するように配列させた状態で保持部材に保持する手順と、前記保持部材により保持された硬質砥粒を、ＣＭＰコンディショナーを構成する支持部材の表面に転写する手順とを有する点に特徴を有する。

【００１４】本発明の他のＣＭＰコンディショナーに使用する硬質砥粒の配列方法は、複数の硬質砥粒の存在しない領域が略放射状に確保された状態で前記複数の硬質砥粒を保持部材に保持する手順と、前記保持部材により保持された硬質砥粒を、ＣＭＰコンディショナーを構成する支持部材の表面に転写する手順とを有する点に特徴を有する。

【００１５】本発明のＣＭＰコンディショナー製造方法は、前記ＣＭＰコンディショナーに使用する硬質砥粒の配列方法を利用して前記硬質砥粒を前記支持部材の表面上に配列させた後、前記硬質砥粒を前記支持部材の表面に固着する点に特徴を有する。

【００１６】

【発明の実施の形態】以下、図面を参照して、本発明の半導体基板用研磨布のＣＭＰコンディショナー、半導体基板用研磨布のＣＭＰコンディショナーに使用する硬質砥粒の配列方法、及びＣＭＰコンディショナー製造方法の実施の形態について説明する。

【００１７】図１を用いて、ＣＭＰコンディショナーについて説明する。同図に示すように、ステンレス鋼等からなる円板状の支持部材１の表面には、硬質砥粒としてダイヤモンド粒２が固着されている。

【００１８】図２、３には、支持部材１の表面におけるダイヤモンド粒２の配列の概要を示す。図２に示す例は、円板状の支持部材１の中心から放射状に伸びる複数の直線（一点鎖線Ｌ）を考え、それら直線上にダイヤモンド粒２を配置したものである。このようにしたＣＭＰコンディショナーでは、ダイヤモンド粒２が支持部材１の内側から外側にかけて密度が小さくなるように配列されており、支持部材１の表面上には、ダイヤモンド粒２の存在しない領域が放射状に確保されることになる。

【００１９】また、図３に示す例は、円板状の支持部材１の中心から放射状に伸びる複数の曲線（一点鎖線Ｌ）を考え、それら曲線上にダイヤモンド粒２を配置したものである。このようにしたＣＭＰコンディショナーでは、ダイヤモンド粒２が支持部材１の内側から外側にかけて密度が小さくなるように配列されており、支持部材１の表面上には、ダイヤモンド粒２が存在しない領域が放射状に確保されることになる。本発明でいう略放射状とは、図２に示すように直線的に放射する場合だけでなく、図３に示すように曲線的に放射する場合も含むものとする。

【００２０】なお、実際のダイヤモンド粒２は、支持部材１に比べて非常に小さなものであるが、図１や後述する図２、３では、説明を簡単にするためダイヤモンド粒２を大きく図示する。また、直線や曲線の数についても、より密な状態で放射させるようにするが、図２、３では簡単に図示する。

【００２１】以下、図４～７を参照して、ダイヤモンド粒２の配列方法について説明する。本実施の形態では、次の２通りの方法により、ダイヤモンド粒２を配列させている。

【００２２】第１の方法では、図４に示すように、ろう材３が設けられた支持部材１の表面に、接着剤４を塗布しておく。そして、接着剤４を塗布した支持部材１の表面上に配列板５を載置して、マスキングする。

【００２３】図５に示すように、配列板５には、ダイヤモンド粒２を配列させるための貫通穴６が形成されている。すなわち、配列板５には、図２や図３に示す配列と同様に貫通穴６を配列させている。貫通穴６の口径Ｘは、ダイヤモンド粒２のサイズＤに対して、１．０Ｄ＜Ｘ＜２．０Ｄとなっており、１つの貫通穴６に１個以上のダイヤモンド粒２が同時に入り込まないようにしている。なお、配列板５の周囲には、飛散防止用壁５ａが設けられている。

【００２４】図４に示すように、前記配列板５を支持部材１の表面に載置した状態で、配列板５上にダイヤモンド粒２を散布する。このとき、配列板５に適当な振動を加える等して、ダイヤモンド粒２が全ての貫通穴６に入り込むようにする。全ての貫通穴６にダイヤモンド粒２が入り込んだならば、配列板５上の余分なダイヤモンド粒２をはけ等を用いて取り除く。その後、配列板５を支持部材１の表面から取り外せば、ダイヤモンド粒２は、図２や図３に示すように配列された状態で支持部材１の表面上に残ることになる。

【００２５】以上述べたようにして支持部材１の表面にダイヤモンド粒２を配列させたならば、単層、ろう付けを行い、ダイヤモンド粒２を固定する。このろう付けの際に、支持部材１の表面に塗布された接着剤４はろう材３への加熱によって昇華し、支持部材１の表面上に残留しない。

【００２６】なお、第１の方法において、配列板５の代わりに、ワイヤで編まれたメッシュを用いてもよい。すなわち、メッシュの各開口部分を配列板５でいう貫通穴６として使用し、該開口部分にダイヤモンド粒２を入れ込んで、支持部材１の表面に配列させる。

【００２７】第２の方法では、前記第１の方法のようにダイヤモンド粒２を支持部材１の表面に直接的に配列するのではなく、粘着シート等の保持部材にいったん配列させてから、支持部材１の表面に転写するようにしている。

【００２８】図６（ａ）に示すように、配列板７には、ダイヤモンド粒２を配列させるための凹部８が形成されている。すなわち、配列板７には、図２や図３に示す配列と同様に凹部８を配列させている。なお、凹部８の口径Ｘを、ダイヤモンド粒サイズＤに対して、１．０Ｄ＜Ｘ＜２．０Ｄとすることは、前記第１の方法で述べた貫通穴６と同じである。

【００２９】前記配列板７上にダイヤモンド粒２を散布する。このときも、前記第１の方法で説明したように、配列板７に適当な振動を加える等して、ダイヤモンド粒２が全ての凹部８に入り込むようにする。全ての凹部８にダイヤモンド粒２が入り込んだならば、配列板７上の余分なダイヤモンド粒２をはけ９等を用いて取り除く。

【００３０】次に、配列板７の凹部８が開口する面に粘着シート１０を貼り付ける。そして、図６（ｂ）に示すように、配列板７の上下を逆にする等して、粘着シート１０を剥がすと、粘着シート１０にダイヤモンド粒２が配列された状態で保持されることになる。

【００３１】前記粘着シート１０のダイヤモンド粒２を保持する粘着面を、接着剤４が塗布された支持部材１の表面に貼り合わせるようにする。したがって、図７に示すように、ダイヤモンド粒２は、一端が粘着シート１０側で、他端が支持部材１の表面側で支持された状態となる。その後、支持部材１の表面側にダイヤモンド粒２を残し、粘着シート１０だけを取り除けば、ダイヤモンド粒２を支持部材１の表面上に配列させることができる。

【００３２】粘着シート１０だけを取り除く手法としては、例えば、粘着シート１０の接着材の溶解性と、支持部材１側の接着剤４の溶解性とに差を持たせておけばよい。この場合、図７に示す状態で粘着シート１０の接着剤が溶けるような環境にすれば、支持部材１側の接着剤

４は保持力を維持したまま．粘着シート１０の接着材だけを溶かし、砥着シート１０だけを取り除くことができる。

【００３３】以上述べたようにして支持部材１の表面にダイヤモンド粒２を配列させたならば．単屋、ろう付けを行い、ダイヤモンド粒２を固定する。このろう付けの際に．支持部材１の表面に塗布された接着剤４はろう材３への加熱によって昇華し．支持部材１の表面上に残留しない。

【００３４】なお、第２の方法では．配列板７に凹部８を形成するようにしたが．貫通穴としてよい。この場合．図４に示す支持部材１を粘着シート１０に変更すれば．砥着シート１０にダイヤモンド粒を配列させることができるので．それを支持部材１の表面に転写すればよい。

【００３５】以上述べたように本実施の形態によれば、ダイヤモンド粒２を規則的に配列させているので．ＣＭＰコンディショナー間での固体差がなくなり、安定したＣＭＰコンディショナー特性を得ることができる。また．ダイヤモンド粒２を．支持部材１の中心から略放射状に配列させることにより．支持部材１の内側から外側にかけて密度が小さくなるよう配列するようにし．また．ダイヤモンド粒２が存在しない領域を放射状に確保するようにしたので、研磨時にスラリーを支持部材１の外側に向けて逃すことができ、マイクロスクラッチが減少する。そして．スラリーを逃すための特別な加工を支持部材１に施す必要がなくなるので．加工の手間やコストを軽減させることができる。

【００３６】なお、本実施の形態では．本発明でいう硬質砥粒としてダイヤモンド粒２を用いたが、その他の材質．例えば立方晶窒化ホウ素、炭化ホウ素、炭化珪素又は酸化アルミニウム等からなるものであってもよい。

【００３７】また、ダイヤモンド粒２の支持部材１への固着方法としては、ろう付け以外の方法、例えばニッケル電着等により固着させてもよい。

【００３８】ここで、好適な一例として、ダイヤモンド粒をろう付けにより固着する方法について説明すると、ろう材として．チタン、クロム、又はジルコニウムより選ばれた１種以上を０．５～２０ｗｔ％含む融点６５０℃～１２００℃の合金を用いることにより、ダイヤモンド粒とろう付け合金との界面に当該金属の炭化物層が形成される。ろう材に含まれるチタン．クロム、又はジルコニウムより選ばれた１種以上を０．５～２０ｗｔ％とするのは、０．５ｗｔ％より少ない含有量ではダイヤモンド－ろう付け合金の界面に当該金属の炭化物層が形成されないためであり、２０ｗｔ％添加すれば十分な接合強度を示す炭化物層が形成されるためである。

【００３９】ろう付け合金を融点６５０℃～１２００℃の合金とするのは、６５０℃未満のろう付け温度では、接合強度が得られず、１２００℃超のろう付け温度では．ダイヤモンドの劣化が起こるので好ましくないからである。ろう付け合金としては、例えば、上記成分を含有するニッケル（Ｎｉ）基合金等が好適に用いることができる。

【００４０】ろう付け合金の厚さは．ダイヤモンド粒の０．２～１．５倍の厚さが適当である。薄すぎると、ダイヤモンドとろう付け合金との接合強度が低くなり、厚すぎると、ろう材と支持部材との剥離が起こりやすくなるためである。

【００４１】ダイヤモンド粒の径は．５０μｍ～３００μｍとすることが好ましい。５０μｍ未満の微粒ダイヤモンド粒では．十分な研磨速度が得られず、また．凝集しやすい傾向があり、脱落しやすくなるためである。また．３００μｍ超の粗粒のダイヤモンド粒では．研磨時の応力集中が大きくなり．脱落しやすくなるためである。

【００４２】

【発明の効果】以上述べたように本発明によれば．ＣＭＰコンディショナー間での固体差がなくなり、安定したＣＭＰコンディショナー特性を得ることができるので、安定した量産ＣＭＰプロセスを実現することが可能となる。また、研磨時にスラリーを逃すことができ．マイクロスクラッチを減らすことができ、しかも、そのための特別な加工を支持部材に施す必要がなくなるので．加工の手間やコストを軽減させることができる。

【図面の簡単な説明】

【図１】ＣＭＰコンディショナーについて説明するため図である。

【図２】ダイヤモンド粒２の配列の一例を示す図である。

【図３】ダイヤモンド粒２の配列の一例を示す図である。

【図４】第１の方法によるダイヤモンド粒２の配列方法を説明するための図である。

【図５】配列板５を説明するための図である。

【図６】第２の方法によるダイヤモンド粒２の配列方法を説明するための図である。

【図７】第２の方法によるダイヤモンド粒２の配列方法を説明するための図である。

【図８】ＣＭＰ工程を説明するための図である。

【図９】従来のＣＭＰコンディショナーについて説明するための図である。

【図１０】逃し溝２０３を形成したＣＭＰコンディショナーを示す模式図である。

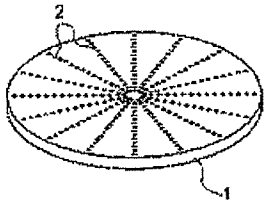
【符号の説明】

１　支持部材
２　ダイヤモンド粒
３　ろう材
４　接着剤
５　配列板

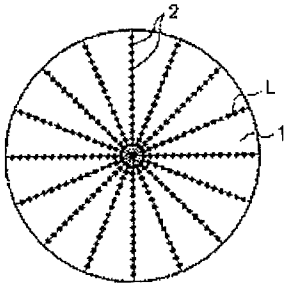
9　　10

5 a　飛散防止用壁
6　貫通穴
7　配列板
8　凹部
9　はけ
＊１０　粘着シート
１０１　化学スラリー
１０２　研磨布
１０３　半導体基板
＊

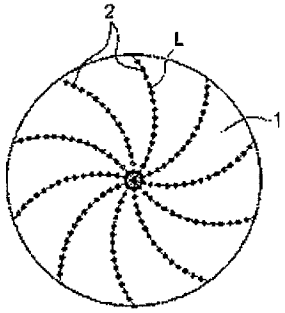
【図１】



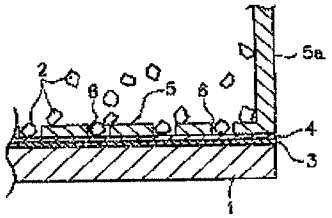
【図２】



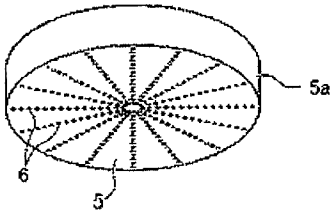
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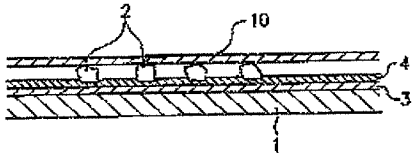
【図４】



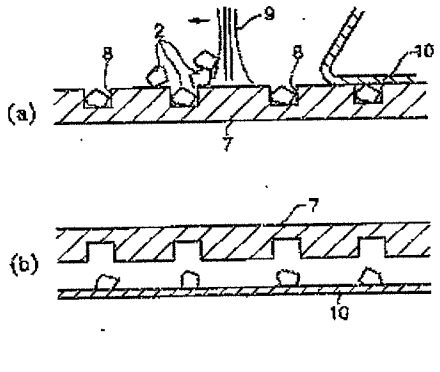
【図５】



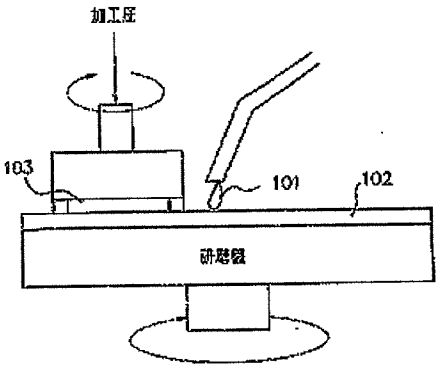
【図７】



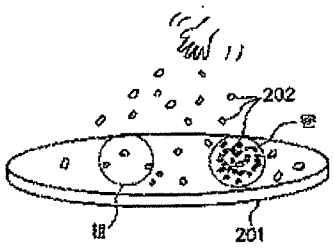
【図６】



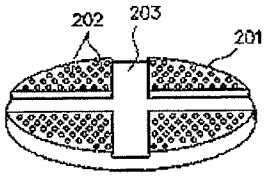
【図８】



【図９】



【図１０】



フロントページの続き

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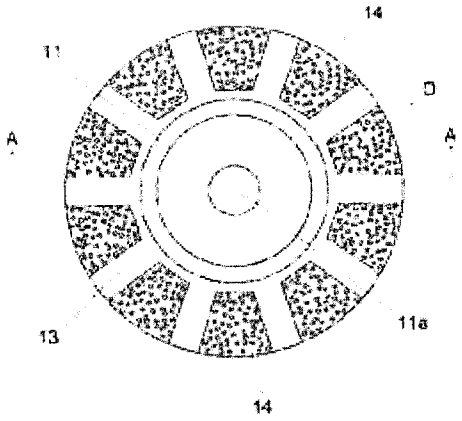
(51)Int.Cl. B24D 7/06
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(54) DISC-SHAPED DIAMOND GRINDING WHEEL

(57)Abstract:
PROBLEM TO BE SOLVED: To provide a disc-shaped diamond grinding wheel hardly causing loading and having flexibility.
SOLUTION: A base plate 11 of the disc diamond grinding wheel is made into a cup form of 10 cm in diameter having flexibility, and a jig mounting hole 11a to mount the base plate 11 on a grinder, etc. is provided on a central part of the base plate 11. Additionally, a rubber sheet 13 is adhered on a do-nut shaped part on a flat surface of a peripheral part of the base plate 11 , and a plurality of polishing chips 14 are adhered along a circumference under a deposition method coating diamond abrasive grains D on its upper layer. As they are supported by the base plate 11 excellent in flexibility, strength, etc. and the rubber sheet 13 transmits its elasticity to the polishing chips 14, the polishing chips 14 respectively and independently polish a polishing article along its surface and also polish the small area part and the curved surface.



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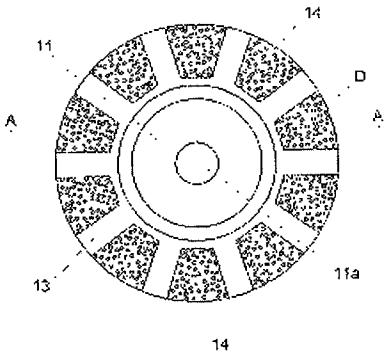
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(54)【発明の名称】ディスク状ダイヤモンド砥石

(57)【要約】
【課題】目詰まりの起こし難く、可撓性を有するディスク状ダイヤモンド砥石を得る。
【解決手段】ディスク状ダイヤモンド砥石の基板１１は可撓性を有する直径１０ｃｍのカップ状とされ、基板１１の中心部には基板１１をグラインダ等に取り付けるための治具取付孔１１ａが設けられている。また、基板１１の周辺部の平面上のドーナツ状部分にはゴムシート１３が接着され、更にその上層にダイヤモンド砥粒Ｄを塗布した溶着法による複数個の研磨チップ１４が円周に沿って接着されている。可撓性、強度等に優れた基板１１に支持され、ゴムシート１３がその弾力性を研磨チップ１４に伝えるため、研磨チップ１４はそれぞれ独立に被研磨物の面に沿って研磨でき、小面積部や曲面も研磨することができる。
【選択図】　図１



【特許請求の範囲】
【請求項１】
ダイヤモンド砥粒を塗布した複数個の金属片から成る研磨チップを可撓性材料から成るディスク状基板上の外周平坦部表面に配列したことを特徴とするディスク状ダイヤモンド砥石。
【請求項２】
前記研磨チップは前記ディスク状基板の円周に沿って等間隔に配列したことを特徴とするディスク状ダイヤモンド砥石。
【請求項３】
前記研磨チップは前記ディスク状基板上に積層したゴム層上に接着した請求項１に記載のディスク状ダイヤモンド砥石。
【請求項４】
前記ダイヤモンド砥粒は溶着法により前記研磨チップに塗布した請求項１に記載のディスク状ダイヤモンド砥石。
【発明の詳細な説明】
【０００１】
【発明の属する技術分野】
本発明は、グラインダ等の回転工具に取り付け、硬質材料表面に塗装された表面塗膜を剥離したり、金属表面の錆を除去したり、或いは研磨をするディスク状ダイヤモンド砥石に関するものである。
【０００２】
【従来の技術】
例えば、既設の橋梁や工場の煙突、タンク等の保守に際して、表面塗膜の補修をする場合において、それらの表面に塗装されている重防食系塗料の剥離はなかなか困難であり、二度、三度の手間を要する難作業である。
【０００３】
通常では、グラインダ等の電動工具の回転により金属片を表面塗膜に打ち付けることにより面を荒らし、その後にディスク状サンドペーパによって塗膜を剥離する。
【０００４】
【発明が解決しようとする課題】
しかしながら上述の従来例においては、金属片を打ち付ける際に、その母材の鉄やコンクリートの打撃音や振動が激しく、母材を痛めることもある。また、ディスク状サンドペーパも重防食塗料により短時間で目詰まりを起こしてしまい、交換頻度も多く、作業効率も極めて悪い。
【０００５】
通常の建物の外壁塗膜の剥離においても、塗料の違いこそあれ、目詰まりによる交換損失を生ずる。目詰まりさえしなければ摩耗し難い砥粒が好適であることは明白であるが、実際には砥粒は摩耗しておらず研磨性能は十分あっても、目詰まりで砥石が使用できなくなるという問題がある。
【０００６】
現在、ダイヤモンド砥石を使用した研磨材としては、図４に模式的に示すような金属粉末を用いてダイヤモンド砥粒を混入して固めたメタルボンドと称される研磨剤１と、図５に示すように表面にメッキによる電着法により製造された研磨剤２が知られている。
【０００７】
しかしながら、前述のメタルボンド製の研磨剤１は、ダイヤモンド砥粒Ｄの突き出しが少なく、目詰まりするため砥膜剥離には不適である。後者の電着製の研磨剤２は砥粒の突き出しは多いが、ダイヤモンド砥粒Ｄとメッキの間に隙間Ｓが発生してメッキが剥離し易く、ダイヤモンド砥粒Ｄの脱落が多く目詰まりを生じ易い。
【０００８】
また、現状のディスク状ダイヤモンド砥石としては、カップ型のものが多く用いられてい

るが、金属製の椀形基板の平坦部にメタルボンド製ダイヤモンドを下駄歯状のブロックにして取り付けたものが多く、騒音、振動共に非常に激しい。

【０００９】

本発明の目的は、上述の問題点を解消し、金属片を打ち付ける作業を不要とし、目詰まりが少なく長時間の作業に耐え、作業音や振動が静かな可撓性を有し、小面積部や曲面をも研磨することのできるディスク状ダイヤモンド砥石を提供することにある。

【００１０】

【課題を解決するための手段】

上記目的を達成するための本発明に係るディスク状ダイヤモンド砥石は、ダイヤモンド砥粒を塗布した複数個の金属片から成る研磨チップを可撓性材料から成るディスク状基板上の外周平坦部表面に配列したことを特徴とする。

【００１１】

【発明の実施の形態】

本発明を図１～図３に図示の実施の形態に基づいて詳細に説明する。

図１は本実施の形態におけるディスク状ダイヤモンド砥石の平面図、図２は図１におけるＡ－Ａ線に沿った断面図を示している。基板１１は例えばエポキシ樹脂材に繊維質材としてガラスファイバ材料を混合し、例えば直径１０ｃｍの可撓性を有するカップ状とされ、基板１１の中心部には基板１１をグラインダ等に取り付けるための治具取付孔１１ａが設けられている。また、基板１１の周辺部の平面状のドーナツ状部分１２にはゴムシート１３が接着され、更にその上層にダイヤモンド砥粒Ｄを塗布した例えば１０個の研磨チップ１４が接着されている。

【００１２】

研磨チップ１４としては、特に溶着方法を用いてダイヤモンド砥粒Ｄを塗布したたものが好適である。溶着方法は自溶性合金タイプとブロンズタイプの２種があり、自溶性合金タイプはＮｉ－Ｃｒ系合金粉末、ブロンズタイプはブロンズ系粉末及びＴｉ等の活性金属粉末を、市販の真空用バインダと混合することにより、先ずペーストを作製する。続いて、所定の形状、例えば本実施の形態では、周辺の基板１１と同曲率にして扇状に打ち抜いた金属片上に、厚みが一定になるようにすり切り治具を使用して上述のペーストを塗布する。

【００１３】

ペーストを塗布すり切りした後に、塗布したペースト上に振動機等を用い、ダイヤモンド砥粒を散布する。なお、自溶性合金タイプの場合には市販の真空用バインダを金属片上に均一に塗布し、ダイヤモンド砥粒Ｄを散布した後に、Ｎｉ－Ｃｒ系合金粉末を振りかける方法でも同様なものが作製できる。

【００１４】

次に、ダイヤモンド砥粒Ｄを散布した金属片を乾燥機に入れ、２４時間程乾燥することにより、バインダに含まれている油脂成分を十分に除去する。続いて、この乾燥処理を行った金属片を真空炉にセットし、真空度が10^{-2}以上の高真空とした後に、自溶性合金タイプは１０００～１１００℃、ブロンズタイプは８００～９５０℃の温度で焼成を行う。これらの温度で焼成を行うことによりダイヤモンド砥粒ＤをＮｉ－Ｃｒ系金属、活性金属含有ブロンズ系金属でそれぞれ良好に溶着することができる。

【００１５】

溶着されたダイヤモンド砥粒Ｄは、図３の模式図に示すように活性金属と反応層Ｒを形成し強固な金属結合することにより、研磨チップ１４上からのダイヤモンド砥粒Ｄの突き出しが大きい。そして、研磨チップ１４は真空炉内の温度が室温に下った後に取り出す。

【００１６】

なお、研磨チップ１４のダイヤモンド砥粒Ｄの溶着や電着等の塗布方式では、被研磨物によって耐久性上問題があることもあり、基板１１にダイヤモンド砥粒Ｄを混入したメタルボンド製のブロックを、円形や扇状等に成形し貼り付けたものでも、振動や騒音を格段に解消することができる。

【００１７】
ディスク状ダイヤモンド砥石を被研磨物の研磨に用いる際には、基板１１をグラインダ等の回転工具に取り付けて回転させ、被研磨物に研磨チップ１４を押し当てる。この際に、基板１１は柔軟性、屈曲性、強度等に優れた基板１１に支持されつつ、ゴムシート１３がその弾力性を研磨チップ１４に伝えるため、研磨チップ１４はそれぞれ独立に被研磨物の面に沿って研磨できるため、小面積部や曲面においても、優れた研磨を行うことができる。

【００１８】
なお、本実施の形態においては研磨チップ１４はゴム層１３を介して取り付けたが、ゴム層１３を省略して基板１１に直接取り付けてもよい。また、研磨チップ１４は扇状の金属片上にダイヤモンドを散布したが、研磨チップ１４の形状は扇状に限らず、円形やその他の形状でも支障はない。

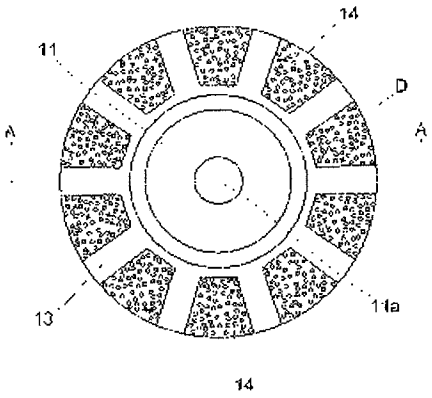
【００１９】
【発明の効果】
以上説明したように本発明に係るディスク状ダイヤモンド砥石は、特に、金属の錆取りや硬質樹脂類、塗料等の研磨・剥離に好適であり、均一な広い面或いは狭い面をも容易に得ることができると共に、打撃音や振動を押さえ、作業者の労務上も、周囲への騒音問題についても、問題が発生することは少ない。

【００２０】
また、可撓性を有するため研磨チップが被研磨面に良く密着し、効率良く剥離作業をうことができる。更に、ダイヤモンド砥粒を溶着法により塗布すれば、電着法のように切れ味があり、メタルボンド法に近い耐久性のあるものとなる。

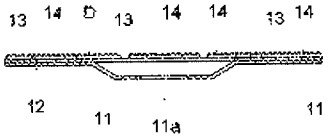
【図面の簡単な説明】
【図１】ディスク状ダイヤモンド砥石の平面図である。
【図２】図１のＡ－Ａ線に沿った断面図である。
【図３】溶着による研磨チップの模式的断面図である。
【図４】メタルボンドによる研磨チップの模式的断面図である。
【図５】電着法による研磨チップの模式的断面図である。

【符号の説明】
１１　基板
１２　ドーナツ状部分
１３　ゴムシート
１４　研磨チップ
Ｄ　ダイヤモンド砥粒
Ｒ　反応層

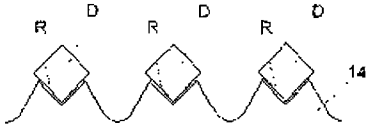
【図１】


14
11
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11a
14

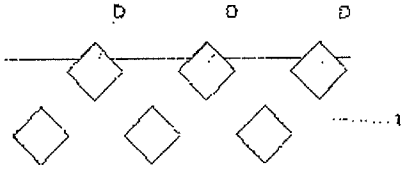
【図２】


13 14 D 13 14 14 13 14
12
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11

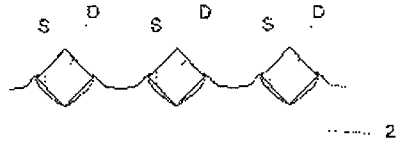
【図３】


R D R D R D
14

【図４】


D D D
1

【図５】


S D S D S D
2

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Reparing and milling device for chemical-mechanical polishing soft pad and its producing method

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Abstract of CN1351922 (A)

The present invention is one kind of chemical and mechanical polishing soft pad trimmer with great amount of uniformly spaced diamonds or isometric boron nitride grains. The granular abrasive is brazed to a substrate and coated with an anticorrosive layer containing diamond or diamond-like graphite to prevent the corrosion of chemical grinding paste to the brazed alloy. The structure makes it possible to trim the soft pad while using the soft pad to polish. In addition, the abrasive grains protruding beyond the substrate in the same height makes the soft pad trimmed homogeneously in both vertical and horizontal directions.

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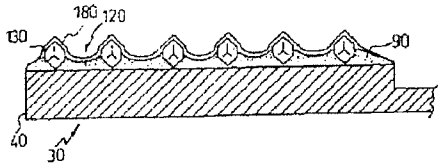
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[54]发明名称 化学－机械抛光软垫的修磨器及其制造方法

[57]摘要

一种化学—机械抛光软垫的修磨器及一种制造这种软垫修磨器的方法，该修磨器表面有大量均匀间隔的磨料颗粒，颗粒质地为金刚石或立方氮化硼等。磨料颗粒钎焊于基底，再覆以一层含有金刚石或仿金刚石石墨的防腐层，以防钎焊料合金受化学研磨膏的腐蚀。这种措施使修磨器得以在软垫进行抛光工作的同时修磨软垫。此外，磨料颗粒还基本等高地突出基底，使垂直、水平两方向均得以均匀地梳理或修磨软垫。



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权 利 要 求 书

1. 一种化学一机械抛光软垫的修磨器，包括尺寸在所需范围内且固接于基底的大量磨料颗粒，其特征在于：磨料颗粒在基底上固接成相互均匀间隔，并以一种预定的高度突出基底。

2. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中磨料颗料为金刚石或立方氮化硼晶体颗粒，单晶或多晶状态不论。

3. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中该尺寸范围为介于 50 至 250 微米之间。

4. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中磨料颗粒尺寸大抵均匀，各颗粒的尺寸差在 10%之内。

5. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中均匀间隔的磨料颗粒依照一种预定图形进行分布，使任何两粒颗粒间保持预定的距离。

6. 根据权利要求 5 的化学一机械抛光软垫的修磨器，其特征在于：其中各颗粒间预定距离为颗粒尺寸的 1.5 至 10 倍。

7. 根据权利要求 5 的化学一机械抛光软垫的修磨器，其特征在于：其中该预定图形为一栅格。

8. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中该预定高度为一均匀高度，对此所有磨料颗粒的突出偏差在 50 微米之内。

9. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中磨料颗粒具有自形的形状。

10. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中磨料颗粒具有预定的形状。

11. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中磨料颗料具有背向基底的尖点。

12. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中基底由金属材料制成。

13. 根据权利要求 12 的化学一机械抛光软垫的修磨器，其特征在于：其中金属材料为不锈钢。

14. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中磨

料颗粒藉助于钎焊料合金固定于基底上。

15. 根据权利要求 14 的化学一机械抛光软垫的修磨器，其特征在于：其中该钎焊料合金包括一种铬含量至少约为 2%重量百分比的镍合金。

16. 根据权利要求 14 的化学一机械抛光软垫的修磨器，其特征在于：其中该钎焊料合金以一种预定的厚度覆于基底的表面，并使各磨料颗料约有 10—90%露出。

17. 根据权利要求 1 的化学一机械抛光软垫的修磨器，其特征在于：其中该软垫修磨器覆以一防腐层。

18. 根据权利要求 17 的化学一机械抛光软垫的修磨器，其特征在于：其中该防腐层含有金刚石的石墨。

19. 根据权利要求 17 的化学一机械抛光软垫的修磨器，其特征在于：其中该防腐层含有仿金刚石的石墨。

20. 根据权利要求 17 的化学一机械抛光软垫的修磨器，其特征在于：其中防腐层的厚度约小于 3 微米。

21. 根据权利要求 18 的化学一机械抛光软垫的修磨器，其特征在于：其中仿金刚石的石墨的原子碳含量至少约为 95%。

22. 一种制造化学一机械抛光软垫修磨器的方法，其诸步骤包括 a ）提供一基底，其特征在于：该法的步骤还包括：

b ）于基底的某一表面均匀地间隔大量磨料颗粒，以及

c ）将磨料颗料固定于基底成，使各磨料颗粒以一种预定的高度突出基底。

23. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中磨料颗粒为金刚石。

24. 根据权利要求 22 所述的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中磨料颗粒为立方氮化硼质地的晶体颗粒，单晶或多晶不论。

25. 根据权利要求 22 所述的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中步骤 b ）与 c ）尚包括下列步骤：

a ）将一形成有预定孔图形的模板置于一钎焊料合金片上，使磨料颗粒的放置可受孔位置的控制，

b ）于模板的各孔内充填磨料颗粒，

c ）去除任何未进入模板孔内的磨料颗粒，

d ）将滞留于模板孔内的磨料颗粒压入钎焊料合金片中，使磨料颗粒部份埋

置于钎焊料合金内，

e）除去模板，使磨料颗粒留在钎焊料合金片上，以及

f）使带磨料颗粒的钎焊料合金片固接于基底。

26. 根据权利要求 25 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中各孔的尺寸为仅足以容置一粒磨料颗粒。

27. 根据权利要求 26 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中各孔具有预定的尺寸，可容纳预定尺寸的磨料颗粒。

28. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中该等磨粒颗的尺寸各在大约 50 至 250 微米的范围内。

29. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中磨料颗粒的尺寸大致均匀，使所有磨料颗粒的尺寸差在 10%之内。

30. 根据权利要求 25 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中成预定图形的各孔之间间隔成足以在任何两粒颗粒间产生预定的距离。

31. 根据权利要求 30 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中各颗粒间该预定的距离为颗粒尺寸的 1.5 至 10 倍。

32. 根据权利要求 25 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中该预定图形为一栅格。

33. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中该高出基底的预定高度为一均匀高度，对此所有磨料颗粒的突出偏差在 50 微米之内。

34. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中磨料颗粒具有自形的形状。

35. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中磨料颗粒具有一种预定的形状。

36. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中各磨料颗料具有一背向基底的尖点。

37. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中基底由金属材料制成。

38. 根据权利要求 37 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中该金属材料为不锈钢。

39. 根据权利要求 25 的化学一机械抛光软垫修磨器的制造方法，其特征在于：

其中钎焊料合金片的制造步骤为：以一种有机结合剂将钎焊料合金颗粒结合在一起，并使这些相结合的颗粒形成一片厚度符合需要的片体。

40. 根据权利要求 39 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中使钎焊料合金颗粒形成片体的步骤为经滚轧法进行。

41. 根据权利要求 39 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中使钎焊料合金颗粒形成片体的步骤为经挤压法进行。

42. 根据权利要求 39 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中使钎焊料合金颗粒形成片体的步骤为经带条铸造法进行。

43. 根据权利要求 25 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中钎焊料合金包括一种铬含量至少约为 2%重量百分比的镍合金。

44. 根据权利要求 25 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中钎焊料合金片具有隆起的钎焊厚度，足以让各磨料颗粒约 10—90%露出钎焊料合金。

45. 根据权利要求 22 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中尚括包括一步骤：即对磨料颗粒以及钎焊料合金覆以一防腐层。

46. 根据权利要求 45 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中该防腐层含有金刚石的石墨。

47. 根据权利要求 45 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中该防腐层含有仿钻石的石墨。

48. 根据权利要求 45 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中防腐层的厚度小于约 3 微米。

49. 根据权利要求 45 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中仿金刚石的石墨的原子碳含量至少约为 95%。

50. 根据权利要求 49 的化学一机械抛光软垫修磨器的制造方法，其特征在于：其中该覆层步骤是使用阴极电弧法进行。

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说　明　书

化学一机械抛光软垫的修磨器及其制造方法

本发明涉及一种修磨或调理化学一机械抛光软垫的修磨器及其方法，特别是一种含有超硬材料（如金刚石或立方氮化硼）、供修磨或调理化学一机械抛光软垫的修磨盘。

许多任务业今使用化学一机械方法抛光某些工件。尤其是计算机制造业已充分依靠化学一机械抛光法来抛光陶、硅、玻璃、石英以及金属质的芯片。这种抛光方法通常需要将芯片压于一由耐用的有机物质，如聚亚胺脂制成的旋转软垫上。并对该软垫添加一种研磨膏，内含可切削芯片物质的化学品，以及一定量的磨料颗粒，其作用是以物理方法刻蚀芯片表面。研磨膏持继地加于旋转中的软垫上，而得以有双重的化学兼机械力施加于芯片上，使之以所需的方式抛光。

对所产生的抛光品质尤为重要的，乃是软垫各处磨料颗粒的分布状况。软垫的顶部通常藉空穴之类卡持颗粒。挠性的软垫顶部可提供所需的支承，让磨料得以作用于芯片。

对软垫顶部进行保养，此问题归因于来自工件、研磨膏、以及修磨盘的抛光污腻的堆积。这种堆积会造成软垫顶部的发亮或硬化，使软垫不太能吸附研磨膏中的磨料颗粒。

因此，人们已作出诸多尝试，以各种装置“梳理”软垫顶部来修复，此法现已称之为“修磨”或“调理”化学一机械抛光软垫。为此，已使用多种装置及方法。这些装置中的一种为一圆盘，其表面或基底上固定大量的超硬晶体颗粒，例如固接于其某一表面或基底上的金刚石颗粒。

但是，这种由传统方法制成的金刚石盘表现出种种问题。首先，金刚石会自该盘的基底上脱落并沾附在化学一机械抛光软垫表面。其次，此种旧式生产方法有可能使生产出的圆盘上金刚石成多组簇集，即非均匀地散布于基底的表面。这种非均匀的成组现象，使该软垫的某些部位被过度修磨，造成磨损区域，而其它部位修磨不足，造成光亮层。另一种情况是，软垫的抛光效率降低，并出现抛光不匀现象。最后，这些圆盘的金刚石不能以一种均匀的高度突出圆盘表面。这种非均匀性又造成对该软垫的不均匀修磨，因为仅是那些足够突出的颗粒方可接触

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软垫。

金刚石自圆盘基底脱落，是因为它们被固接的方法不当。当金刚石是由电镀的镍加以固定于基底上时，无结合力惟有对金刚石的机械锁紧作用。因此一旦摇松，这些颗粒即会脱落。此种脱落现象又因化学品，即化学研磨膏中的酸对电镀材料的化学侵蚀而加剧。

另一方面，当金刚石是钎焊于基底上时，化学力会更牢固地固定金刚石。然而，化学研磨膏的酸性会快速溶化钎焊料而使金刚石脱落。因此，为使钎焊料曝露于化学品的程度降至最小，抛光过程需时时暂停，期间进行修磨，而后方可再度开始抛光。这种依次交替地抛光与修磨，浪费大量时间，而且极度低效。

鉴于上述，故需要一种可对化学一机械抛光软垫提供调理作用的软垫修磨器。此外，非常需要一种可将化学一机械抛光软垫调理至均匀深度的软垫修磨器。再者，很需要一种不易使金刚石颗料脱落的修磨器。最后，极需要一种可防化学研磨膏的酸性侵蚀，而且甚至可在以酸性研磨膏进行抛光的同时，连续修磨化学一机械抛光软垫的软垫修磨器。

本发明的目的是提供一种使用磨料颗粒来均匀修磨化学一机械抛光软垫的软垫修磨器。

本发明的另一目的是提供一种不易让磨料颗粒脱落的软垫修磨器。

本发明的又一目的是提供一种防腐的软垫修磨器，使之可以恒定地修磨化学一机械抛光软垫，纵然该软垫正于酸性研磨膏中进行研磨时亦然。

本发明的再一目的提供一种化学保持层，以防修磨盘元素溶解而污染研磨中的芯片。

本发明的另一目的是提供一种均匀修磨化学一机械抛光软垫的方法。

本发明的又一目的是提供一种方法，以降低软垫修磨器的磨料颗粒脱落的可能性，纵然当该软垫浸润酸性研磨膏时亦然。

按照本发明的一个方面，本发明的技术方案在于提供一种化学一机械抛光软垫的修磨器，其包括尺寸在所需范围内且固接于基底的大量磨料颗粒。其特点在于：磨料颗粒在基底上固接成相互均匀间隔，并以一种预定的高度突出基底。

而且，上述的修磨器上还可覆以一防腐层。

按照本发明的另一方面，本发明的技术方案在于提供一种制造上述修磨器的方法，其诸步骤包括：

a）提供一基底；b）于基底的某一表面均匀地间隔大量磨料颗粒；以及，

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c）将磨料颗料固定于基底成，使各磨料颗粒以一种预定的高度突出基底。

而且，上述方法还可包括一步骤：即对磨料颗粒以及钎焊料合金覆以一防腐层。

本发明与已有技术相比优点和积极效果非常明显。由以上的技术方案可知，本发明的软垫修磨器可均匀地修磨抛光软垫，而且磨料颗粒不易脱，特别是可以在软垫进行抛光的同时，对软垫进行修磨，从而大大提升软垫的工作效率，并延长其使用寿命。

以下结合附图进一步说明本发明的具体结构特征及目的。其中，诸附图为：

图 1 是一种现有的软垫修磨器的侧视图，该修磨器使用电镀法将金刚石固定于盘状基底上。

图 2 是另一种现有的软垫修磨器的侧视图，该修磨器经使用传统钎焊法将金刚石颗粒固定于盘状基底上而制成。

图 3 是本发明的软垫修磨器的侧视图。

图 4 是本发明的钎焊料合金片，以及将磨料颗粒置于其表面的模板的侧视图。

图 5 是钎焊料合金片表面覆以模板，且磨料颗粒充填该模板的各孔的侧视图。图中显示依照本发明的原理，有一平面将磨料颗料压入钎焊料合金片。

图 6 是钎焊料合金片中已依据本发明的原理压入磨料颗粒的侧视图。

图 7 表示了作为本发明实例一制作的两个软垫修磨盘对一个 28 英寸的化学一机械抛光软垫进行修磨的情况。

图 8 表示了作为本发明实例二制作的两个金刚石修磨盘修磨一个用于研磨 8 英寸硅芯片的化学一机械抛光软垫的情况。

请注意，在说明书及权利要求书中，下列技术术语使用时将依照以下提出的定义。如文中所使用的“磨料颗粒”或“砂粒”，或者相似的词，表示任何超硬质的晶体或多晶体物质，或者这些物质的混合物，而且包括（但不限于）金刚石、多晶体金刚石、立方氮化硼、以及多晶体立方氮化硼。再者，“磨料颗粒”、“砂粒”、“金刚石”、“多晶体金刚石”、“立方氮化硼”、以及“多晶体立方氮化硼”等各词可互换使用。如文中所使用的“基底”，表示修磨器中表面可固定磨料颗粒的基础部份。该基础部份可为任何形状、厚度、或者材料，而且包括（但不限于）金属、合金、陶瓷及其混合物。如文中所使用的“自形”，表示自然形状，即未被人为变更的天然形状。如文中所使用的“尖锐点”，表示晶体中可能出现的任何尖狭顶峰，而且包括（但不限于）角、棱、尖峰以及其它突起。如文中所使用的“金属”，表

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示任何类型的金属、金属合金、或者它们的混合物，尤其包括（但不限于）钢、铁、以及不锈钢。

现参阅图 1，图中显示一现有的软垫修磨器 10，该修磨器中有大量金刚石颗粒 50 电镀于一基底 40。电镀材料 60 通常为经酸液沉淀而出的镍。这种电镀法不仅成本高且费时，而且亦因该法所产生的残留物质而对环境有害。

由图 1 可看出，电镀而成的软垫修磨 10 有许多缺点。首先，电镀材料 60 不能与金刚石颗粒 50 形成任何化学结合。因此，仅有微弱的机械力将金刚石颗粒 50 固定于基底 60 上。当该软垫修磨器压在化学一机械抛光软垫上旋转时，这种机械力会被作用于金刚石颗粒 50 上的较大摩擦力快速克服，使之易于自电镀材料 60 松落，于电镀材料 60 上留下孔穴，例如空隙 70。此种孔穴会被快速充填以工件上磨下的残留物，以及来自研磨膏的化学品及磨粒颗粒，为此进一步削电镀材料 60。由于电镀材料 60 所产生的机械力是唯一将金刚石颗粒 50 固定于基底 40 上的手段，使金刚石颗粒 50 露出电镀材料的高度必须保持最小。因此，电镀材料 60 与化学一机械抛光软垫的接触不可避免。这种接触会磨损电镀材料，而易使金刚石颗粒 50 脱落。此外，电镀材料 60 易在各金刚石 50 四周的凹部 80 等处起泡。这些气泡，加之过低的露出高度以及金刚石颗粒 50 间的紧密间距，即使能也难以使金刚石颗粒 50 深深戳入软垫纤维。无此种戳入，则对修磨过程大为有碍。

现参见图 2，图中显示现有的软垫修磨器 20，其基底 40 有金刚石颗粒 50 用钎焊材料 190 及传统的钎焊技术钎焊于基底 40。钎焊材料通常含有一种混以碳化物形成元素的合金。这种碳化物形成元素可让金刚石颗粒 50 得以以化学方式结合于钎焊料，后者则进而结合于基底 40。这种结合方式可大为增加修磨器 20 的强度，但会伴随某些副作用。钎焊材料 90 必须保持最低之量，以免完全覆盖金刚石颗粒 50。因此，金刚石颗粒 50 仅被包以薄薄一层钎焊材料 90。此问题偏遇典型的钎焊材料机械性能非常弱。这种机械性能的弱抵销了金刚石颗粒 50 与钎焊材料间的化学结合强度，因为钎焊材料本身会随金刚石颗粒的脱落而被割断。

另一个与钎焊材料 90 有关的问题是，其非常易受研磨膏的化学腐蚀。这种化学腐蚀会促成金刚石颗粒 50 的脱落，因为其使原已机械性能弱的钎焊材料 90 变得更弱。因此，为减少软垫修磨器 20 接触化学研磨膏的时间，软垫修磨器 20 应用前，对工件的抛光必须暂停，而让化学研磨膏得离软垫而去。这种抛光过中的暂停使精加工产品的时间大为增加，因而低效。

传统钎焊法的另一缺点为，当加诸于基底 40 时，融熔状金属合金的表面张

力易使磨料颗粒聚集成簇状。此种簇状标以 100，间隔为 110。其总体表现为金刚石颗粒 20 的非均匀分布，为此使调理效率较低。此低效率应当归因于间隔 110，因为其使化学一机械抛光软垫的部份区域依然保持为未调理前的状态。这种非均匀的调理使软垫的一部份区域磨损较他处快，总体结果为工件接受一种非均匀的抛光，因为已磨损的区域抛光效率低于经正确调理的区或。

磨料颗粒的簇状所产生的另一效应，是会于钎焊材料 90 中形成大量隆起。隆起的形成会提升某些磨料颗粒相对基底 40 的高度，使之高于其它磨料颗粒。因此，最高凸的磨料颗粒会深深戳入软垫的纤维，妨碍不甚高凸的磨料颗粒发挥任何梳理作用。此举亦造成调理效果的低效与不合理。

与现有的软垫修磨器相反，本发明得以均匀地修磨化学一机械抛光软垫。

现参见图 3，图中显示一以本发明原理制成的软垫修磨器。该软垫修磨器有大量磨料颗粒 180 以钎焊材料 90 固定于一基底 40。磨料颗粒 180 可为任何超硬质的材料。较佳的材料包括（但不限于）金刚石、多晶体金刚石、立方氮化硼以及多晶体立方氮化硼。

同时示于图 3 的，为一防腐层 130。此防腐层形成于软垫修磨器表面之前，磨料颗料先以下述方法固定于基底 40 上。防腐层 130 为另一种超硬质材料，如金刚石、仿金刚石的石墨、或者立方氮化硼，而且是可以匹配磨料颗粒 180 的材料。在一较佳实施例中，防腐层 130 约含有至少为 90－95%的金刚石，或者仿金刚石的石墨。防腐层 130 可为任何厚度，但通常在 0.5 至 5μm的范围内。在一较佳实施例中，防腐层 130 的厚度约为 1 至 3μm。这种防腐薄层 130 可采用物理气相淀积法（PVD）产生。物理汽相淀积法，如使用石墨电弧及石墨阴极的，已为业界所知，而且可用以产生防腐层 130。

由防腐层 130 产生的优点是可有效密封工件表面，而且也可密封化学一机械抛光软垫上易受化学侵蚀的其它所需表面。作为密封层，防腐层 130 可保护钎焊材料 90，使之免受沾于该软垫上的化学研磨膏的侵蚀。这种保护作用甚至于软垫正研磨工件之时，让软垫修磨器 30 得以连续修磨该软垫，从而可消除过去用以延长现有软垫修磨器寿命的生产停顿。对化学一机械抛光软垫的连续与均匀修磨，使得可有较高的产量，并且可延长该软垫的寿命与效率。

图 4 至 6 显示一种将磨料颗粒 180 固定于基底 40 上的方法。首先，将具有大量孔 150 的模板 140 置于钎焊料合金片 190 上。使用该模板可让磨料颗粒 180 的放置得以通过将模板的各孔设计成所需的分布图形而加以控制。用于磨料颗粒

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放置的分布图形，可由熟悉该项技术的普通技术人员加以选定，以满足该软垫修磨器的特定使用要求。

作为本发明的一个方面，这些孔的分布将呈一种栅格图形，且孔距预定为可使钎焊料合金片 190 上的磨料砂粒 180 间产生所需的间隔。在一较佳实施例中，该等砂粒均匀间隔，间距为各砂粒尺寸的 1.5 至 10 倍。当模板 140 置于钎焊料合金片 190 后，各孔 150 即被充填以磨料颗粒 180。孔 150 有预定的尺寸，使各孔中仅可容纳一粒磨料颗粒。任何尺寸的磨料颗粒或砂粒均可使用，但作为本发明的一个方面，颗粒尺寸为直径约 50 至 250 微米之间。

作为本发明的另一方面，模板中各孔的尺寸也可定制，以使所获得分布图形为令各磨料颗粒尺寸不一，或者尺寸大抵均一。在一较佳实施例中，该模板的各孔为足以仅选择相互尺寸差在 10%微米内的砂粒。这种砂粒尺寸的均匀性有助于对化学一机械抛光软垫梳理的均匀性，因为各磨粒颗粒的工作负荷均匀分布。进而，该均匀的工作负荷分布可减小各磨料颗粒的应力，而延长软垫修磨器 30 的有效寿命。当模板 150 的各孔被充填以砂粒 180 后，将任何多余的磨料颗粒除去，并将平面 160 加诸于磨料颗粒 180。平面 160 必须是质地为极强固的刚性材料，因为其必须能将磨料颗粒 180 下压至钎焊料合金片 190 内。典型材料包括（但不限于）钢、铁，以及它们的合金等。

图 6 显示磨料颗粒 180 埋置于钎焊料合金片 190 中。由于表面 160 为平面状，故磨料颗料 180 以一种均匀的距离突出基底 40。这种距离取决于模板 140 的厚度，并且在较佳实施例中，各磨料颗粒将突出成使此距离在 50 微米之内。

图 4 至 6 中所示的磨料颗粒为圆形，而图 3 中的为尖形。本发明的范围包罗任何形状的磨料颗粒，包括自形即天然形状的颗粒。不过在较佳实施例中，磨粒颗粒 180 有一背向基底 40 的尖点。

当磨料颗粒 180 埋置于钎焊料合金片 190 中后，即可将该片固定于基底 40，如图 3 所示。所使用的钎焊料合金可为业内所知的任何钎焊材料，但最好为镍合金，且铬含量大于 2%重量百分比。此种成份的钎焊料合金自身质地超硬，而且不易受内含磨料的研磨膏的化学侵蚀。因此，当使用一种超硬的钎焊材料时，防腐层 130 为最佳。

由于磨料颗料 180 埋置于钎焊料合金片 190 中，故液态钎焊料合金的表面张力不足以使颗粒簇集。此外，钎焊料厚度以远为薄的程度出现，且无隆起形成。再者，钎焊料于各磨料颗粒间形成一种凹面，为此提供强大支承。最后，在较佳

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实施例中，钎焊料合金片 190 的厚度选定成可让各磨料颗粒有大约 10 至 90%突出钎焊材料 190 的外表面。

由于本法先将磨料颗粒埋置于钎焊料合金片 190 内之故，遂形成均匀的间隔。此外，磨料颗粒 180 可突出基底 40 均匀的高度或距离，此举意味着当应用于化学一机械抛光软垫时，它们将突入软垫纤维内同一深度。均匀的间隔及匀一的突入使软垫得以被均匀地修磨或梳理，进而提升该软垫的研磨效率并延长其使用寿命。

为便于更好地理解本发明，以下将提供两实例。不过这些实例绝非意味着用作限制本发明的范围。

〔实例 1〕

以下制作两个软垫修磨盘。即通过滚轧金属粉末混合物以及两轧辊间的有机结合剂，预制一钎焊料合金片。再藉助于一模板，将通用电子公司(General Electric Company)生产、平均尺寸为 135 及 225 微米的 MBS970 号金刚石砂粒埋入该钎焊料合金片。所使用的模板使金刚石砂粒形成一种令各金刚石砂粒距离为 900 微米的栅格图形。当金刚石砂粒置入钎焊料合金片后，采用丙烯酸凝胶将该片胶合于一金属基底。所形成的组件随后于真空炉内 1000° 的温度下进行钎焊。所产生的产品为两个直径约 100 毫米、厚度约 6.5 毫米的平盘。再将两盘与一个以随机方式放置两倍金刚石颗粒量的修磨盘进行对比试验。具体为修磨一个 28 英寸的化学一机械抛光软垫（该软垫以碱性研磨膏研磨 8 英寸的硅芯片）。试验结合显示在图 7 中。表中 DG135－900 是颗粒为 135 微米的盘，而 DG225 是颗粒为 225 微米的盘。

由图 7 可看出，颗粒均匀放置的两盘均大大优于金刚石随机放置的盘。此外，颗粒为 135 微的盘，性能几乎高达该随机颗粒盘的两倍。

〔实例 2〕

以实例 1 的方法再制两金刚石修磨盘。不过，金刚石尺寸采用 225 微米及 275 微米。此外，各盘覆以 1 微米厚的仿金刚石的石墨层，以保护钎焊料合金。仿金刚石的石墨膜以阴极电弧法加以沉积。这些盘然后与一传统的金刚石修磨盘进行比较，具体方法是修磨一个用于研磨 8 英寸硅芯片的化学一机械抛光软垫。该软垫浸润 P H值为 3.0 的酸性研磨膏。修磨过程于研磨进行的同时就地完成。其结果显示在图 8 内。表中 DG275－900 是含有尺寸为 275 微米且均匀间隔的砂粒的盘。DG225－900 是含有尺寸为 225 微米且均匀间隔的砂粒的盘，而 A T 是该传统式金刚石盘。

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由图 8 可看出，以传统方式生产出的金刚石盘，于研磨膏的酸性环境中不能保持 1 小时以上。然而，本发明的两盘可保持 30 小时以上。这种寿命期使得有大为良好的修磨效果，并且对现有技术构成重大改进。当然，应理解上述实施例仅是对应用本发明原理的例示性说明。

熟悉这项技术的人员自可在不偏离本发明范围的条件下，设计出大量的变形形态及变更形态，本案附录的权利要求意在涵盖这种变形形态能及变更形态。因此，尽管以上本发明已结合目前看最实用且最佳的本发明实施例，以特列情形加以详细描述，然对熟悉该项技术的普通人士而言，可在不偏离本文中所提出的原理及概念的条件下作出大量变形形态，包括（但不限于）在尺寸、材料、形状、形式、功能、操作方式、组合以及使用方面的变更。

说 明 书 附 图

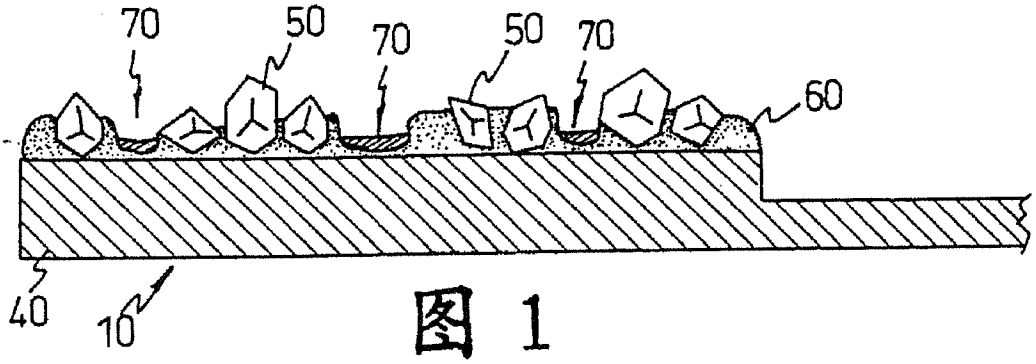


图 1

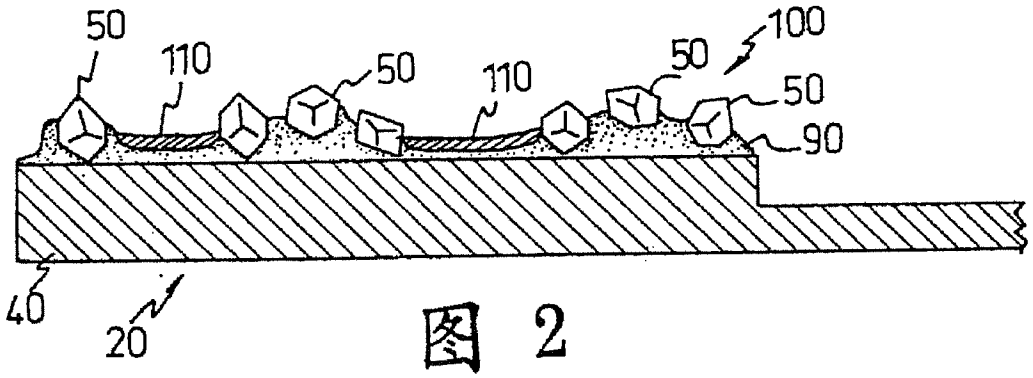


图 2

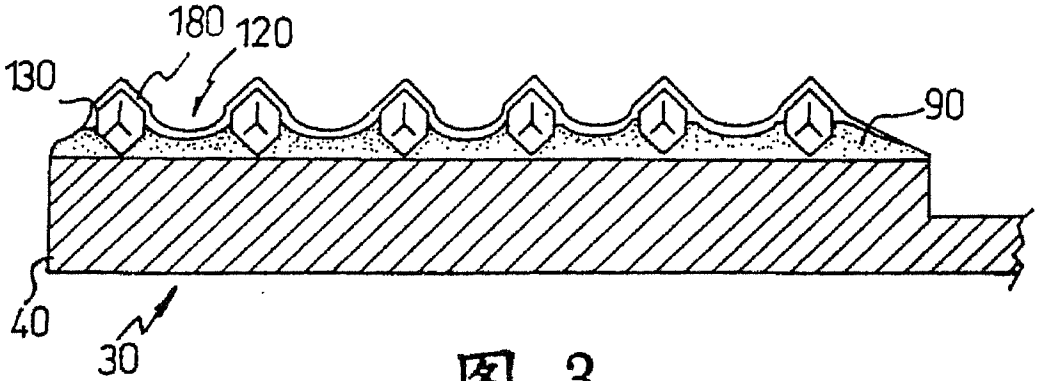


图 3

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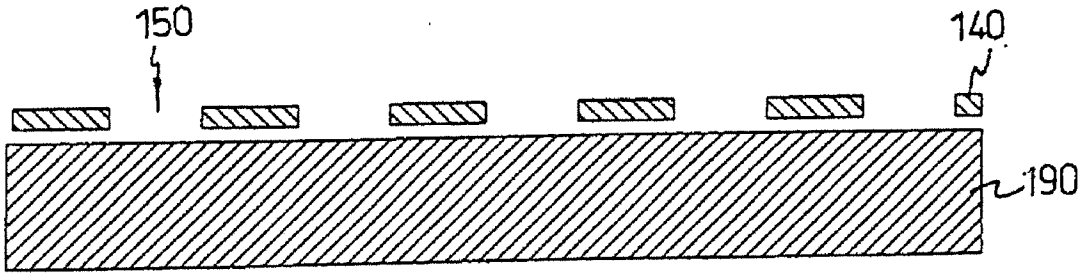


图 4

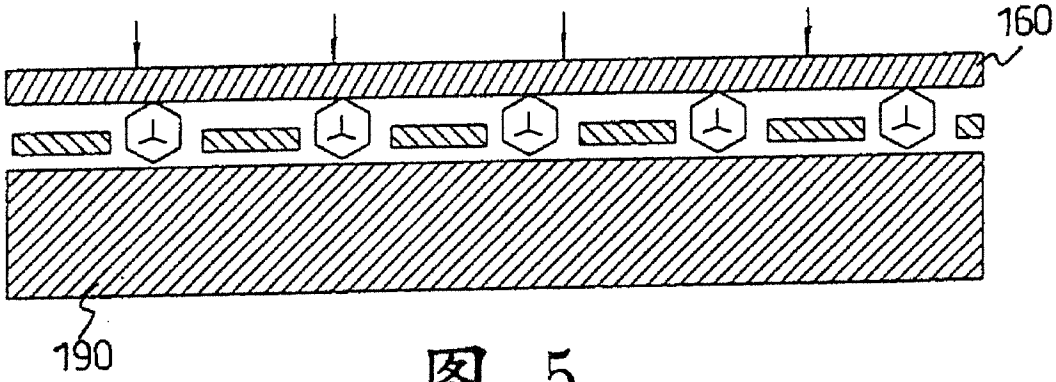


图 5

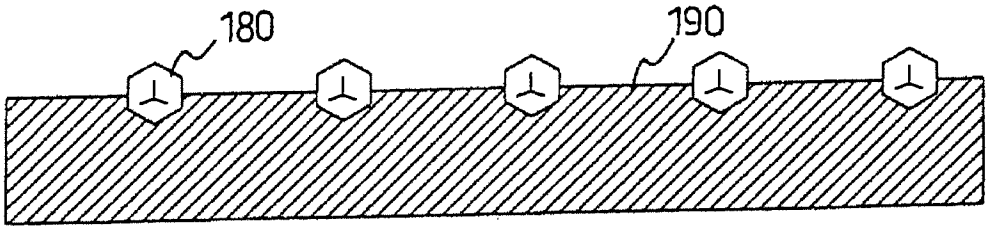


图 6

Ex. 1003, Page 530

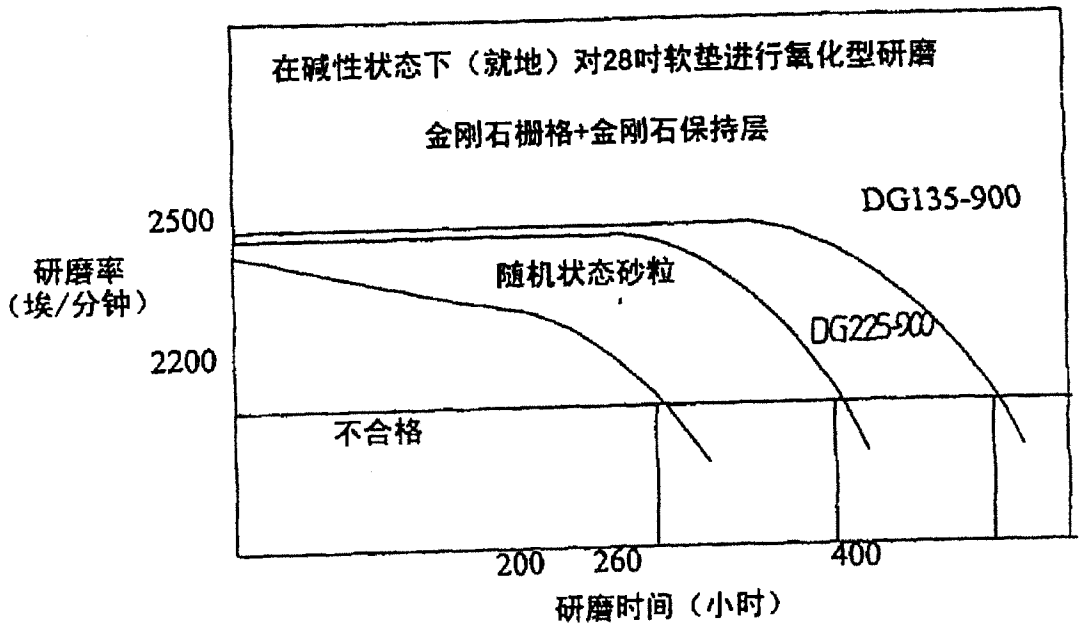


图　7

Ex. 1003, Page 531

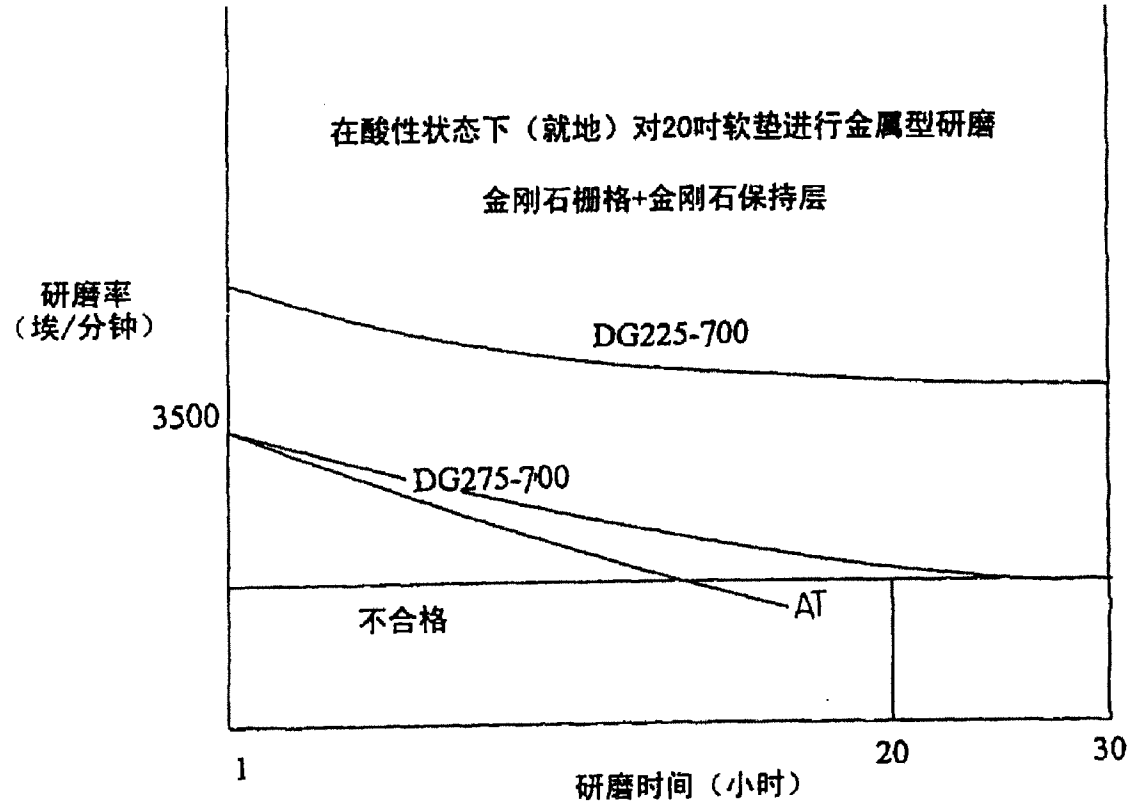

在酸性状态下（就地）对20吋软垫进行金属型研磨
金刚石栅格+金刚石保持层
研磨率
（埃/分钟）
3500
DG225-700
DG275-700
AT
不合格
1
20
30
研磨时间（小时）

图 8

Espacenet

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기술평가청구 : 없음

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요약

본 고안은 화학적-기계적-연마(CMP)용 폴리싱 패드의 평탄화를 향상시킴과 동시에, 이 패드의 컨디셔닝을 효과적으로 행하는 기능을 가지고, 더구나 컨디셔닝 성능이 우수하고, 수명이 길며, 컨디셔너의 제조가 용이하여 제조시의 불량률을 현저히 감소시킬 수 있는 CMP 장치용 컨디셔너를 제공함에 그 목적이 있다.

이러한 목적을 달성하기 위한 본 고안은, 샹크(3)의 표면에 구멍 형상의 비마스킹부(1)를 가지는 마스킹 시트(2)를 점착하고, 하나의 비마스킹부(1)에 하나의 다이아몬드 입자(4) 만을 예비 고정한 후에 마스킹 시트(2)를 박리시키고, 이어서 도금액 안에 넣어서 다이아몬드 입자 직경의 40~60% 정도의 두께를 가지도록 Ni 도금층(6)을 석출시키며, 더욱이 1개 구멍 형상의 비마스킹부(1)의 면적이 다이아몬드 입자(4)의 투영 면적의 110~160%배로 하고, 상기한 마스킹 시트(2)의 비마스킹부(1)의 전면적이 바스킹 시트(2)의 전면적의 0.04~0.2배의 범위로 하는 것이 특징으로 된 화학적-기계적-연마 패드용 다이아몬드 전착 컨디셔너를 제공한다.

본 고안에 의해 치수 정밀도가 엄격한 패턴 형상을 재현성 높게 용이하게 형성시킬 수 있고, 마스킹 시트(2)의 샹크(3)에 대한 밀착력이 높으며, 또한 샹크(3)에 전착되는 80~120메쉬의 다이아몬드 입자(4)가, 구멍형의 비마스킹부(1)에 한 개씩 분산된다. 따라서 CMP용 폴리싱 패드의 평탄화를 향상시킴과 동시에, 이 패드의 컨디셔닝을 효과적으로 행하는 기능을 가지고, 더구나 컨디셔닝 성능이 우수하고, 수명이 길며, 컨디셔너의 제조가 용이하기 때문에 제조시의 불량률을 현저히 감소시킬 수 있다.

대표도

도 1

색인어

화학적-기계적-연마, 패드, 컨디셔너, 폴리싱, 다이아몬드

명세서

도면의 간단한 설명

도 1은 마스킹 시트를 점착한 샹크의 부분 평면도

도 2는 다이아몬드 입자가 예비 고정된 샹크의 부분 평면도

도 3은 본 고안 컨디셔너의 연삭면의 부분 단면도

도 4는 본 고안에 의한 일실시예인 컨디셔너의 작용면의 평면도

도 5는 본 고안에 의한 다른 실시예인 컨디셔너의 작용면의 평면도

〈도면의 주요부분에 대한 부호의 설명〉

1 : 구멍형상의 비마스킹부 2 : 마스킹 시트

3 : 샹크 4 : 다이아몬드 입자

5 : 예비 도금층 6 : Ni 도금층

7 : 컨디셔너 8 : 비전착 영역

고안의 상세한 설명

고안의 목적

고안이 속하는 기술 및 그 분야의 종래기술

본 고안은 반도체의 웨이퍼 가공에 사용되는 CMP(Chemical mechanical planarization) 장치의 패드 컨디셔너에 관한 것이다. 보다 상세하게는, 본 고안은 CMP용 폴리싱 패드의 평탄화를 향상시킴과 동시에, 이 패드의 컨디셔닝을 효과적으로 행하는 기능을 가지고, 더구나 컨디셔닝 성능이 우수하고, 수명이 긴 CMP 장치용 컨디셔너에 관한 것이다.

반도체 웨이퍼의 연마를 반복하기 위하여, 연마 입자나 연마칩 등이 폴리싱 패드의 미세한 구멍에 들어가서 눈메움이 일어난다든지, 연마 입자와 웨이퍼와의 화학 반응열에 의해 폴리싱 패드의 표면이 경면화하여 연마 속도를 저하시키게 된다. 이 때문에 폴리싱 패드의 표면을 재생시켜 연마 속도를 회복시키는 컨디셔너라고 불리는 공구가 사용된다. 다이아몬드 입자는 우수한 컨디셔닝 재료이며, 다이아몬드 입자를 이용한 컨디셔닝이 실용화되어 있다. 이와 같은 CMP용 폴리싱 패드의 컨디셔너에 대해서는, 폴리싱 패드의 마멸을 가급적 억제할 수 있으며, 더욱이 패드의 표면 상태를 항상 소정의 연마속도가 얻어지도록 일정하게 유지되는 것과, 다이아몬드 입자의 탈락이 없고, 패드면에 눈메움을 일으키지 않는 것이 요구된다.

다이아몬드 입자를 컨디셔너 본체의 작용면에 금속 결합제를 사용하여 고착하는 방법에는 여러 가지가 있으나, 전착법은 비교적 용이하고 더욱이 다이아몬드 입자를 컨디셔너 본체의 작용면에 확실하게 고착시킬 수 있으므로 많이 사용되고 있다. 전착법에 의해 다이아몬드 입자를 고착하는 경우는, 컨디셔너 본체의 작용면에 다이아몬드 입자의 고정면을 남겨 두고서, 절연성의 마스킹 재료로 피복한다. 컨디셔너의 본체를 도금액에 담그고 입자 고정면에 입자를 놓고서 컨디셔너의 본체에 음극을 접속하고, 도금액에 양극을 접속하여 전기 도금을 행하여 다이아몬드 입자를 예비 고정한다. 다이아몬드 입자를 예비 고정한 후에 대부분의 입자는 그 일 부가 본체의 입자 고정면에 접한 상태에서 예비 고정되지만, 본체의 입자 고정면에 접하지 않은 상태에 부착하여, 부유하는 입자가 존재하는 경우도 있다. 컨디셔너의 본체를 다시 도금액에 넣어서, 본체에 음극을 접속하고 도금액에 양극을 접속하여 다이아몬드 입자 고정면의 도금을 행한다.

그러나 종래의 전착 숫돌의 제조에 있어서, 컨디셔너 본체의 작용면에 다이아몬드 입자의 고정면을 남겨 두고서, 절연성의 마스킹 재료로 피복하는 경우에 미세한 크기의 적절한 치수 정밀도로 피복하는 것이 곤란하여 마스킹 되어 있지 않은 곳에 두 개 이상의 다이아몬드 입자가 동시에 들어가는 문제가 발생하였고, 마스킹 위치가 어긋나서 동일한 형상으로 재현하는 것이 곤란하였고, 피복층이 평활하게 되지않고 요철(凹凸)이 심하였으며, 피복층의 밀착력이 약하여 이후에 공정에서 벗겨지는 경우가 있었기 때문에, CMP 패드를 컨디셔닝 하는데 있어서 불량률이 매우 높았다. 또한 종래의 컨디셔너는, 패드의 표면 상태를 항상 소정의 연마속도가 얻어지도록 일정하게 유지시키는 것이 곤란하였으며, 다이아몬드 입자의 탈락이 많고, 패드면에 눈메움을 일으키는 경우가 많았으며, 종래의 컨디셔너를 사용하여 패드를 컨디셔닝하면, 웨이퍼의 표면거칠기 값 및 스크래치 개수가 높은 것이 큰 문제로 되어왔다.

고안이 이루고자 하는 기술적 과제

본 고안은 CMP용 폴리싱 패드의 평탄화를 향상시킴과 동시에, 이 패드의 컨디셔닝을 효과적으로 행하는 기능을 가지고, 더구나 컨디셔닝 성능이 우수하고, 수명이 길며, 컨디셔너의 제조가 용이하여 제조시의 불량률을 현저히 감소시킬 수 있 는 CMP 장치용 컨디셔너를 제공함에 그 목적이 있다.

고안의 구성 및 작용

본 고안자들은, 상기의 과제를 해결하기 위하여 실험적인 연구를 거듭한 결과, 전착 컨디셔너의 연삭면에 있어서, 하나의 비마스킹부에 한 개씩의 다이아몬드 입자를 분산시키는 것에 의해, 연삭 저항을 감소시키고 컨디셔너의 수명이 증가되며, 연마속도비와 컨디셔닝 속도가 높아지며, 웨이퍼의 표면거칠기 값이 낮아지며, 웨이퍼의 스크래치 개수가 감소됨을 확인하였다. 즉, 본 고안은, 샹크(3)의 표면에 구멍 형상의 비마스킹부(1)를 가지는 마스킹 시트(2)를 점착하고, 하나의 비마스킹부(1)에 하나의 다이아몬드 입자(4) 만을 예비 고정한 후에 마스킹 시트(2)를 박리시키고, 이어서 도금액 안에 넣어서 다이아몬드 입자 직경의 40~60% 정도의 두께를 가지도록 Ni 도금층을 석출시키며, 더욱이 1개의 구멍 형상의 비마스킹부(1)의 면적이 다이아몬드 입자(4)의 투영 면적의 110~160%배로 하고, 상기한 마스킹 시트(2)의 비마스킹부(1)의 전면적이 마스킹 시트(2)의 전면적의 0.04~0.2배의 범위로 하는 것이 특징으로 된 화학적-기계적-연마 패드 컨디셔너를 제공하는 것이다.

아래에, 도면을 참고하여 본 고안을 상세히 설명한다. 그림 1은 마스킹 시트(2)를 점착한 샹크의 부분 평면도이다. 그림 1에서 원으로 표시되는 부분이 비마스킹부(1)로서, 한 개의 비마스킹부(1)에 1개의 다이아몬드 입자(4)가 고착된다. 1개의 비마스킹부(1)에 고착되는 다이아몬드 입자(4)가 2개를 넘으면, 패드에 의한 연마에서 웨이퍼의 표면거칠기 값이 낮아지며, 웨이퍼의 스크래치 개수가 감소되기 쉽다. 그림 1에서 비마스킹부(1)의 전면적이 다이아몬드 입자(4)를 고착한 연삭면 적의 0.04~0.2배이다. 비마스킹부(1)의 전면적이 다이아몬드 입자(4)를 고착한 연삭면의 전면적의 0.04배 미만이면, 컨디셔너(7)로서의 연삭력이 부족한 문제가 있으며, 컨디셔너(7)의 수명이 짧아지게 된다. 또한 비마스킹부(1)의 전면적이 다이아몬드 입자(4)를 고착한 연삭면의 전면적의 0.3배 이상이면 패드에 의한 연마에서 웨이퍼의 표면거칠기 값이 낮아지며, 웨이퍼의 스크래치 개수가 감소되기 쉽다. 본 고안의 컨디셔너의 샹크(3) 재료로는, 스테인레스 강재인 STS 304를 사용하는 것이 바람직하나, 경우에 따라서는 예를 들면 알루미늄 합금 등이 사용될 수 있다.

본 고안의 컨디셔너를 제조하기 위해서는, 우선 샹크(3)의 탈지를 행하는 것이 바람직하다. 탈지를 종료한 샹크면에, 구멍 형상의 비마스킹부(1)를 가지는 마스킹 시트(2)를 점착한다. 그림 1에서, 원형의 구멍 형상의 비마스킹부(1)를 가지는 마스킹 시트(2)가 샹크(3)에 점착되고, 샹크(3)의 일부가 비마스킹부(1)의 형상으로 노출되어 있다. 본 고안에서는, 마스킹 시트(2)를 점착한 상태에서, 컨디셔너의 연삭면으로 되는 샹크면에 예비 도금층(5)을 형성시키는 것이 바람직하다. 예비 도금을 실시하는 것에 의해, 다이아몬드 입자(4)와 샹크(3)가 직접 접촉하는 것이 아니고, 다이아몬드 입자(4)의 샹크(3)에 대한 고착성이 개량된다. 예비 도금하는 금속으로는 니켈 및 니켈 합금을 사용할 수가 있다. 본 고안에서는, 예비 도금을 실시한 샹크를, 마스킹 시트(2)를 점착한 상태에서 도금 용기에 넣고, 도금 용기 중에서 샹크의 마스킹 시트(2)를 점착한 면의 부분에 다이아몬드 입자(4)를 충진한다. 이어서, 샹크에 음극을 접속하고, 도금액에 양극을 접속하여, 예비 도금층(5)의 형성을 위한 전기 도금을 실시한다. 예비 도금을 위한 금속은 다이아몬드 입자(4)를 샹크(3)에 예비 고정할 수 있는 것이라면 제한이 없으나, 니켈 및 니켈 합금을 사용할 수가 있다. 각 다이아몬드 입자(4)의 일부분이 비마스킹부(1)에서 예비 도금층(5)을 사이에 두고 예비고정되며, 샹크 표면에서 탈락하지 않는 상태로 되면, 예비 고정을 위한 도금을 종료하고, 샹크를 도금 용기로부터 꺼낸다. 그림 2는, 다이아몬드 입자가 예비 고정된 샹크의 부분 단면도이다. 본 그림에서, 샹크(3)에 마스킹 시트(2)가 점착되고, 마스킹 시트의 구멍 형상의 비마스킹부(1)에 다이아몬드 입자(4)가 예비 도금층(5)에 의해 예비 고정되어 있다.

이어서 샹크(3)의 표면으로부터 마스킹 시트(2)를 박리시키고, 더욱이 마스킹부의 탈지와 활성화 처리를 행한 후에, 다시 샹크(3)를 도금 용기에 담그서 음극을 접속하고, 도금액에 양극을 접속하여 도금을 계속하며, 다이아몬드 입자(4)를 샹크(3)에 전착하여 연삭면을 형성하고, 컨디셔너를 완성하게 된다. 도금에 사용하는 금속은, 예비 고정의 경우

와 마찬가지로 다이아몬드 입자(4)를 샹크(3)에 고착할 수 있는 것이면 제한이 없고, 예를 들면 니켈 및 니켈 합금을 사용할 수 있다. 그림 3은 본 고안의 컨디셔너의 연삭면의 부분 단면도이다. 본 그림에서 다이아몬드 입자(2)는 샹크(3)에 예비 도금층(5)에 의해 예비 고정되며, 더욱이 도금에 의해 형성된 Ni 도금층(6)에 의해 완전히 고착되어 있다. 본 고안에서 이용하는 마스킹 시트(2)는, 도금 조건에 견딜 수 있는 것이면 제한은 없으며, 예를 들면 폴리 염화비닐 등의 수지 시트의 일면에 아크릴계 또는 비닐 에테르계 등의 점착제를 도포한 뒤에 박리시트를 적층시키고, 또한 구멍 형상의 비마스킹부(1)의 가공을 실시한 것을 용이하게 사용할 수가 있다. 마스킹 시트(2)의 두께란, 수지 시트 및 점착 제 층의 두께의 합이 되며 이러한 마스킹 시트의 두께는 다이아몬드 입자 직경의 60%~140%의 범위로 하는 것이 바람직하다. 또한 더욱이 1개의 구멍 형상의 비마스킹부(1)의 면적이 다이아몬드 입자의 투영 면적의 110~160%배의 범위로 되어야 한다. 마스킹 시트의 두께를 다이아몬드 입자 직경의 60% 미만으로 한다든지, 또는 한 개의 비마스킹부의 면적이 다이아몬드 입자의 투영 면적의 160%를 초과하면, 한 개의 비마스킹부에 2개 이상의 다이아몬드 입자가 고착되어서 균등한 분산이 이루어지지 않는다. 또한 비마스킹부의 면적이 다이아몬드 입자의 투영 면적의 110% 미만에서는, 다이아몬드 입자의 샹크에 대한 부착이 곤란하게 된다. 따라서 마스킹의 두께를 전착할 다이아몬드 입자경의 60~140%의 범위로 하고, 마스킹하지 않는 구멍의 직경을 전착할 입자경의 110~160%의 범위로 하는 것에 의해, 컨디셔너 금속에 전착되는 다이아몬드 입자(4)가, 비마스킹부(1)에 한 개씩 분산되도록 된다. 다이아몬드 입자의 평균 투영 면적은, 다이아몬드 입자가 분산된 상태에서 확대 사진을 촬영하는 것에 의해 구할 수 있다. 본 고안에서는, 상기한 마스킹 시트의 비마스킹부의 전면적이 마스킹 시트의 전면적의 0.04~0.2배의 범위이다. 마스킹 시트의 비마스킹부의 전면적은, 본 고안의 컨디셔너의 연삭면에서 다이아몬드 입자가 고착된 부분의 전면적에 대응한다. 마스킹 시트의 비마스킹부의 전면적이 마스킹 시트의 전면적의 0.04배 미만이면, 구멍 형상의 비마스킹부의 전면적이 다이아몬드 입자를 고착한 연삭면의 전면적의 0.04배 미만으로 되어, 컨디셔너로서의 연삭력이 부족할 염려가 있다. 마스킹 시트의 비마스킹부의 전면적이 마스킹 시트의 전면적의 0.2배를 초과하면, 구멍 형상의 비마스킹부의 전면적이 다이아몬드 입자를 고착 한 연삭면의 전면적의 0.2배를 초과하여, 연삭시에 눈메움이 발생할 염려가 있다.

〈실시예〉

컨디셔너 샹크(3)의 연삭면으로 되는 작용면을 탈지하고, 마스킹 시트를 점착한 후에, 니켈에 의한 예비 도금층(5)을 형성하였다. 마스킹 시트(2)의 두께를 전착할 #120 메쉬 다이아몬드 입자경의 80%로 하였으며, 더욱이 다이아몬드 입자(4)를 전착시키기 위해 비마스킹부(1)의 직경을 전착할 다이아몬드 입자경의 140%로 하였다. 구멍 형상의 비마스킹부(1)의 전면적을 마스킹 시트(2)의 전면적의 0.1배가 되도록 하였다. 그 후에 컨디셔너의 본체를 도금액에 담그고 입자 고정면에 다이아몬드 입자(4)를 놓고서 컨디셔너의 본체에 음극을 접속하고, 도금액에 양극을 접속하여 전기도금을 행하여 다이아몬드 입자(4)를 예비 고정하였다. 샹크를 도금액으로부터 빼내고, 마스킹 시트(2)를 박리시키며, 탈지를 행한 후에 컨디셔너의 본체를 다시 도금액에 담그며, 본체에 음극을 접속하고 도금액에 양극을 접속하여 다이아몬드 입자 고정면의 최종 Ni 도금을 행함에 의해 다이아몬드 입자(4)를 샹크의 연삭면에 고착하였다.

컨디셔너의 형상은 실시예 1에서는 도 4와 같은 다이아몬드 입자의 분포를 가지도록 하였으며, 실시예 2에서는 도 5와 같이 전착부가 스파이럴 형상이 되도록 하였고, 실시예 2에는 비전착 영역(8)이 형성되도록 하였다. 실시예 1 및 실시예 2는 컨디셔너의 형상을 제외하고는 다른 모든 제조 조건은 동일하였다. 비교예는 실시예 1 및 실시예 2의 컨디셔너의 성능과 비교를 행하기 위하여 당사에서 종래의 제조방법으로 제조되어 시중에서 판매되는 것으로, 비교예 1은 실시예 1과 동일 형 상이며, 비교예 2는 실시예 2와 동일 형상의 컨디셔너를 사용하였다. 실시예 1, 실시예 2, 비교예 1 및 비교예 2의 컨디셔너를 사용하여, 반도체의 웨이퍼 가공에 사용되는 화학-기계-연마 장치의 패드 컨디셔닝을 행한 결과를 표 1에 나타낸다.

[표 1]

	실시예 1	실시예 2	비교예 1	비교예 2
연마속도비	1.38	1.35	1	0.9
컨디셔닝속도(㎛/h)	35	34	12	11
컨디셔너수명(hr)	600	590	160	155
웨이퍼표면거칠기(nm)	0.33	0.34	0.43	0.44
웨이퍼의 스크래치 개수	1	1	7	8
패드의 표면상태	연삭흔 거의 없음	연삭흔 거의 없음	연삭흔 많음	연삭흔 많음

실시예 1 및 실시예 2의 패드 연마속도비, 컨디셔닝 속도 및 컨디셔너 수명이 비교예에 비해 현저히 높으며, 웨이퍼의 표면거칠기 및 스크래치 개수의 경우에서도 실시예 1과 실시예 2가 비교예에 비해 현저히 낮은 값을 보이며, 실시예 1 및 실시예 2의 컨디셔너를 사용한 경우 패드의 연삭흔이 거의 나타나지 않았으나, 비교예의 컨디셔너를 사용한 경

우는 패드의 표면에 연삭흔이 많이 나타났다.

고안의 효과

이상에서 서술한 바와 같이 본 고안은, 마스킹 시트(2)의 점착에 의해 마스킹을 행하므로 치수 정밀도가 엄격한 패턴 형상을 재현성 높게 용이하게 형성시킬 수 있으며, 마스킹 시트(2)의 컨디셔너 금속에 대한 밀착력이 높으며, 또한 컨디셔너 금속에 전착되는 80~120메쉬의 다이아몬드 입자(4)가, 비마스킹부(1)에 한 개 씩 분산된다. 따라서 CMP용 폴리싱 패드의 평탄화를 향상시킴과 동시에, 이 패드의 컨디셔닝을 효과적으로 행하는 기능을 가지고, 더구나 컨디셔닝 성능이 우수하고, 수명이 길며, 컨디셔너의 제조가 용이하기 때문에 제조시의 불량률을 현저히 감소시킬 수 있다.

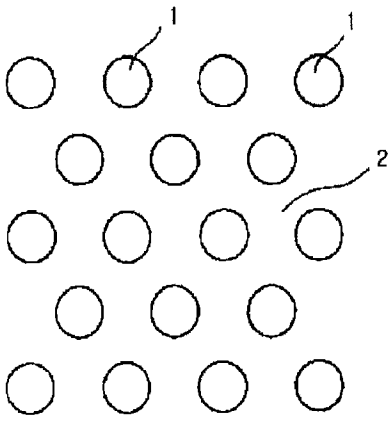
(57) 청구의 범위

청구항 1.

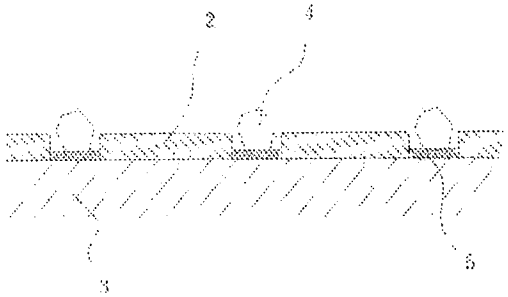
Ni 도금층이 다이아몬드 입자 직경의 40~60% 정도의 두께를 가지며, 샹크의 표면에 있어서, 1개의 구멍 형상의 비마스킹부의 면적이 다이아몬드 입자의 투영 면적의 110~160%배로 하고, 마스킹 시트의 비마스킹부의 전면적이 마스킹 시트의 전면적의 0.04~0.2배의 범위로 하는 것이 특징으로 된 화학적-기계적-연마 패드 컨디셔너.

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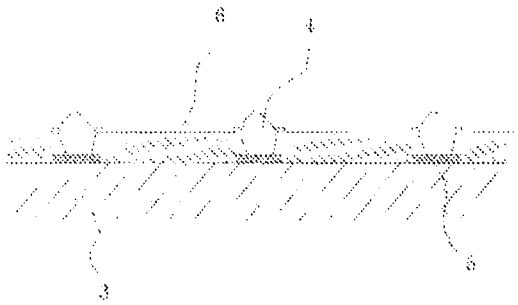
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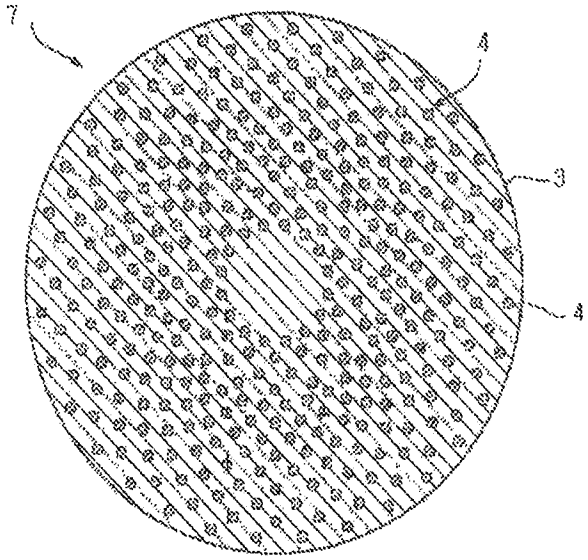
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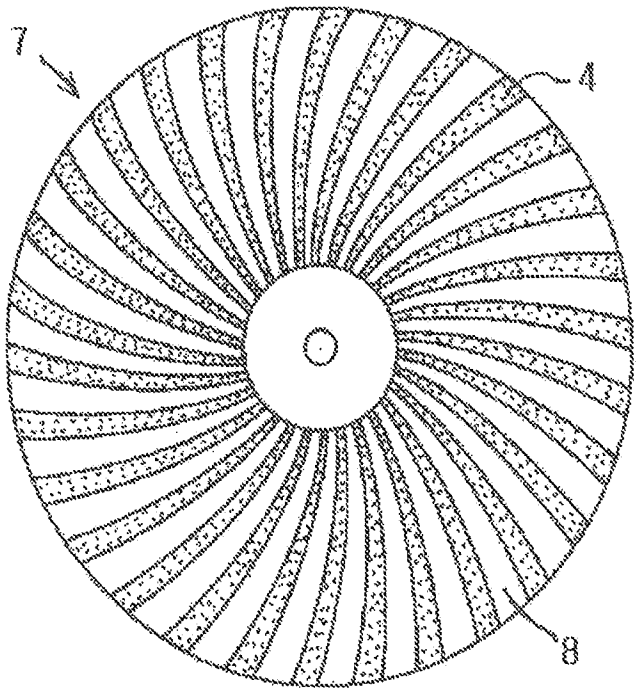
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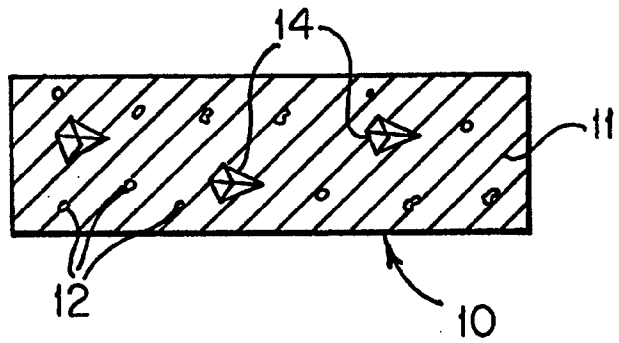
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(54) Title: METHOD FOR MAKING POWDER PREFORM AND ABRASIVE ARTICLES MADE THEREFROM

(57) Abstract

A method for making abrasive articles uses a soft, easily deformable and flexible preform having a high binder content. The binder gives the preform its integrity, and is present in greater quantity than the retaining powder. The preform can have superabrasive particles mixed therein, or added later. The preform allows even distribution of a small quantity of retaining powder for thin superabrasive articles. A porous layer may be added to the assembly for making an abrasive article, the porous layer absoring the liquid binder, supporting the retaining powder and superabrasive particles to prevent lateral movement, and perhaps giving strength to the preform. The final assembly to be heated or sintered (preferably under pressure) for making the abrasive article, which may include any number of layers of superabrasive particles, porous layers and preforms.



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Description

METHOD FOR MAKING POWDER PREFORM AND ABRASIVE ARTICLES MADE THEREFROM

Technical Field

This invention relates generally to the making of abrasive articles and the like, and is more particularly concerned with the use of soft, flexible and easily deformable powdered pieces as preforms for the manufacture of abrasive articles having superabrasive particles therein.

Background Art

Powdered preforms are widely used in the manufacture of abrasive articles that include a plurality of superabrasive particles such as diamond, cubic boron nitride and the like. Such powdered preforms are conventionally manufactured by compacting powder mixtures of retaining compositions and superabrasives particles in cold presses or roll compactors. Compacting pressure ranges from 300 to 10,000 kg/sq. cm, resulting in 20-50% relative density of the green compacts. Such green compacts are hard, stiff and brittle. The green compacts are sintered, either with or without pressure, and with or without impregnation.

There is a method of making abrasive articles wherein a non-compacted mixture of the powdered retaining composition, with the plurality of superabrasive particles therein, is placed directly into a sinter mold, then compacted and sintered in the sinter mold. This method requires a lot of adjustments in attempts to spread the powder evenly within the sinter mold. The required adjustments slow the manufacturing process, so the method does not fit well with mass production requirements.

In all the above mentioned methods, the powdered mixture can contain some binders, but the conventional green compacts are held together, not by the binder, but primarily by interaction among the particles of the powder, e.g. by mechanical interlocking of the particles. The above mentioned methods are widely used to produce traditional

cutting, drilling, and grinding abrasive tools and elements of abrasive tool, such as segments for saws and the like.

There are powdered preforms formed by spraying powder onto a substrate, and fixing the powder to itself and to the substrate by an adhesive, for example by an adhesive spray. Such preforms are flexible, but may experience loss of some powder when flexed. Also, such a method must deal with air borne particles and aerosol sprays that, because of environmental concerns, put serious limitations on the implementation of the method. This method has been used by the present inventor to make articles disclosed in U.S. Patents Nos. 4,925,457, 5,049,165, 5,092,910 and 5,190,568, as well as in U.S. patent Application Ser. No. 08/066,475 titled "patterned Abrasive Material and Method" and Ser. No. 08/024,649 titled "Abrasive Cutting Tool".

Soft and flexible preforms of powders and/or fibers, including both metallic and non-metallic materials, are also known; but, to the knowledge of the present inventor, such preforms are not known in the art of manufacturing articles that include superabrasive particles. Presently, the soft and flexible preforms are made by casting, or extruding a composition of brazing filler metal, or ceramic components, or hard facing compositions including metallic components and non-metallic abrasive components such as tungsten carbide particles. Such soft and flexible preforms can be bent more than 90°, and can be cut by scissors or the like.

The earlier known soft and flexible preforms comprise a high content of various binders, up to 95% by volume, and up to 20% by weight. It is the binder that makes such preforms soft and flexible; but, even with the high content of binders, the preforms are flimsy and must be handled with care. This is especially true for the very thin preforms, around .005--.010", or 0.10--0.25 mm.

It is important to distinguish between the soft and flexible preforms and the products of roll compacting of powders, even in the presence of a binder. When a roll compacted product includes a binder, the binder is in a much

smaller quantity than in a flexible preform. The roll compacted product is held together, not by the binder, but by the mechanical interlocking of particles, which makes the roll compacted product much less flexible than the soft and flexible preforms.

Soft and flexible preforms made of brazing filler metal compositions are used to put some parts together through brazing, mostly through furnace brazing. Soft and flexible preforms made for hard facing compositions are used to repair worn parts. For this purpose, the preforms are applied to a worn spot on the part.

The brazing process using the soft and flexible preforms made of brazing filler metal has a significant time duration because of the necessity for removal of the substantial quantity of binder. The time for removal of the binder is called the "dewaxing" cycle, and it allows the binder to melt, evaporate, or run out from the preform. It has been found that, if the dewaxing time is shortened or omitted, the powder of the soft and flexible preform can be literally washed out by the liquefied binder.

In attempting to use the known soft and flexible preform to hold a plurality of superabrasive particles in order to produce abrasive articles, it will be recognized that:

1. Compositions of the brazing filler preform do not correspond to the desired matrix compositions to hold superabrasive particles;

2. Soft and flexible preforms are not produced with superabrasive particles on, or within, the preforms;

3. Soft and flexible preforms are quite flimsy and not as strong as desired for production of abrasive articles, especially for mass production requirements of abrasive articles requiring thin (.005--.020", or 0.1-- 0.5 mm) flexible preforms;

4. De-waxing time must be severely reduced to meet production rates, especially for mass production; and,

5. Heating and/or brazing processes alone do not provide the most reliable matrix for retaining superabrasive particles.

Disclosure of the Invention

The present invention provides a method for manufacturing abrasive articles and wear resistant parts, such articles or parts comprising a plurality of superabrasive particles such as diamond, cubic boron nitride or the like randomly or systematically distributed in a retaining matrix. Specifically, the method of the present invention includes the preparation and utilization of powdered preforms in the form of soft, easily deformable flexible (SEDF) bodies that may include a plurality of superabrasive particles.

In making the SEDF preforms, the powdered compositions will be chosen based on criteria related to the holding necessary for the superabrasive particles to be included. Any number of matrix materials, or powdered compositions may be used, with any number of binders. The binder will be selected to provide the desired integrity of the product, while maintaining the flexibility and processability. In any case it must be remembered that the concentration of powdered composition and abrasive particles (if included) is low, and the volume of the binder is high. The volume of the binder phase substantially exceeds the volume of the powdered composition and the abrasive particles within the SEDF preform.

In one preferred form of the present invention, a porous layer will be placed against the SEDF preform. The purpose of the porous layer is to hold the abrasive particles in place during subsequent processing of the material. Successful material can be made without the porous layer, but the porous layer provides a better quality product than is obtained without the porous layer.

Final processing of the SEDF preform of the present invention includes sintering or other heat treating. The result is a high quality abrasive material, with or without a

porous layer therein, which can be used for numerous cutting or abrasive tools and the like.

Brief Description of the Drawings

These and other features and advantages of the present invention will become apparent form consideration of the following specification when taken in conjunction with the accompanying drawings in which:

Fig. 1 is a cross-sectional view showing one form of preform made in accordance with the present invention, the preform having some superabrasive particles therein;

Fig. 2 is a cross-sectional view of another preform made in accordance with the present invention, the preform being formed on a substrate which may be a porous material;

Fig. 3 is a view similar to Fig. 1 but showing the superabrasive particles on the surface of the preform;

Fig. 4 is a view similar to Fig. 3 wherein the superabrasive particles are held by a carrier which is placed against the preform;

Fig. 5 is a cross-sectional view illustrating a continuous process for forming the preform, and placing superabrasive particles on one surface of the preform;

Fig. 6 is a view similar to Fig. 5, but showing the preform being formed on a substrate having superabrasive particles thereon;

Fig. 7 is a view similar to Fig. 1 and showing a comparison between the thickness of the preform and the size of the superabrasive particles;

Fig. 8 is a view similar to Fig. 7, but showing the preform after sintering;

Fig. 9 is a cross-sectional view illustrating a method and apparatus for casting preforms according to the present invention;

Fig. 10 is a cross-sectional view showing a process of sintering under pressure;

Fig. 10A is a view similar to Fig. 10 but showing a plurality of preforms within the mold;

Fig. 11 is a cross-sectional view illustrating an assembly of a preform with porous layers in accordance with the present invention;

Figs. 12--17 are similar to Fig. 11 and show various modifications thereof;

Fig. 18 is a cross-sectional view illustrating extrusion of the preform into openings of a porous layer;

Fig. 19 is a cross-sectional view showing a continuous process for assembling a preform in accordance with the present invention using rolls;

Fig. 19A is a cross-sectional view illustrating the casting of a profiled preform on a substrate;

Fig. 19B is a view similar to Fig. 19A but showing a preform being cast between two substrates;

Fig. 19C is a cross-sectional view showing the deformation of a flat preform;

Fig. 20 is an exploded, cross-sectional view showing an be mixed assembly for producing an abrasive article;

Fig. 20A is a view similar to Fig. 20 but showing a modification thereof;

Fig. 21 is a cross-sectional view showing the assembly of Fig. 20 after assembly and sintering;

Figs. 22 and 23 are similar to Figs 20 and 21 but showing a modification thereof;

Figs. 24 and 25 and Figs. 26 and 27 are similar to Figs 20 and 21 but showing additional modifications thereof; and,

Fig. 28 is a side elevational view showing the assembly of a cutting tool in accordance with the present invention.

Best Mode for Carrying Out the Invention

Referring now more particularly to the drawings, and to those embodiments of the invention here presented by way of illustration, the invention has two major parts: preparation of soft, easily deformed flexible (SEDF) preforms; and, utilization of SEDF preforms for making abrasive articles.

Preparation of Preform

The preform is prepared by mixing a binder with a powder composition in the required proportions. The mixture may or may not include a plurality of superabrasive particles. Thus, depending on the particular portions chosen, one may produce the binder-powder mixture in the form of a slurry, granulated powder, or a paste.

If the granulated powder is used, a plurality of superabrasive particles can be placed onto the granules by a supplementary process. The granules may be mixed with a plurality of superabrasive particles, and the superabrasive particles may stick to the granules either because of the binder in the granules, or because of an additional binder covering the granules and/or the superabrasive particles.

Mixing the binder with the retaining powder can be performed on a variety of standard equipment, including virtually any equipment suitable for mixing powder and liquid together. Thus, no detail discussion of the equipment is necessary herein.

There is a variety of materials that can be used as the binder for the preform. The binder may be organic or inorganic, but should be selected to carry the particles of the powder, keep the particles suspended, and provide integrity and flexibility to the final preform. It is preferable to choose a binder that allows air, a low vacuum, heat, or a combination of these, to evaporate at least some of the volatile components of the binder for at least partial curing of the binder. Such binders include water soluble binders.

It is well recognized that the prior art powder technology requires that a person mix powders and superabrasive particles. Such powders and superabrasive particles become air borne, and are deleterious to the health of workers. Safety masks and the like are available, but are uncomfortable to wear, and of course are not totally effective. The present invention overcomes this difficulty with the prior art in that the powders and superabrasive

particles can be handled by machines, appropriately covered to minimize the escape of particles. The material is available to be manipulated by people only after mixing powdered components with the binder, so there is no longer a hazard of air borne particles.

Those skilled in the art will understand that many materials will be acceptable as binders, depending on the precise characteristics desired. However, by way of example, the following have been found to be suitable binders: Sanford's Rubber Cement (commercially available from Sanford Corporation, Bellwood IL) in a combination with Carter's Rubber Cement Thinner (commercially available from Dennison Carter's Division, Dennison Manufacturing Company, Framington, MA); Nicrocoat Cements (available from Wall Colmanoy Company, Madison Heights, MI) in a combination with Exosen No. 40 (available from Smithkline Beckman Company, Lewistown, PA).

In the binder-powder composition, the binder is usually 3 to 20% by weight of the composition, but the ratio can be extended. By volume, the percentage of the powder within the binder-powder composition is usually from 1 to 5%, but it can be extended to a range of 0.3 to 10%. One successful preform has from 5.0 to 8.5% by weight of rubber cement and thinner. The retaining powder is dispersed in the binder and held thereby. Superabrasive particles may also be dispersed within the binder, and also held therein.

Referring to Fig. 1 of the drawings, it will be seen that the SEDF preform 10, comprises mostly binder 11. There is a plurality of particles 12 of a retaining powder distributed in the binder 11, and there are superabrasive particles 14 also distributed in the binder. From the above discussion it will be understood that the superabrasive particles 14 may or may not be included. This will also be discussed in more detail below.

Looking at Fig. 2, it will be seen that the SEDF preform 10 includes the binder 11 and retaining powder 12. Superabrasive particles 15 are here shown as fixed to a

substrate 16, the substrate 16 then being placed against the SEDF preform 10. The substrate 16 may take many forms, including a film having a low melting point or the like, but it is preferably a porous material, which will be discussed in more detail hereinafter.

Fig. 3 shows a modification of Fig. 2, the SEDF preform 10 being substantially the same. The superabrasive particles 18 in Fig. 3, however, are placed on the upper surface of the preform 10. The superabrasive particles may be pressed into the preform 10, or may be held by an adhesive. The adhesive may be the binder 11, or may be a separately applied adhesive. Similarly, Fig. 4 shows the arrangement of Fig. 3, but with a carrier 19 having the abrasive particles 20 adhered thereto. The particles 20 on the carrier 19 can therefore be brought into contact with the preform 10 when desired.

In accordance with the present invention, SEDF preforms can be formed by spreading a binder-powder composition on a substrate. The composition may be powdered slurry, granules, or a paste. The composition is then cured, e.g. dried, on the substrate, and one may use applied heat or pressure if desired.

When dealing with granules, an external pressure in the range of 50 to 200 kg/cm^2 is helpful to apply a binder to the granules while the granules are on the substrate. The binder, which may be spread on the substrate, may penetrate between the granules and assists in integrating the granules into a preform.

In some cases, especially when the superabrasive particles are substantially larger than the particles of the retaining powder, or the viscosity of the liquid is not balanced to suspend the superabrasive particles, some measure must be taken to prevent separation or sedimentation of the superabrasive particles after mixing has stopped. One might therefore pour immediately after mixing, or combine continuous mixing with simultaneous pouring or coating.

The superabrasive particles in the SEDF preforms are not surrounded by closely packed particles of a retaining powder as in the traditional green compacts. Rather, the superabrasive particles in the SEDF preform are suspended predominantly by the binder, and in contact with a very few particles of the retaining powder. This is illustrated in Figs. 1--4 of the drawings.

Superabrasive particles can be added to the SEDF preform during the process of forming or curing the preform. By way of example, attention is directed to Fig. 5 of the drawings. A binder- powder composition 21 is dispensed onto a substrate 22, and doctored to a uniform thickness by a doctor blade 24. After the doctor blade 24,. superabrasive particles 25 are dispensed onto the surface of the preform 26. It will be understood that the composition 21 is not cured at the time the superabrasive particles 25 are placed onto the preform 26, so the particles will be adhered thereto. If desired, or necessary due to the viscosity of the preform and the weight of the particles 25, pressure can be applied to assist in urging the superabrasive particles 25 at least partially into the preform 26. Also, additional adhesives or the like can be applied as needed.

Fig. 6 illustrates a modification of the arrangement shown in Fig. 5. In Fig. 5, the binder-powder composition 21 is dispensed onto the substrate 22 and doctored to the desired thickness by doctor blade 24. In Fig. 6, however, the substrate 22 carries a plurality of superabrasive particles 28, and the binder-powder composition is dispensed onto the particles 28. The superabrasive particles 28 may be completely covered, or only partially covered by the binder-powder composition as desired.

The difference between the thickness of the SEDF preform and the size of the superabrasive particles can vary considerably; but, it will be realized that the difference will change significantly in sintering. Fig. 7 shows an SEDF preform 10 having superabrasive particles 14 therein. At this stage, the thickness t of the SEDF preform may be equal

to 3d to 10d, where d is the dimension of the superabrasive particles in the direction of the thickness of the SEDF preform. After sintering, the same preform is shown in Fig. 8. It will of course be realized that the superabrasive particles 14 will not change in size during sintering, but the preform 10 will be significantly condensed. After sintering, the preferable ratio is that the thickness t is approximately equal to the dimension d, the desirable range being t = 0.3--2d. It should be mentioned that superabrasive particles of all sizes are suitable for use with the technology disclosed herein, but the preferable sizes are from 18 to 324 mesh (about 1.0 mm to about 0.035 mm).

The weight of the dry retaining powder per unit volume of the SEDF preform (grams of powder per cubic centimeter of preform) determines the thickness of the sintered abrasive material, it being realized that the binder will run off, or evaporate, during sintering or other heat processing. For example, the density of cobalt is 8.9 g/cm^3, and a cobalt preform contains 0.8 g/cm^2 of the dry cobalt powder; therefore, the thickness of the fully densified, sintered product will be about 0.9 mm, which is found by dividing 0.8 g/cm^2 by 8.9 g/cm^3. It will be noted that the thickness of the SEDF preform is not in the calculation, this being irrelevant. The important consideration is the quantity of the dry powder per unit area of the preform.

One technique for production of SEDF preforms of the present invention is illustrated in Fig. 9. Essentially, a plurality of trays 29 is moved under a hopper 30 which dispenses the binder-powder composition. Each tray 29 will receive a predetermined quantity of the composition to provide SEDF preforms of predetermined weight. As shown in Fig. 9, the trays 29 can be placed on a conveyor 31, or may be part of a conveyor 31 which can move continuously, or intermittently, and timed so the binder in the composition will be cured before the preforms are removed from the trays 29. In the system illustrated, the preforms are received by another conveyor 32 which will carry the preforms to the next

processing step. It should be understood that the conveyor 31 can take various geometrical arrangements, including a zig-zag shape in the horizontal plane and a stepped shape in vertical plane.

In using the system shown in Fig. 9, if a substrate is desired on the preform, the substrate, with or without superabrasive particles thereon, can be placed in the bottom of the trays 29. Also, superabrasive particles, with or without a substrate, can be placed on top of the preform after the tray 29 is filled to the desired extent.

It will therefore be realized that the SEDF preform may be made in the form of discrete plates as shown in Fig. 9, or may be made in the form of continuous tapes as shown in Figs. 5 and 6. Either form can then be cut easily with scissors, paper cutter, die cutting or the like.

Preparation of Abrasive Articles

Fig. 10 of the drawings shows the preferred means and method for heating an SEDF preform and condensing the preform. Fig. 10 illustrates a generally conventional sinter fixture for sintering under pressure. It will be seen that there is a bottom punch 34 and a top punch 35, the space between the punches 34 and 35 being closed by the side plates 36. Within the cavity so defined, there is an SEDF preform 38, here shown as having superabrasive particles 39 distributed therein, and a plurality of superabrasive particles 40 on the top side of the preform 38.

Those skilled in the art will understand that the punches 34 and 35 will be urged towards each other as indicated by the arrows, and an electric current will be passed through the sinter fixture and/or the preform to heat the preform. An important feature of the present method is that the side plates 36 will tend to restrain lateral movement of the SEDF preform during sintering, even though there may be a flow of liquid as the binder and/or retaining matrix melt and run.

A further advantage of the SEDF preform in a sintering fixture as shown in Fig. 10 is that the softness of the preform makes redistribution of material quite easy. As a result, variations in thickness and stress can be made uniform simply through the usual pressure on the preform during sintering. The preform therefore has less sensitivity to various non- uniformities, and tends to reduce damage to the sinter molds. The inventor has experienced a 50-fold reduction in consumption of graphite mold parts since using the technique disclosed herein. It should be noted that, because of the softness and deformability of the SEDF preform, abrasive articles with a corrugated shape can be mass produced without significant consumption of corrugated (hence expensive) punches, e.g. graphite or metal punches.

It should be understood that the sinter mold can be loaded with several assemblies of SEDF preforms, the assemblies being separated from one another by punches and/or separators as disclosed in U. S. Patent No. 5,203,880, "Method and Apparatus for Making Abrasive Tools", by the present inventor. Such sintering "in stock" is illustrated in Fig. 10A. The unique uniformity, softness and deformability of the SEDF preform make sintering in stock acceptable for mass production technology.

While the heating of the SEDF preforms under pressure has many advantages, there is one severe disadvantage: the heating melts and vaporizes the binder, which runs; and, the liquid or vaporized binder, intensified by the applied pressure, tends to carry the retaining powder and superabrasive particles out of the mold. If most of the retaining powder is washed out of the mold, there will of course be practically no matrix material to hold the left over superabrasive particles in place. Also, melted binder and/or melted or moved retaining matrix of SEDF preform will catch the superabrasive particles, which can be washed out of the mold.

To solve the problem of the loss of retaining powder and superabrasive particles, it has been found that a porous

layer can be placed against the SEDF preform to prevent lateral movement of the particles. The porous layer may take many forms, but will not be held together by a binder as used in the SEDF preform. Rather, the porous layer may be screen wire, a conventional compacted preform, egg-crate or reticulated metal structures or the like.

Looking at Fig. 11, it will be noticed that the superabrasive particles 41 are larger than the openings in the porous layer 42. Under pressure, the particles 41 may cut into the porous layer 42. The particles 44 of the retaining powder are smaller than the opening in the layer 42, so these particles will pass easily into the openings of the layer 42.

As shown in Fig. 11, there is a second porous layer 45 on the opposite side of the SEDF preform; and, the assembly shown in Fig. 11 will be urged together and heated under pressure. The porous layers 42 and 45 will support the superabrasive particles and prevent lateral movement (perpendicular to the direction of the applied compaction force), and will provide additional volume to receive the SEDF preform, and restrain lateral motion of the particles of retaining powder in the SEDF preform. The porous layers will also temporarily absorb liquid binder to reduce the flow of binder and thereby help prevent washout of retaining powder and superabrasive particles.

The porous layer, or layers, can be placed in various positions relative to the SEDF preform and other layers of an assembly to be sintered. By way of example, and not by way of limitation, Fig. 12 shows the SEDF preform 46 having a porous layer 48 on one side, and a layer of abrasive particles 49 on the opposite side of the porous layer 48, a substrate, or carrier 50 holding the particles 49 in place. Fig. 13 shows the same arrangement, but the substrate 50 is between the particles 49 and the porous layer 48.

Fig. 14 shows the SEDF preform 46 in the middle with the porous layer 48 on one side, and the superabrasive particles 49 and substrate 50 on the opposite side. Fig. 15 shows the

superabrasive particles 49 and substrate in the middle, with the SEDF preform 46 on one side, and the porous layer 48 on the opposite side. Fig. 16 is like Fig. 15, except that the positions of the superabrasive particles 49 and the substrate 50 are reversed.

Fig. 17 shows two SEDF preforms 46 and 46'. A porous layer 48 is between the preforms, and the superabrasive particles 49 with the substrate 50 are on the opposite side of one of the preforms.

The porous layer may take the form of a woven mesh, a nonwoven material, expanded foil, knitted materials and textile fabrics. Also, a material that is roll-compacted, extruded, sintered or the like can be used. Virtually any material can be used so long as the material is highly porous (about 30% to 99.5% porosity), having pores open to the surface and interconnected, with sufficient integrity to support the superabrasive particles and to restrain motion of the retaining powder in the process of sintering.

Presently, the best material known for use as porous layers are metallic non-woven materials, and particularly a nickel fiber powder non-woven mat, manufactured by National Standard, Woven production Division, Corbin KY, and sold under the trademark "Fibrex". The porosity of this mat is 85-98%; the fiber is 20 microns in diameter and is about 80 weight percent of the mat, while the powder is about 20 weight percent.

It has also been found that copper wire mesh, in the range of 20 to 200 mesh, works well as the porous layer. Some expanded metals (manufactured by Delker Corporation) have been used, for the same purpose.

Fig. 18 of the drawings illustrate an SEDF preform 51 after the preform 51 has been urged against a porous layer 52. The porous layer 52 is here shown as having some substantial thickness, and being made up of a plurality of cells 54 so the porous layer 52 comprises a cellular type of material. It will be seen, then, that the material of the preform 51 has been urged into the cells 54. It has been

found desirable in some cases to compress the preform 51 with the porous layer 52 prior to applying heat and pressure during sintering. The material of the preform 51, being received in the openings, or cells, 54 of the porous layer 42, tends to stay within the openings and not to move laterally.

It should be understood that the role of the porous layer 52 can be limited to the restriction of flow of the material of the SEDF preform 51. Thus, a porous layer 52 may be made of a material having a melting point below the sintering temperatures. In this case, after at least a portion of the binder has been removed from the preform in the process of heating, and the retaining powder is at least partially solidified, the porous layer will melt onto the preform, and thereby modify the retaining composition. For example, a cobalt-nickel SEDF preform may utilize a porous layer made of copper, bronze, brass, zinc, aluminum, or various combinations of these, as well as other porous layers.

Another function of a porous layer 52 may be conduction of heat and/or electricity during heating of the preform. For example, a mesh or expanded foil of copper will readily conduct heat or electricity to facilitate uniform heating. Further, the porous layer may include superabrasive particles within the cells 54. A preform as shown in Fig. 18 may be placed against a porous layer 52 having superabrasive particles therein, or the porous layer may be used as a substrate in an arrangement such as that shown in Fig. 6 of the drawings.

In any arrangement, it must be realized that, if the porous layer is filled with superabrasive particles, the ability of the porous layer to absorb binder during heating is reduced. Thus, if one wish to provide a full, or nearly full, layer of superabrasive particles through the use of a porous layer, an additional porous layer may be needed, or desired, to absorb the binder and prevent displacement of the retaining powder.

Looking at Fig. 19 of the drawings, it will be seen that the SEDF preform of the present invention is admirably suited to mass production techniques. The arrangement shown in Fig. 19 includes rolls 55 and 56 for assembling a plurality of layers to be sintered. There is a roll of preform 58 to form one side of the assembly, and a roll of substrate 59 to form the opposite side of the assembly. Optionally, a roll of a porous layer 60 is placed between the preform 58 and the substrate 59.

The substrate 59 may have a plurality of superabrasive particles 61 previously placed thereon; or, as here illustrated, a dispenser 62 may place superabrasive particles on the substrate 59 during the assembling process. In either case it is contemplated that the substrate, or carrier, 59 will have an adhesive to hold the superabrasive particles 61 temporarily.

The SEDF preform 58 may take many forms as discussed above. The preform 58 may include a plurality of superabrasive and abrasive particles, or may not. Further, the preform may be placed on a substrate in order to give the preform greater integrity.

The porous layer 60 may or may not be included in the assembly. As is mentioned above, the preform 58 may utilize a porous layer as a substrate, or carrier, and this may be sufficient for some products. However, if one or more additional porous layers are desired, they may be fed to the assembly as shown in Fig. 19. Fig. 19 also shows separators 66 and 67. Such separators are disclosed in U. S. patent No. 5,203,880, "Method and Apparatus for Making Abrasive Tools", by the present inventor. In accordance with the disclosure in that patent, these separators assist in protrusion of the superabrasive particles through the retaining matrix, and in distribution of the temperature within the sinter mold during the sintering process. These separators 66 and 67 may or may not be attached to the SEDF preform assembly. When attached to the preform, the separators will be part of the assembly itself.

It should be understood that, in all techniques disclosed in the present application, separators such as the separators 66 and 67 may or may not be used. If separators are used, they may also be utilized as the substrate for SEDF preform (see numeral 22 in Figs. 5 and 6). It should be understood that, in the majority of the figures in the drawings, separators are not shown for the sake of simplification of the illustration.

Those skilled in the art will understand that the rolls 55 and 56 will urge the layers 58, 59 and 60, and separators 66 and 67 together into a single assembly 64. It is contemplated that the assembly 64 will then be cut into discrete pieces, or plates, 65 by a cutter 66. The individual plates 65 can be received by a conveyer 68 for transport to means for sintering.

Examples

Figs. 20 and 21 of the drawings show one assembly and one resulting sintered abrasive material respectively in accordance with the present invention. There is an SEDF preform 70 having superabrasive particles 71 distributed therein. The opposite side of the assembly is an SEDF preform 72 without abrasive particles. Between these two outside layers, there are two additional preforms 74 and 75, both having superabrasive particles distributed therein. Then, between the preforms 70 and 74 there is a porous layer 76; and between the preforms 74 and 75 there is a porous layer 78.

In Fig. 21 it can be seen that the superabrasive particles remain in layers; and, on one side, the superabrasive particles 71 are at the surface of the sintered assembly, while on the opposite side the preform 72 provides a backing without superabrasive particles. This sintered abrasive material can now be used to manufacture cutting and grinding tools.

The SEDF preform may have a profiled shape, which may or may not correspond to the shape of a compacting means, e.g. punches used for providing pressure during sintering. The

profiled SEDF preform, along with the non-profiled, or flat ones, are utilized by the present inventor for manufacturing abrasive articles according to U. S. patent No. 5,190,568 titled "Abrasive Tool with Contoured Surface".

Fig. 19A illustrates a one-sided profiled SEDF preform. One-way to manufacture the one-sided profiled SEDF preform includes the use of a profiled substrate 111, a binder-powder composition 112 being poured onto the substrate 111.

Fig. 19B illustrates the formation of a two-sided profiled SEDF preform. Fig. 19B shows two substrates, or walls, 114 and 115 and a binder-powder composition 116 between the walls 114 and 115. According to the method illustrated in Fig. 19B, the two-sided profiled SEDF preform is manufactured by pouring a binder-powder slurry between the two profiled walls 114 and 115, resulting in the formation of the two-sided profiled SEDF preform 116.

It should be understood that wall 114 and wall 115 may have different profiles, and each side of the SEDF preform has a profile corresponding to the profile (relief) of the respective wall. It also should be understood that the walls can be positioned vertically or horizontally; and, application of pressure and/or changing the distance between the walls in the process of solidification of the binder-powder composition 116 are optional.

A non-profiled, or flat, SEDF preform can be converted prior to sintering into a profiled one. The flat profile 118 can be shaped between profiled compacting means. Fig. 19C illustrates one of the processes for shaping a flat SEDF preform 118 into a profiled SEDF preform 119 by two profiled rolls or gears 120 and 121. The preferable arrangement does not require change of the thickness of the SEDF preform as a result of the shaping. This type of shaping does not require very great pressure because of the easy deformability of the SEDF preform.

Fig. 20 also-shows separators 66a and 67a placed against SEDF preforms 70 and 72 as a part of the assembly itself. Fig. 21 does not show these separators, indicating that at

least some of the separators have been removed from the sintered abrasive material in the process of after-sintering cleaning, or in the process of dressing the abrasive tool.

One method for utilization of the separators in combination with the SEDF preform is shown in Fig. 20A. The separator 100 is placed on one side of the assembly 103 that includes an SEDF preform 101, a layer of porous material 102 and a layer of superabrasive particles 104 on a substrate 105. A mesh type material 106 having openings 108 is applied against the separator 100; and, the preferable mesh type material 106 has orderly distributed openings 108. Under pressure provided by one or both of the punches 35a and 35b, the assembly 103 extrudes at least partially into openings 108 of the mesh type material 106, de forming the separator 100 and leaving imprints on the surface of the assembly 103. The whole assembly 103 is put into the sintering mold as is shown in Figs. 10 and 10A, and then sintered, providing that sintering under pressure is preferable. The pressure to extrude the assembly 103 into the openings 108 can be applied prior to sintering, outside of the sinter mold and/or within this sinter mold, and/or in the process of sintering. After sintering the mesh type material 106 is removed from the mold, as well as the separator 100. The removal of the mesh type material 106 from the sintered abrasive article is not a problem because the separator 100 prevents diffusion between the assembly 103 and the mesh type material 106. The resulting abrasive article will comprise a profile corresponding to the design of the mesh type material 106.

It should be understood that there are additional options (some being shown in Fig. 20A) that may or may not be implemented: the mesh type material 106 can be placed against both sides of the SEDF preform 101 for making two-sided profiled abrasive article (see separator 109 in Fig. 20A); another separator 110 can be used to separate mesh type material 106 from the punch 35a, and separator 115 can be used to separate another side of the assembly 103 from the punch 35b. It also should be understood that several

assemblies comprising SEDF preforms and the mesh material for extrusion can be sintered in stock as is shown in Fig. 10A. Furthermore, separators of different thicknesses and different types can be used for opposite sides of the SEDF preform 101. The mesh type material 106 for extrusion can be made from different materials, e.g. steel woven mesh, expanded metal, machined crags, honeycomb or the like. It is also preferable that openings in the mesh 106 be big enough to allow at least one superabrasive particle 104 to go therethrough. For example, diamonds have sizes of 0.015 to 0.200 mm (80-100 mesh) while the mesh type material for extrusion comprises openings of 1.00 to 0.850 mm (18 to 20 mesh). It is also preferable that the mesh type material 106 for extrusion does not melt under, sintering temperatures, and have a minimum deformability under the pressure that makes this mesh multiusable.

Figs. 22 and 23 of the drawings show an assembly and a sintered single layer cutting tool respectively. Fig. 22 illustrates the layers to be assembled, and includes a central porous layer 79 having a plurality of superabrasive particles 80 in the openings thereof. It should be noticed that the particles 80 are at least as wide as the layer 79, so the particles 80 extend completely through the porous layer 79.

Each side of the central layer 79 includes two SEDF preforms 81, 82 and 81', 82', separated by porous layers 84, 84'.

When the assembly is heated under pressure, the material shown in Fig. 23 results. The present inventor has used this method to produce abrasive articles with one layer of diamonds as shown. It should be understood, however, that the abrasive article can include as many layers as desired, in accordance with other disclosures herein.

Figs. 24 and 25 show the production of a no-diamond foot on a conventional diamond segment. Current methods are difficult to use because the foot 85 is quite thin, requiring that powder be distributed very thinly, yet very uniformly,

in a sinter mold. Using the methods and apparatus of the present invention, however, an SEDF preform 86 can be placed against the segment 88, and the retaining powder is readily distributed uniformly. As is discussed in detail above, the final thickness of the foot 85 can be easily calculated.

Figs. 26 and 27 show the use of a conventional green compact having randomly distributed abrasive and/or superabrasive particles in combination with preforms of the present invention, and porous layers having orderly arranged superabrasive particles. The central green compact 89 has a porous layer 90, 90' on each side thereof, then an SEDF preform 91, 91'. The outside comprises a porous, or cellular, layer 92, 92' having a plurality of superabrasive particles 94, 94' distributed therein in an orderly fashion.

The assembly of Fig. 26 can be compressed in the direction indicated by the arrows 95, or in the direction indicated by the arrows 96. The inventor has used this technique, with pressure in the direction of the arrows 95, to manufacture diamond segments for saw blades, and a ream saw blade.

Fig. 28 illustrates the making of a cut-off disk. Individual pieces 98, or a complete ring, of the SEDF preform can be prepared of the proper shape, and placed around the periphery of a core 99. From the foregoing discussion it will be understood that the pieces 98 may include any number of layers, may or may not include porous layers, and may have as many or as few superabrasive particles as desired.

After the pieces 98, or the ring, is assembled on the core 99, the assembly will be sintered (preferably under pressure) so the sintering of the preform and fixing the preform to the core 99 are performed in one step.

Following are some specific examples of use of the technology of the present invention:

1. a) Make an SEDF preform in the form of a plate or a tape from a diamond retaining composition, e.g., from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an

application of the superabrasive articles. Do not mix these retaining powders with diamonds in the process of making SEDF preform.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Put diamonds into openings of the mesh type material and temporarily retain them with an adhesive carrier. As an option, the mesh type material can be then removed.

d) Apply SEDF preform against the carrier that includes superabrasive particles. As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device e.g., between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g., up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

2. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of the diamond particles and a diamond retaining composition, e.g., from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) As an option, separators can be placed on at least one side of the preform as disclosed in U.S. patent

5,203,880, "Method and Apparatus for Making Abrasive Tools", forming an assembly.

d) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

e) Heat the assembly under pressure, e.g. up to 1040°C and 300 kg/cm^2, so called "hot compacting".

f) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

3. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of a first plurality of diamonds and a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Put a second plurality of diamonds into openings of the mesh type material and temporarily retain them with an adhesive carrier. As an option, the mesh type material can be then removed.

d) Apply SEDF preform, including the first plurality of diamonds against the carrier including the second plurality of diamonds. As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g. up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

It should be understood that the first and second pluralities of diamonds, and generally, any superabrasive particles, can be of the same or different origin, size, shape and physical-mechanical parameters.

4. a) Make an SEDF preform in the form of a tape from a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles. Do not mix these retaining powders with diamonds in the process of making SEDF preform.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Take the nickel non-woven mat of National Standard, cut it into the proper pieces.

d) Assemble a sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, apply pressure and/or an adhesive to improve the integrity of this assembly.

e) Put diamonds into openings of the mesh type material and temporarily retain with an adhesive carrier. As an option, the mesh type material can be then removed.

f) Apply this carrier including the superabrasive particles against the sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g. up to 1040°C and 300 kg/cm^2, so galled "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

5. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of the superabrasive particles and a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Take the nickel non-woven mat of National Standard, cut it into the proper pieces.

d) Assemble a sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, apply pressure and/or an adhesive to improve the integrity of this assembly. As another option separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g., up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

6. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of the superabrasive particles and a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder

N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Take the nickel non-woven mat of National Standard, cut it into the proper pieces.

d) Assemble a sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, apply pressure and/or an adhesive to improve the integrity of this assembly.

e) Put diamonds into openings of the mesh type material and temporarily retain with an adhesive carrier. As an option, the mesh type material can be then removed.

f) Apply this carrier including the superabrasive particles against the sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g. up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

It should be understood that the preferred embodiments of the invention here presented comprise assemblies of superabrasive particles such as diamonds, cubic boron nitride or the like, distributed in an orderly fashion on a substrate, or a carrier, and a pre-made SEDF preform formed from metals, ceramics, epoxy materials with binders or other plastics. The assemblies of the above components are heated or sintered, preferably under an external pressure. The SEDF

preform may or may not include randomly distributed superabrasive particles therein; and, and a separator can be a part of the assembly itself to prevent contacting and/or diffusion between the SEDF preforms and the molding parts.

It will of course be understood by those skilled in the art that the particular embodiments of the invention here presented are by way of illustration only, and are meant to be in no way restrictive; therefore, numerous changes and modifications may be made, and the full use of equivalents resorted to, without departing from the spirit or scope of the invention as outlined in the appended claims.

Claims

1. In a method for making abrasive articles, wherein said abrasive articles comprise a quantity of a retaining powder and at least one plurality of superabrasive particles, said method including the steps of making a preform of said retaining powder, placing said plurality of superabrasive particles into said preform, and heating said preform, the improvement comprising the steps of making said preform of a binder and said quantity of retaining powder wherein the volume of said binder is greater than the volume of said quantity of retaining powder, so that said preform is soft, easily deformable and flexible.

2. In a method as claimed in claim 1, the further improvement wherein the said step of heating said preform includes the steps of heating said preform while exerting pressure on said preform.

3. In a method as claimed in claim 1, the improvement including the step of adding said superabrasive particles to said binder and retaining powder before the said step of making said preform.

4. In a method as claimed in claim 1, wherein the said step of placing said plurality of superabrasive particles into said preform comprises the step of placing said plurality of superabrasive particles on one side of said preform.

5. In a method as claimed in claim 1, the improvement wherein said step of placing said plurality of superabrasive particles into said preform comprises the step of randomly distributing said superabrasive particles.

6. In a method as claimed in claim 1, the improvement wherein said step of placing said plurality of superabrasive particles into said preform comprises the step of distributing said superabrasive particles in an orderly fashion.

7. In a method as claimed in claim 1, the further improvement wherein the said step of making said preform comprises the step of forming said preform on a substrate.

8. In a method as claimed in claim 7, the improvement including the step of placing said plurality of superabrasive particles on said substrate prior to the said step of forming said preform.

9. In a method as claimed in claim 8, the improvement wherein said superabrasive particles are randomly distributed on said substrate.

10. In a method as claimed in claim 8, the improvement wherein said superabrasive particles are distributed on said substrate in an orderly fashion.

11. In a method as claimed in claim 8, the improvement wherein said substrate includes a plurality of openings extending to the surface of said substrate, and including the step of placing said superabrasive particles in said openings of said substrate.

12. In a method as claimed in claim 1, the further improvement comprising the step of placing a porous layer against said preform for making an assembly prior to the said step of heating said preform, said porous layer having a plurality of openings extending to the surface thereof for restraining movement of said retaining powder and said superabrasive particles.

13. In a method as claimed in claim 12, the improvement including the step of placing said porous layer between said superabrasive particles and said preform.

14. In a method as claimed in claim 12, the improvement including the step of placing another preform against said porous layer prior to the said step of heating said preform.

15. In a method as claimed in claim 12, the further improvement wherein the said step of making a preform is carried out by making said preform on a substrate, said substrate having openings therein and acting as said porous layer.

16. In a method as claimed in claim 15, the improvement including the step of placing said superabrasive particles on said substrate prior to the step of making said preform.

17. In a method as claimed in claim 12, wherein the porous layer is selected to have a lower melting point than the retaining powder, and further including the step of heating the assembly sufficiently to melt said porous layer.

18. The product made in accordance with claim 15.

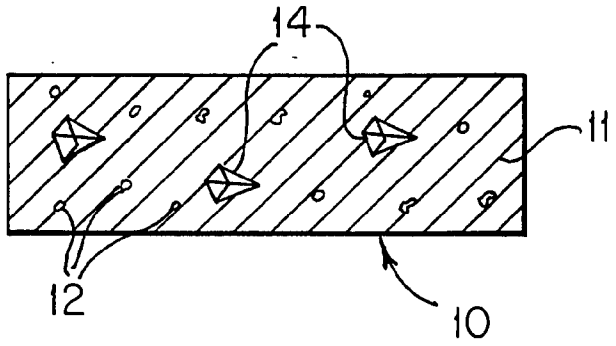


FIG. 1

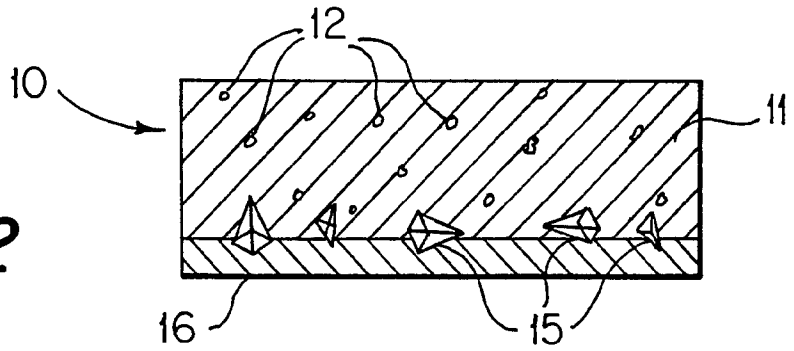


FIG. 2

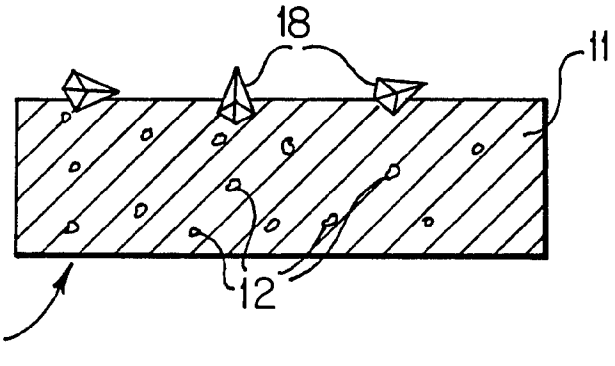


FIG. 3

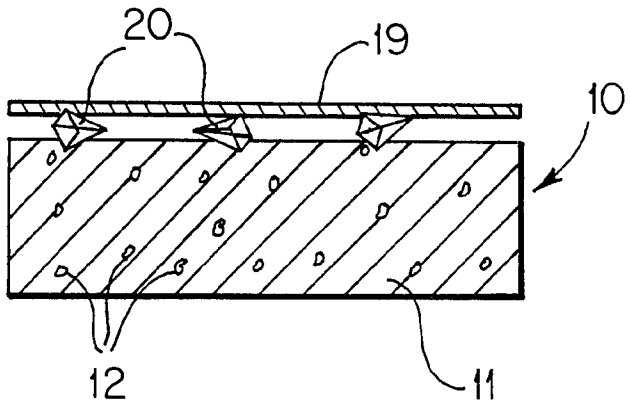


FIG. 4

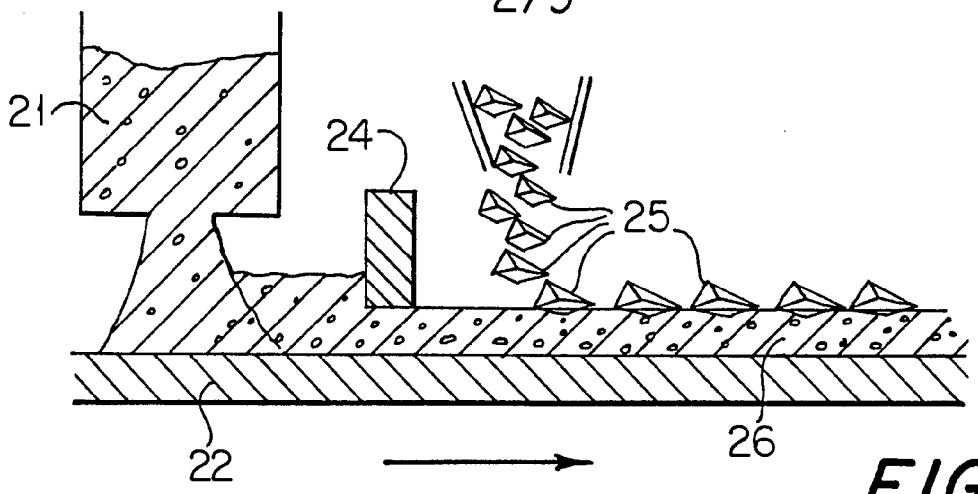


FIG. 5

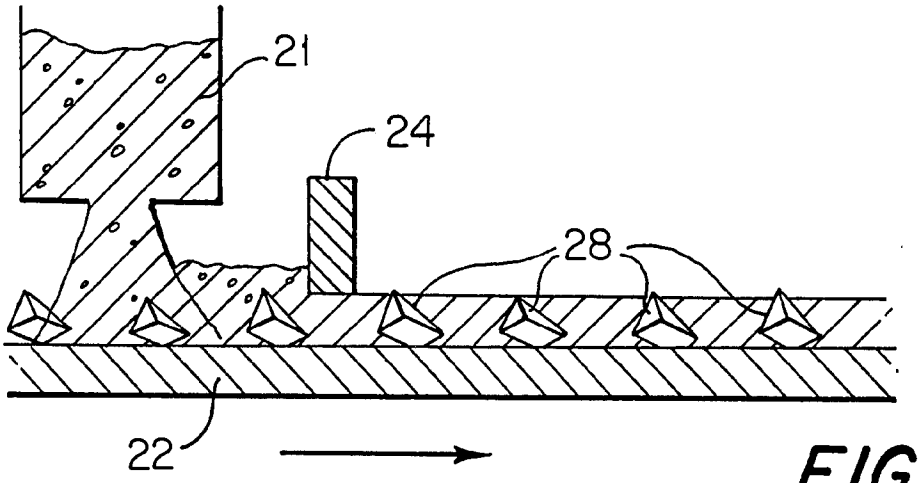


FIG. 6

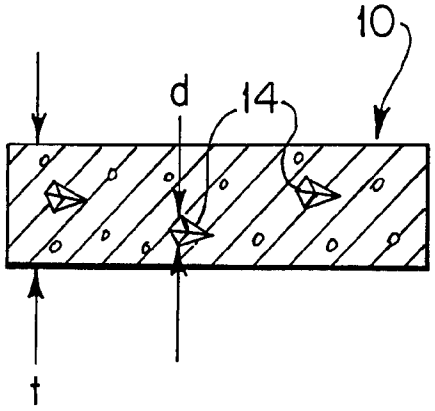


FIG. 7

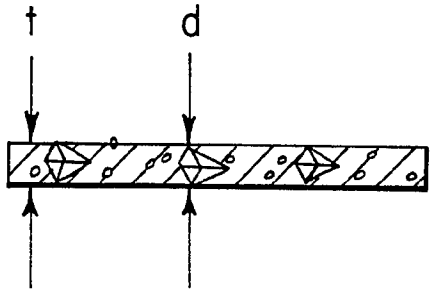


FIG. 8

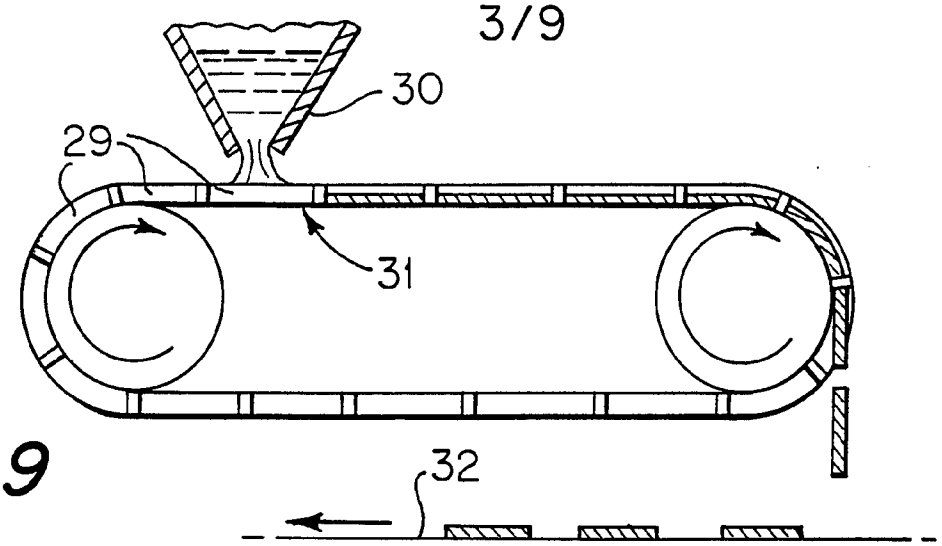


FIG. 9

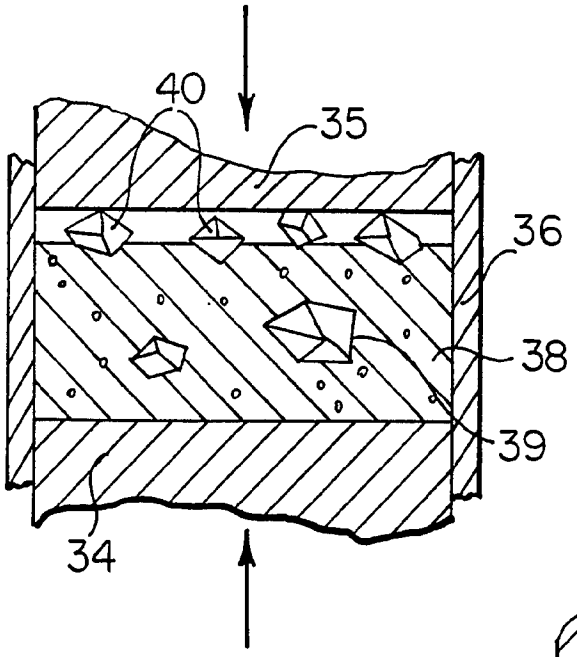


FIG. 10

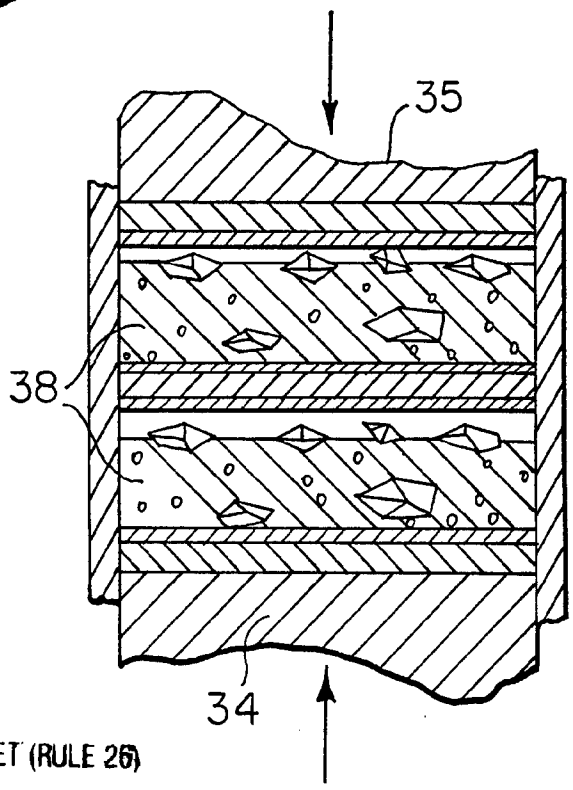


FIG. 10A

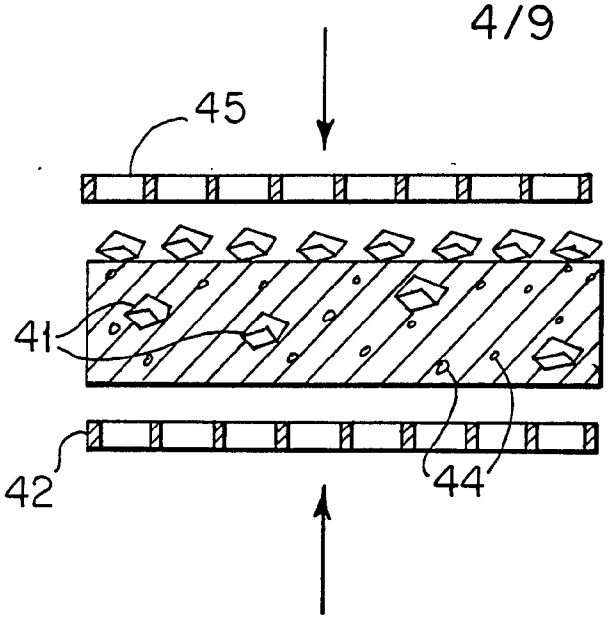


FIG. 11

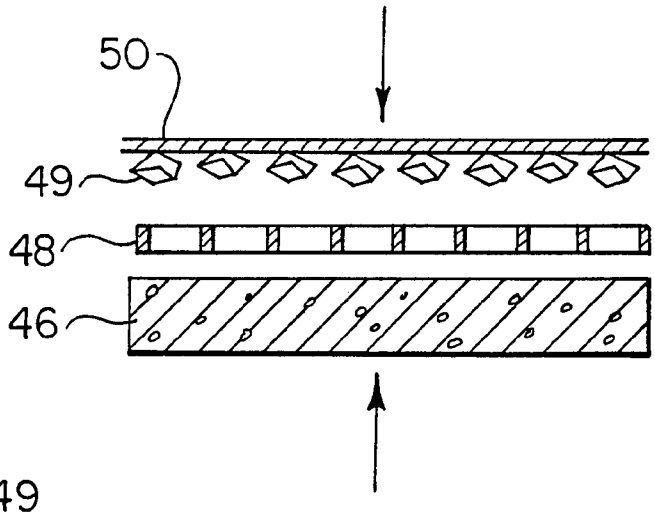


FIG. 12

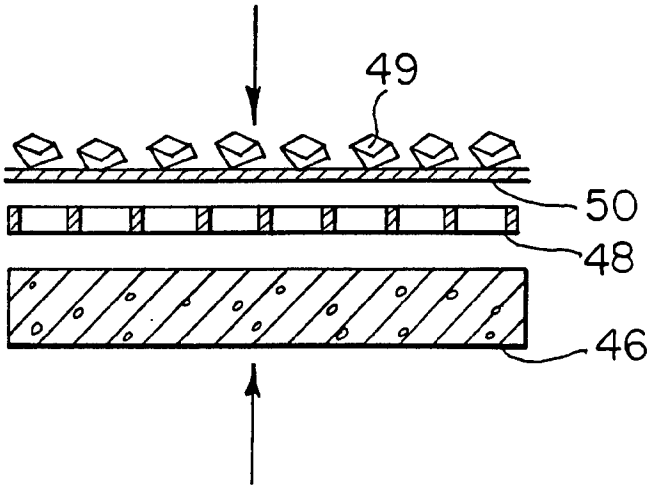


FIG. 13

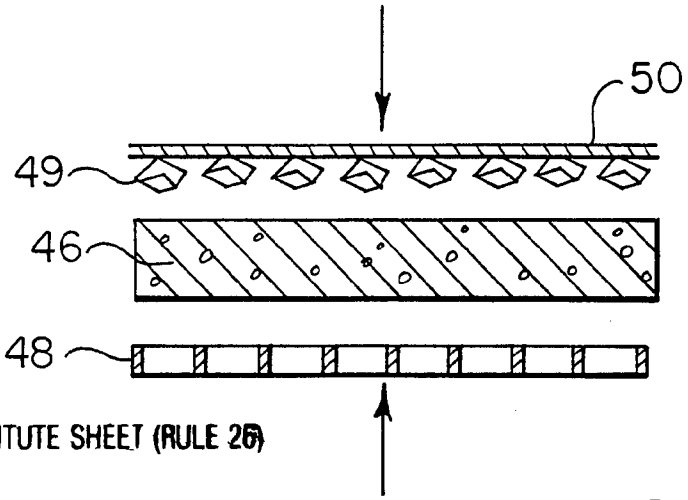


FIG. 14

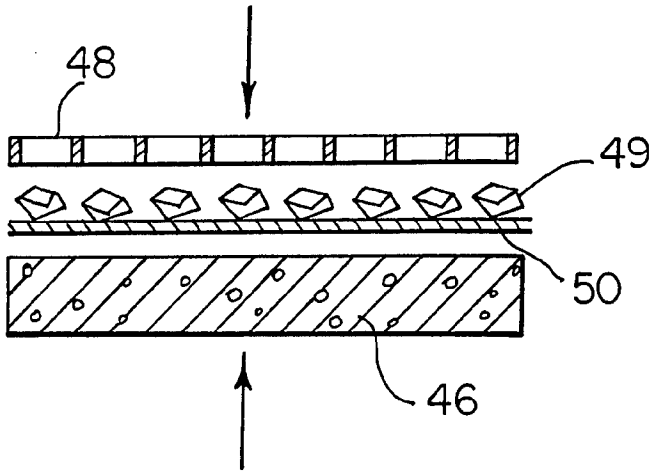


FIG. 15

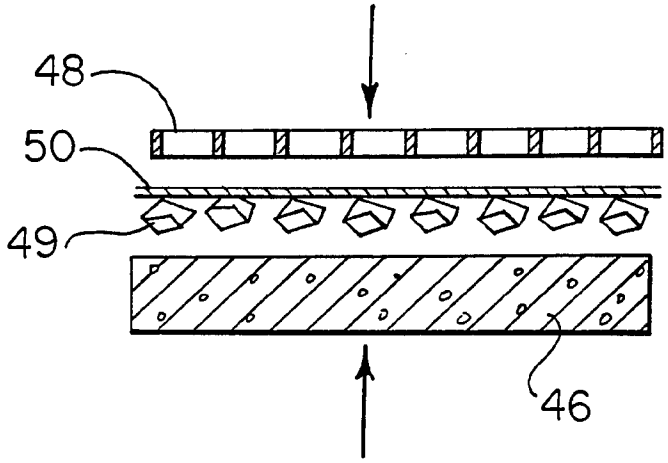


FIG. 16

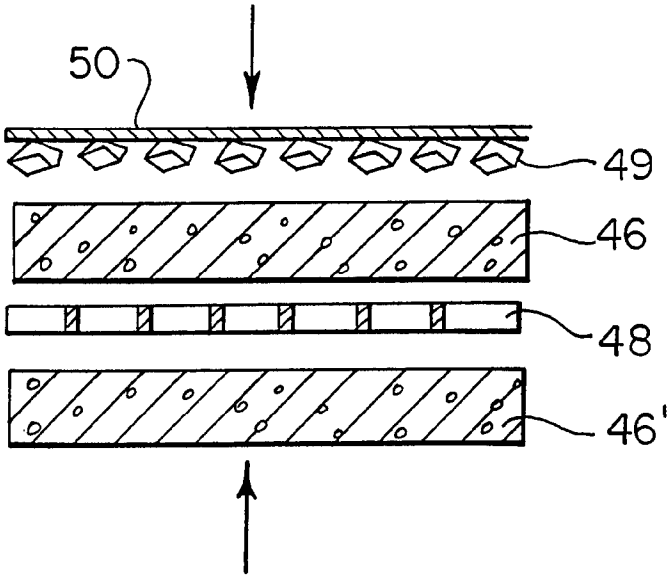


FIG. 17

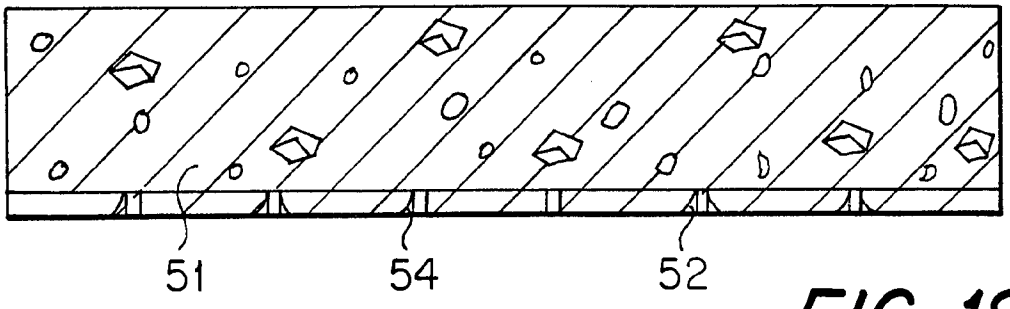


FIG. 18

Ex. 1003, Page 578

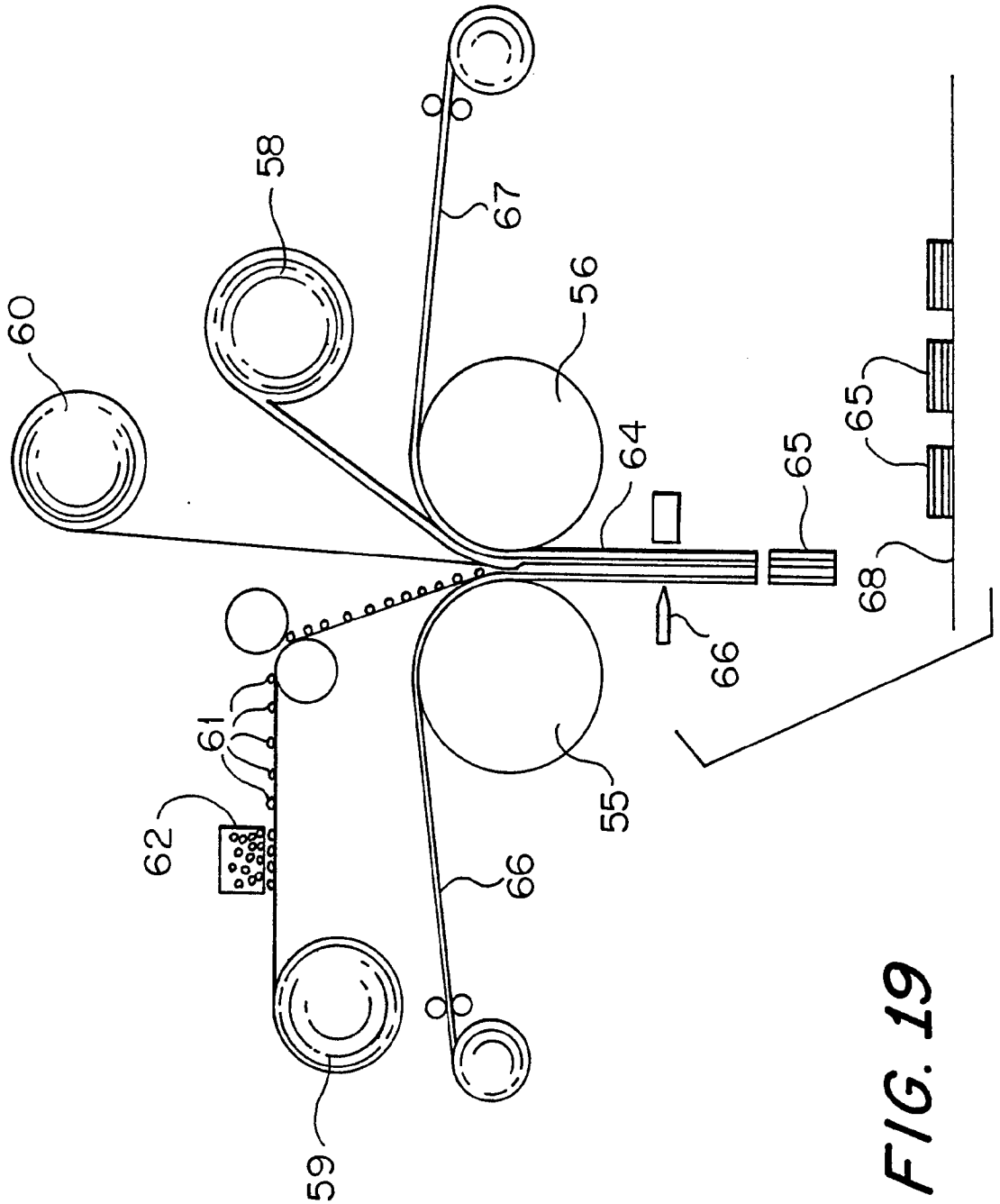


FIG. 19

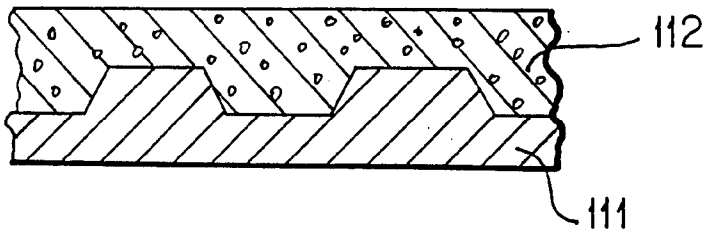


FIG. 19A

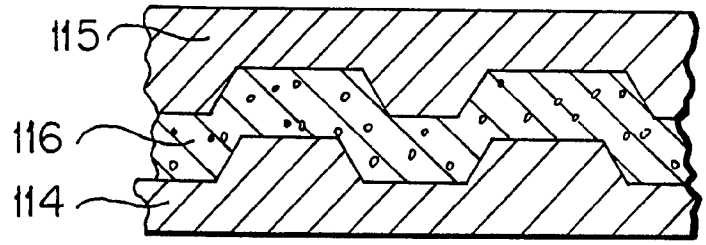


FIG. 19B

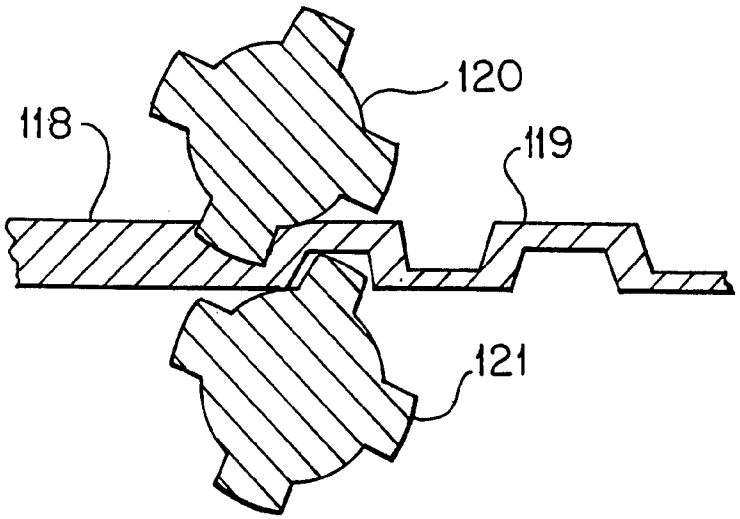


FIG. 19C

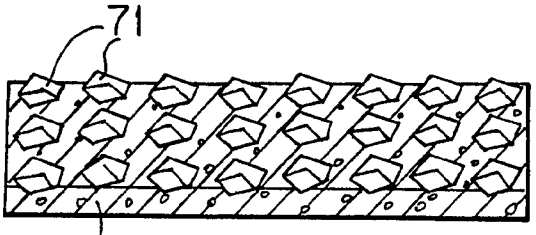


FIG. 21

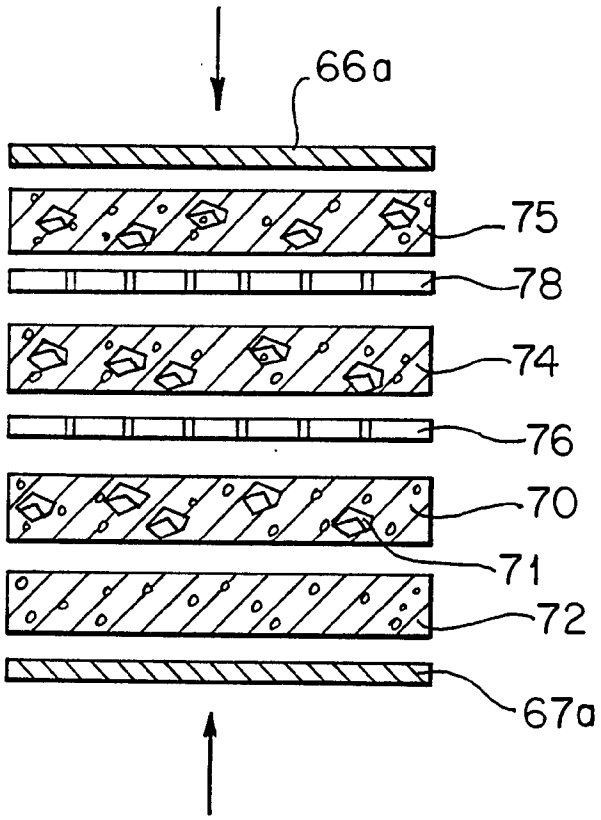


FIG. 20

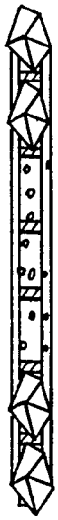


FIG. 23

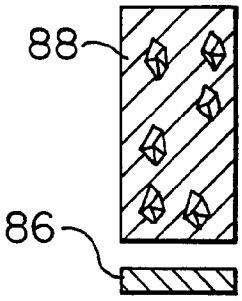


FIG. 24

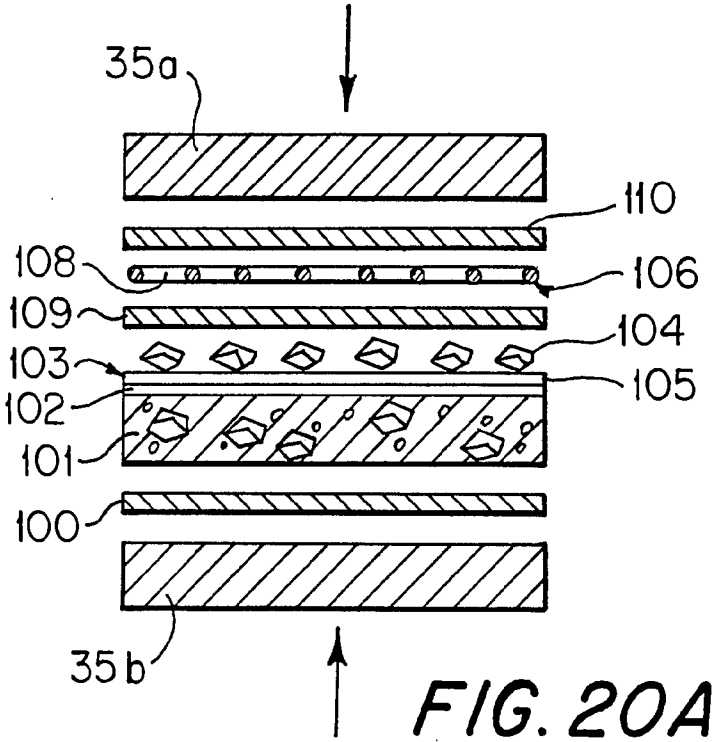


FIG. 20A

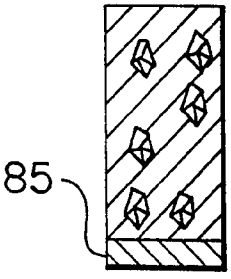


FIG. 25

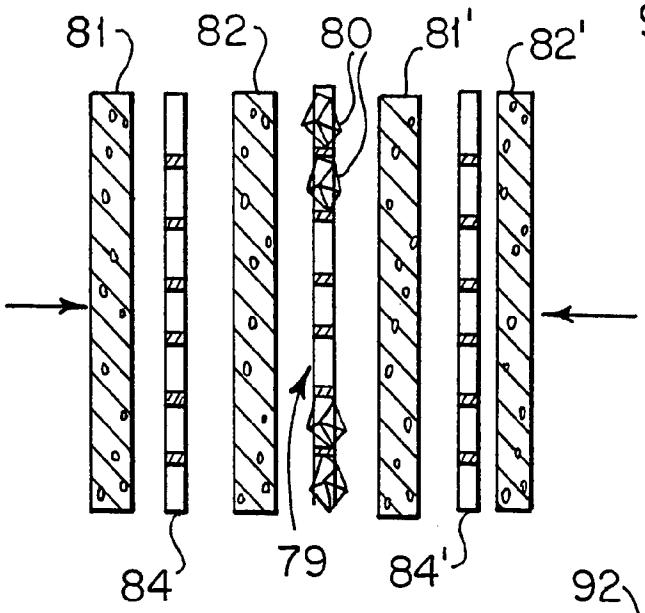


FIG. 22

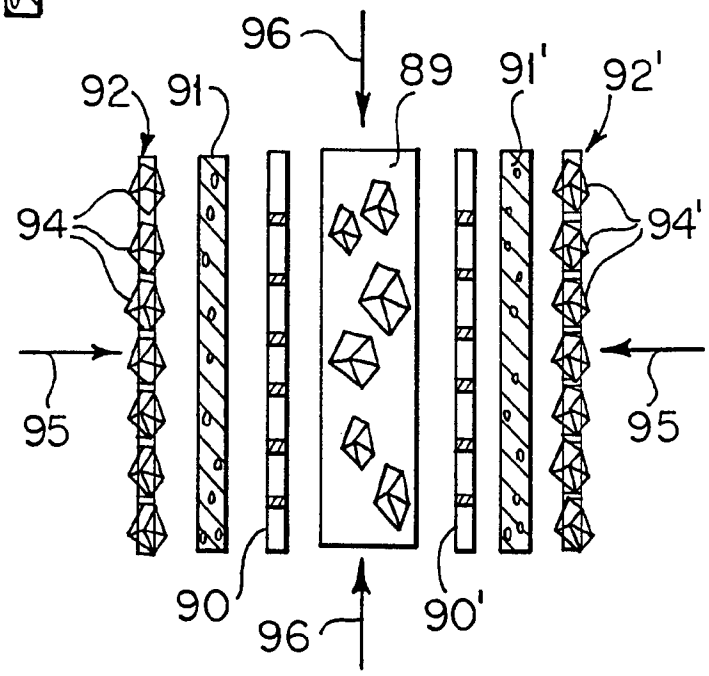


FIG. 26

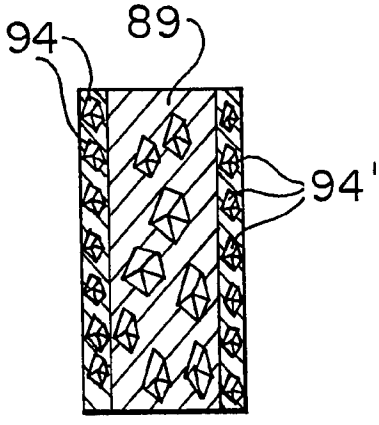


FIG. 27

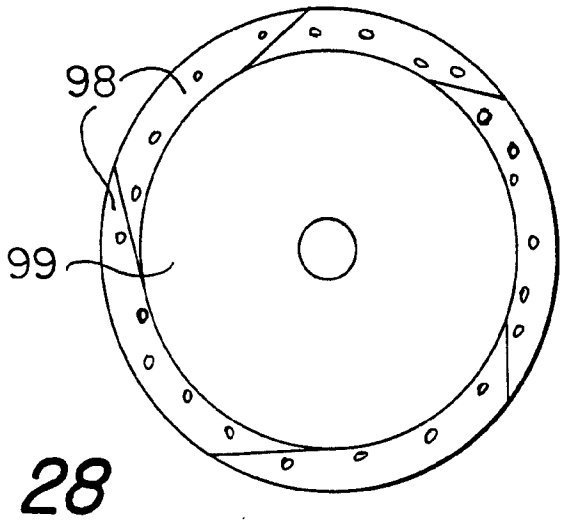


FIG. 28

INTERNATIONAL SEARCH REPORT

Inter ıal Application No
PCT/US 95/01503

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24D18/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24D B22F

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,5 264 011 (BROWN LAWRENCE E ET AL) 23 November 1993 see column 6, line 57 - column 7, line 32; figure 1 ---	1
A	US,A,5 203 880 (TSELESIN NAUM N) 20 April 1993 cited in the application see claims ---	1
A	US,A,5 092 910 (DEKOK PETER T ET AL) 3 March 1992 cited in the application see claims ---	1
A	US,A,4 409 054 (RYAN EDWARD J) 11 October 1983 see claims ---	1
	-/--	

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 June 1995	20. 06. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Eschbach, D

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Ex. 1003, Page 583

INTERNATIONAL SEARCH REPORT

Interr ıal Application No
PCT/US 95/01503

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document; with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 242 955 (DRESSER IND) 28 October 1987 see page 4, line 28 - line 37	1
A	EP,A,0 533 443 (GEN ELECTRIC) 24 March 1993 see page 3, column 3, line 30 - column 4, line 21	1
A	EP,A,0 407 069 (UNICORN IND PLC) 9 January 1991 see abstract; figure 3	1
A	EP,A,0 204 195 (NORTON CO) 10 December 1986 see abstract; figure 1	1
A	US,A,5 221 294 (CARMAN LEE A ET AL) 22 June 1993 see column 4, line 39 - line 43	1

INTERNATIONAL SEARCH REPORT

...formation on patent family members

Inter ...al Application No
PCT/US 95/01503

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-5264011	23-11-93	NONE		
US-A-5203880	20-04-93	NONE		
US-A-5092910	03-03-92	US-A-	4925457	15-05-90
		AU-A-	5080090	05-09-90
		CA-A-	2025567	31-07-90
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		JP-T-	3505849	19-12-91
		WO-A-	9009260	23-08-90
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		US-A-	5190568	02-03-93
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EP-A-0533443	24-03-93	US-A-	5143523	01-09-92
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		JP-A-	5208312	20-08-93
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		JP-A-	3049874	04-03-91
		US-A-	5094671	10-03-92
EP-A-0204195	10-12-86	US-A-	4634453	06-01-87
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		KR-B-	9401132	14-02-94
US-A-5221294	22-06-93	US-A-	5160509	03-11-92

Espacenet

Bibliographic data: WO9427883 (A1) — 1994-12-08

CLOSURE

Inventor(s): KOEHN JOCHEN [DE]; HEYN KLAUS [DE] ± (KOEHN, JOCHEN, ; HEYN, KLAUS)

Applicant(s): ZELLER PLASTIK KOEHN GRAEBNER [DE]; KOEHN JOCHEN [DE]; HEYN KLAUS [DE] ± (ZELLER PLASTIK GMBH, ; KOEHN, JOCHEN, ; HEYN, KLAUS)

Classification: - international: ***B65D47/20; B65D47/24; B65D47/26;*** (IPC1-7): B65D47/20; B65D47/24; B65D47/26
- cooperative: **B65D47/2031; B65D47/244; B65D47/265;** B65D2101/0023

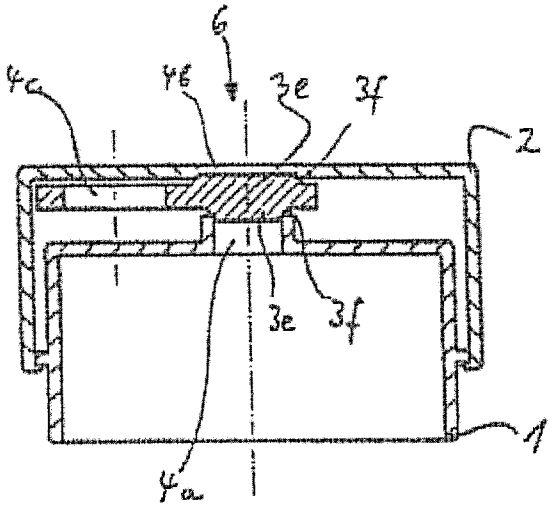
Application number: WO1994EP01695 19940525

Priority number (s): DE19934317550 19930526 ; DE19934343031 19931216

Also published as: ES2126120 (T3) EP0700354 (A1) EP0700354 (B1) AU6971694 (A) AT174295 (T)

Abstract of WO9427883 (A1)

A closure may be easily moved into an open and into a closed position and reliably seals an opening, for example of a container. To open and close the closure, a middle part (3) may be linearly moved or rotated between a top and a bottom part (2, 1). Pre-stressing the middle part (3) between top and bottom parts (2, 1) allows an opening to be sealed.



PCT

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Internationales Büro

INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)

(51) Internationale Patentklassifikation [5]: B65D 47/26, 47/24, 47/20

A1

(11) Internationale Veröffentlichungsnummer: **WO 94/27883**

(43) Internationales Veröffentlichungsdatum: 8. December 1994 (08.12.94)

(21) Internationales Aktenzeichen: PCT/EP94/01695

(22) Internationales Anmeldedatum: 25. Mai 1994 (25.05.94)

(30) Prioritätsdaten:

P 43 17 550.3	26. Mai 1993 (26.05.93)	DE
P 43 43 031.7	16. December 1993 (16.12.93)	DE

(71) Anmelder *(für alle Bestimmungsstaaten ausser US)*: ZELLER PLASTIK GMBH [DE/DE]; Barlstrasse 46, D-56856 Zell/Mosel (DE).

(72) Erfinder; und

(75) Erfinder/Anmelder *(nur für US)*: KOEHN, Jochen [DE/DE]; Bernkasteler Weg 29, D-56841 Traben-Trarbach (DE). HEYN, Klaus [DE/DE]; Obere Bergstrasse 14, D-56859 Bullay (DE).

(74) Anwalt: VOSSIUS & PARTNER; Siebertstrasse 4, D-81675 München (DE).

(81) Bestimmungsstaaten: AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, KZ, LK, LU, LV, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, UZ, VN, europäisches Patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI Patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Veröffentlicht

Mit internationalem Recherchenbericht.

Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist. Veröffentlichung wird wiederholt falls Änderungen eintreffen.

(54) Title: CLOSURE

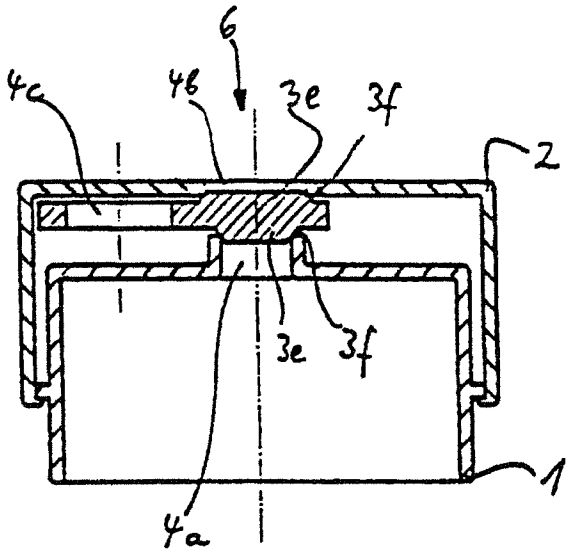
(54) Bezeichnung: VERSCHLUSS

(57) Abstract

A closure may be easily moved into an open and into a closed position and reliably seals an opening, for example of a container. To open and close the closure, a middle part (3) may be linearly moved or rotated between a top and a bottom part (2, 1). Pre-stressing the middle part (3) between top and bottom parts (2, 1) allows an opening to be sealed.

(57) Zusammenfassung

Es wird ein Verschluß zur Verfügung gestellt, der leicht in eine geschlossene und eine geöffnete Stellung bewegbar ist und zuverlässig eine Öffnung, z.B. eines Behälters abdichten kann. Das Öffnen und Schließen kann durch eine lineare Verschiebung oder Drehung eines Mittelteils (3) zwischen einem Ober- und einem Unterteil (2, 1) erfolgen, wobei eine Vorspannung zwischen dem Ober- und dem Unterteil (2, 1) das Mittelteil (3) auf einer Öffnung abdichten kann.



LEDIGLICH ZUR INFORMATION

Codes zur Identifizierung von PCT-Vertragsstaaten auf den Kopfbögen der Schriften, die internationale Anmeldungen gemäss dem PCT veröffentlichen.

AT	Österreich	**GA**	Gabon	**MR**	Mauretanien
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BJ	Benin	**IE**	Irland	**PL**	Polen
BR	Brasilien	**IT**	Italien	**PT**	Portugal
BY	Belarus	**JP**	Japan	**RO**	Rumänien
CA	Kanada	**KE**	Kenya	**RU**	Russische Föderation
CF	Zentrale Afrikanische Republik	**KG**	Kirgisistan	**SD**	Sudan
CG	Kongo	**KP**	Demokratische Volksrepublik Korea	**SE**	Schweden
CH	Schweiz	**KR**	Republik Korea	**SI**	Slowenien
CI	Côte d'Ivoire	**KZ**	Kasachstan	**SK**	Slowakei
CM	Kamerun	**LI**	Liechtenstein	**SN**	Senegal
CN	China	**LK**	Sri Lanka	**TD**	Tschad
CS	Tschechoslowakei	**LU**	Luxemburg	**TG**	Togo
CZ	Tschechische Republik	**LV**	Lettland	**TJ**	Tadschikistan
DE	Deutschland	**MC**	Monaco	**TT**	Trinidad und Tobago
DK	Dänemark	**MD**	Republik Moldau	**UA**	Ukraine
ES	Spanien	**MG**	Madagaskar	**US**	Vereinigte Staaten von Amerika
FI	Finnland	**ML**	Mali	**UZ**	Usbekistan
FR	Frankreich	**MN**	Mongolei	**VN**	Vietnam

Verschluß

Die Erfindung betrifft einen Verschluß, insbesondere für einen Behälter mit pastösen bis flüssigen Füllgütern. Flüssigkeit. Der Verschluß läßt sich jedoch auch als Abschluß für Leitungen von insbesondere Flüssigkeiten einsetzen.

Der Erfindung liegt die Aufgabe zugrunde, einen Verschluß zur Verfügung zu stellen, der leicht zwischen einer geöffneten und einer geschlossenen Stellung bewegbar ist und zuverlässig eine Öffnung z.B. für Flüssigkeiten abdichten kann.

Die Aufgabe wird mit den Merkmalen der Patentansprüche gelöst.

Bei der Lösung geht die Erfindung von dem Grundgedanken aus, ein Mittelteil zwischen einem Unterteil mit einer Öffnung und einem auf dem Unterteil drehbar angeordneten Oberteil anzuordnen, wobei das Mittelteil mit dem Oberteil in kraftschlüssiger Verbindung steht und die Öffnung durch lineare

Verschiebung, Verschwenken oder durch eine über eine zahnradartige Verbindung übertragene Drehbewegung verschließt, und wobei alternativ oder zusätzlich das Oberteil gegen das Unterteil elastisch vorspannbar sein kann und diese Vorspannung das Mittelteil gegen die Öffnung abdichtend drückt.

Im folgenden wird die Erfindung anhand der Zeichnungen näher erläutert. Es zeigen:

Fig. 1 einen Querschnitt einer erfindungsgemäßen Ausführungsform im geöffneten Zustand,

Fig. 2 die erfindungsgemäße Ausführungsform gemäß Fig. 1 im geschlossenen Zustand,

Fig.3 und 4 die erfindungsgemäßen Ausführungsformen gemäß Figuren 1 und 2 mit einem zusätzlich eingebautem Ventil,

Fig. 5 einen Querschnitt längs der Linie A-A' in Fig. 4 mit einem Pendelschieber,

Fig. 6 einen Querschnitt längs der Linie A-A' in Fig. 4 mit einem Drehschieber,

Fig. 7 eine erfindungsgemäße Ausführungsform des Pendelschiebers bzw. Drehschiebers gemäß Figuren 5 und 6 im Querschnitt längs der Linie B-B',

Fig. 8 eine weitere erfindungsgemäße Ausführungsform eines Drehschiebers,

Fig. 9 einen Querschnitt durch eine weitere erfindungsgemäße Ausführungsform,

Fig. 10 einen Querschnitt längs der Linie C-C' in Fig. 9,

Fig. 11 einen Querschnitt längs der Linie D-D' in Fig. 9,

Fig. 12 einen Querschnitt durch eine weitere erfindungsgemäße Ausführungsform,

Fig. 13 einen Querschnitt längs der Linie E-E' in Fig. 12,

Fig. 14 einen Querschnitt längs der Linie F-F' in Fig. 12,

Fig. 15 einen vergrößerten Teilquerschnitt längs der Linie G-G' in Fig. 12,

Fig. 16 eine vergrößerte Darstellung einer Originalitätssicherung gemäß Fig. 12,

Fig. 17a einen Querschnitt durch eine weitere erfindungsgemäße Ausführungsform,

Fig. 17b einen Querschnitt längs der Linie H-H' in Fig. 17a, und

Fig. 18 einen Teilquerschnitt durch eine weitere Ausführungsform.

Fig. 1 zeigt eine erfindungsgemäße Ausführungsform eines Verschlusses in geöffneter Stellung. Der Verschluß besteht aus einem Unterteil bzw. Grundkörper 1, einem Oberteil bzw. einer Drehkappe 2 und einem zwischen den beiden angeordneten verschiebbaren Mittelteil 3. Der Grundkörper 1 und die Drehkappe 2 sind als gegeneinander gewölbte elastisch verformbare Membranen ausgebildet, die miteinander durch eine Öffnung 4c im Mittelteil 3 hindurch ausgerichtete Öffnungen 4a und 4b aufweisen. Die Drehkappe 2 ist drehbar am Grundkörper 1 gehaltert. Die Öffnungen 4a und 4b sind vorzugsweise wie in den vorstehend beschriebenen Ausführungsformen mittig in bezug zur Drehachse angeordnet, so daß beim Verdrehen des einen Verschlußteils gegenüber dem anderen die Öffnungen zueinander ausgerichtet bleiben.

Beim Schließen des Verschlusses wird das Mittelteil 3 durch Drehen der Drehkappe 2 über eine kraftschlüssige Verbindung, z.B.einen Mitnehmer 14 oder eine zahnradartige Verbindung 9 (Figuren 5 und 6) in den von den Öffnungen 4a und 4b ausgebildeten Durchlaß 6 gebracht. Dabei werden wobei der membranartig ausgebildete Grundkörper 1 und die Drehkappe 2 auseinandergebogen, so daß sie durch Vorspannung fest auf das Mittelstück 3 drücken und dieses den Durchlaß 6 abdichtet. Das Mittelteil 3 kann wahlweise als Pendelschieber 3a (Fig, 5) oder als Drehschieber 3b (Fig. 6) ausgebildet sein.

Wie in der Figur deutlich erkennbar, weist das Mittelteil einen dickeren Abschnitt auf, der aus einander gegenüberliegenden Erhabenheiten 3e an der Unterseite und der Oberseite gebildet wird. Diese Erhabenheiten 3e sind in Größe und Form den zugehörigen Öffnungen 4a, 4b, derart angepaßt, daß diese den Durchlaß dichtend verschließen, wenn das Mittelteil 3 in die Schließstellung gebracht wird. Die Erhabenheiten 3e gehen mit einer umlaufenden schrägen Fläche 3f in die umgebenden Flächenteile des Mittelteils 3 über. Diese Schrägflächen bilden in vorteilhafter Weise die Dichtflächen mit den anliegenden Kanten der zugehörigen Öffnungen 4a, 4b im Unterteil 1 bzw. Oberteil 2. Die Schrägflächen 3f bewirken eine Ausrichtung der jeweiligen Erhabenheit 3e in den zugehörigen Öffnungen 4a, 4b, die durch die zwischen dem Oberteil 2 und dem Unterteil 1 vorhandene Vorspannung selbsttätig beim Einrasten des Mittelteils 3 in der Schließlage erfolgt. Die entsprechende seitliche Beweglichkeit der Teile zueinander wird durch ein vorgesehenes Spiel erreicht. Die Schrägflächen 3f haben außerdem den Vorteil, daß beim Öffnen des Verschlusses die Erhabenheiten 3e die Öffnungen 4a, 4b bzw. die umlaufenden Kanten im Unterteil 1 und Oberteil 2 voneinander wegdrücken.

Die Figuren 3 und 4 zeigen die erfindungsgemäße Ausführungsform gemäß Figuren 1 und 2 in ihrer geöffneten Stellung mit einem Ventileinsatz 13 im Bereich der Öffnung 4a des Grundkörpers 1. Der Ventileinsatz 13 besteht aus elastischem Material. Dieser ist in Fig. 3 in ausgestülpter Position und in Fig. 4 in eingesetzter Position gezeigt, wobei das Mittelteil 3 die Öffnung des Ventileinsatzes 13 abdichtet. Vorzugsweise wird als Ventileinsatz das in der US-PS-4,991,745 oder der EP-A-395 380 beschriebene Ventil verwendet.

Fig. 5 zeigt eine erfindungsgemäße Ausführungsform des Mittelteils 3 als Pendelschieber 3a. Der Pendelschieber 3a wird bei einer Drehbewegung α der Drehkappe 2 durch einen an der Drehkappe 2 befestigten Mitnahmestift 14, der in einen

Schlitz 5 im Pendelschieber 3a eingreift, um die Strecke H linear waagerecht verschoben, wobei die Ventilöffnung 13 entweder geöffnet oder geschlossen wird. In den beiden Endstellungen wird der Pendelschieber 3a durch zwei Federnasen 7 jeweils mit einer Aussparung 8 gehalten.

Fig. 6 zeigt den Querschnitt A-A' gemäß Fig. 4 mit einer erfindungsgemäßen Ausführungsform des Mittelstückes 3 als Drehschieber 3b. Der Drehschieber 3b wird durch einen Drehbewegung α der Drehkappe 2 über eine zahnradartige Verbindung 9 um 180° in die geöffnete oder geschlossene Stellung gedreht.

Fig. 7 zeigt einen Querschnitt durch den Pendelschieber 3a oder den Drehschieber 3b längs der Linie B-B' in den Figuren 5 und 6. Die Schieber weisen seitlich eine keilförmige Verdickung 10 an der Ober- und Unterseite auf, die die Membranen des Grundkörpers 1 und der Drehkappe 2 beim Übergang in die geschlossene Stellung des Schiebers auseinanderpressen.

Fig. 8 zeigt eine Draufsicht auf eine weitere erfindungsgemäße Ausführungsform eines Drehschiebers 3b im geschlossenen Zustand. Der Drehschieber weist ein nierenförmiges Langloch 11 und eine am Kreisumfang angeordnete keilförmige Verdickung 10 auf. Das Langloch 11 ermöglicht es z.B. einem vorstehenden Ventil 13 sich zurückzuziehen, bevor der Drehschieber 3b in die geschlossene Stellung gleitet.

Fig. 9 zeigt eine weitere erfindungsgemäße Ausführungsform mit einem Pendelschieber 3c. Der Mitnehmer 14 ragt durch einen Schlitz 23 im Pendelschieber 3c in eine Aussparung 24 in einer Führungsplatte (nicht dargestellt). Dadurch wird eine bessere Sicherung gegen ein Herausrutschen des Mitnehmers 14 bei einer gegebenenfalls vorhandenen unbeabsichtigten Vertikalbewegung des Oberteils 2 erreicht, die beispielsweise bei einem vorhandenen Spiel, Stößen oder Verbiegungen des Oberteils auftreten kann. Der Pendelschieber 3c

ist im Querschnitt U-förmig ausgebildet und weist auf jeder Seite zwei Schenkel 25 auf, die unter der Zeichenebene liegen und gestrichelt dargestellt sind Außerdem weist der Pendelschieber 3c seitlich eine federnde Nase 7 auf, die in zwei Aussparungen 8 in einer der Führungsschienen 15 einrastbar ist. Die Nachgiebigkeit der Nase 7 wird durch einen benachbarten, im Pendelschieber 3c angeordneten Schlitz 26 erreicht. Außerdem weist das Unterteil 1 vier dem Oberteil 2 zugewandte Anschläge 27 auf, an die zwei am Oberteil 2 angeordnete Vorsprünge 28 anschlagen und so die Drehbewegung des Oberteils 2 stoppen, wenn der Pendelschieber die geöffnete bzw. die geschlossene Stellung des Verschlusses erreicht hat, und als Anschlag zum Auf- und Abschrauben des Verschlusses auf einen Behälter dienen können.

In Fig. 10 ist ein Querschnitt längs der Linie C-C' in Fig. 9 dargestellt. Der Verschluß befindet sich in geschlossenem Zustand, und der Pendelschieber 3c verschließt die Entnahmeöffnung 4a mit dem Ventileinsatz 13. Zwischen dem Unterteil 1 und dem Pendelschieber 3c ist eine Führungsplatte 20 angeordnet, auf der der Pendelschieber 3c gleitet und die mit Stiften 22 in dem Unterteil 1 arretiert ist. Die Führungsplatte 20 haltert im Klemmsitz den Ventileinsatz 13. Der Verschluß ist über eine Verschraubung 18 an seinem Unterteil mit einem Behälter 19 verbunden, wobei eine umlaufende Dichtlippe 34 das Unterteil 1 gegen das Innere des Behälters 19 abdichtet. Das Unterteil 1 liegt seitlich mit einer umlaufenden Fläche 29 an dem Behälter 19 an, wobei der Innenraum zwischen dem Unterteil 1 und dem Behälter 19 abgedichtet wird. Das Oberteil 2 ist auf dem Unterteil 1 drehbar mittels zweier umlaufender, ineinander eingepaßter elastischer Lippen 30 gehaltert.

Fig. 11 zeigt einen Querschnitt längs der Linie D-D' in Fig, 9. Es ist der U-förmige Querschnitt des Pendelschiebers 3c mit dem Schenkeln 25 in den Führungsschienen 15 der Führungsplatte 20 zu erkennen.

Fig. 12 stellt den Querschnitt einer weiteren erfindungsgemäßen Ausführungsform dar. In dieser Ausführungsform ist das Mittelteil 3 als Schwenkteil 3d ausgebildet, das am Rande des Verschlusses um einen Zapfen 16 schwenkbar ist. Das Schwenkteil 3d wird durch einen am Oberteil 2 befestigten Mitnehmer 14, der durch einen Schlitz 23 in dem Schwenkteil 3d in eine Aussparung 24 in einem Führungsring 21 ragt, durch Drehen des Oberteils 2 in eine geöffnete oder geschlossene Stellung des Verschlusses geschwenkt. Das Schwenkteil 3d hat im wesentlichen die gleiche Funktion wie das Mittelteil 3 bei den anderen Ausführungsformen und hat eine Öffnung 4c, die mit den Öffnungen 4a und 4b ausgerichtet werden kann.

Das Unterteil 1 weist zwei Ausschnitte 1a auf, in die das Schwingteil 3d in der offenen bzw. geschlossenen Stellung des Verschlusses hineinragt. Dadurch kann der Schwenkwinkel des Schwengteils weiter vergrößert werden.

Der Verschluß weist ferner eine Originalitätssicherung 17 mit einer Sollbruchstelle 17a auf, die bei einer erstmaligen Verwendung des Verschlusses abgeschert wird. Ferner weist der Verschluß zwei Anschläge 27 und zwei Vorsprünge 28 am Oberteil 2 auf. Die Anschläge 27 dienen als Raststellen für die offene oder geschlossene Stellung des Verschlusses, wobei jeweils eine federnde Nase 7, der im Schwenkteil 3d ein Schlitz 26 benachbart ist, hinter dem Anschlag 27 einrastet. Außerdem dienen die Anschläge 27 als Anschläge an die Vorsprünge 28 zum Auf- und Abschrauben des Verschlusses auf einen Behälter.

Fig. 13 zeigt einen Querschnitt längs der Linie E-E' in Fig. 12, wobei der Verschluß geschlossen ist. Der Führungsring 21 ist zwischen dem Schwenkteil 3d und dem Unterteil 1 angeordnet und haltert den Ventileinsatz 13 im Klemmsitz. Der Verschluß ist mittels der Verschraubung 18 mit einem Behälter

19 verbunden und weist eine Abschraubsicherung 31, 31a zwischen dem Behälter 19 und dem Unterteil 1 auf. Das Unterteil 1 ist gegen den Behälter 19 abgeschlossen und sitzt mittels einer umlaufenden Dichtwulst 32 auf dem Behälter 19 auf. Eine radial nach außen vorspringende Stufe am Unterteil 1 erlaubt das leichte Aufdrehen des Verschlusses auf die Abschraubsicherung des Behälters. Die Abschraubsicherung wird von mehreren am Unterteil 1 im Bereich der Stufe 33 angeordneten Vorsprüngen 31 und von damit in Eingriff bringbaren Vorsprüngen 31a am Behälter 19 gebildet.

Fig. 14 ist ein Querschnitt längs der Linie F-F' in Fig. 12. Unterhalb der Schnittebene sind die Anschläge 27 zu erkennen, die auf dem Grundkörper 1 stehen.

Fig. 15 zeigt einen vergrößerten Teilquerschnitt längs der Linie G-G' in Fig. 12. Dabei ist der vom Oberteil 2 herabragende Mitnehmer 14 in dem Schlitz 23 des Schwenkteils 3d und der Vorsprung 28 am Oberteil 2 zu erkennen. In der vergrößerten Darstellung von Fig. 15 ist deutlich sichtbar, daß das Schwenkteil 3d im mittleren Bereich gefertigt ist, und in einem Übergangsbereich Schrägflächen 3f aufweist, an die die innenliegende Kante der Entnahmeöffnung 4b im Oberteil 2 bzw. 4a des Führungsrings 21 anliegt. Die Verdickung im mittleren Bereich des Schwenkteils 3d ist in Größe und Form an der zugehörigen Entnahmeöffnung 4b bzw. 4a angepaßt. Aufgrund der Vorspannung der Deckelfläche des Oberteils 2 in Richtung des Unterteils 1 bzw. des Führungsrings 21 wird ein dichter Abschluß der Entnahmeöffnung 4b im Oberteil 2 und der Entnahmeöffnung 4a im Unterteil 1 bzw. dem Führungsring 21 mittels des dazwischen angeordneten Mittelteils erreicht. Durch die Schrägflächen 3f entlang des Umfangs der Verdickung bzw. der Erhabenheit können Fertigungstoleranzen ausgeglichen werden und eine Selbstzentrierung des Mittelteils gegenüber den beiden Öffnungen erreicht werden. Diese Funktion der Erhabenheiten am Mittelteil sind in gleicher

Weise bei den anderen hierin beschriebenen Ausführungsformen gegeben.

Fig. 16 zeigt eine vergrößerte Darstellung der Originalitätssicherung 17 mit der Sollbruchstelle 17a gemäß Fig. 12. Die Originalitätssicherung 17 ist über eine Dünnstelle 17a am Außendurchmesser des Grundkörpers 1 angeordnet. Die Originalitätssicherung 17 ragt durch eine Öffnung 2a an der Drehkappe 2, vorzugsweise in Form eines an der Unterkante beginnenden Schlitzes nach außen und ist durch einen Griff 17b nach dem Abbrechen entfernbar. Gleichzeitig verhindert der Griff 17b, daß die Originalitätssicherung 17 bei der Relativbewegung von Grundkörper 1 und Drehkappe 2 nach innen gezogen wird. Bei der erstmaligen Drehung der Drehkappe 2 schlägt diese an ihrer Öffnung 2a an die Originalitätssicherung 17 an und bewirkt ihr Abscheren von dem Zapfen 16.

In den Figuren 17a und 17b wird eine weitere erfindungsgemäße Ausführungsform gezeigt, wobei das Oberteil 2 einen ovalen Querschnitt aufweist. Ein solcher Querschnitt paßt z.B. gut zu einem Behälter mit ovaler Form. Fig. 17b ist ein Querschnitt längs der Linie H-H' in Fig. 17a. Das Oberteil 2 verschiebt das als Pendelschieber ausgebildete Mittelteil 3 von der geschlossenen in die geöffnete Stellung des Verschlusses durch eine Drehung um 180°. Dadurch ist das ovale Oberteil 2 sowohl in der geöffneten als auch geschlossenen Stellung mit der ovalen Form des Behälters ausgerichtet. In Fig. 17b ist zusätzlich zu Fig. 17a der Mitnehmer 14 eingezeichnet. Dieser läuft beim Öffnen oder Schließen auf einem Halbkreis K.

Die vorstehend beschriebenen Verschlüsse können durch eine Schraubverbindung, ein Aufprellsystem oder durch Aufspritzen mit einem Behälter verbunden werden. In Fig. 18 ist ausschnittsweise dargestellt, wie bei einem tubenförmigen Behälter die Folie 19a des Behälters am Unterteil 1 des Verschlusses angespritzt ist. Das Folienmaterial 19a überdeckt

in einem Kantenbereich die Oberseite des Unterteils 1. Hierdurch wird in vorteilhafter Weise die Tube direkt mit dem Verschluß verbunden.

Patentansprüche

1. Verschluß, mit

(a) einem Unterteil (1), das eine Entnahmeöffnung (4a) aufweist,

(b) einem Oberteil (2) mit einer korrespondierenden Entnahmeöffnung (4b), wobei eines der Verschlußteile (1 oder 2) gegen das andere verdrehbar ist, und

(c) einem Mittelteil (3), das in eine erste Stellung, in der die Entnahmeöffnungen (4a, 4b) frei sind, und eine zweite Stellung, in der es die Entnahmeöffnungen (4a, 4b) verschließt, bewegbar ist,

wobei

(d) das Mittelteil (3) linear verschiebbar, verschwenkbar oder in Umfangsrichtung beweglich angeordnet ist, und

(e) ein an dem verdrehbaren Verschlußteil (1 oder 2) oder am Mittelteil (3) angeordneter Mitnehmer (14) derart kraftschlüssig mit dem jeweils anderen Teil in Verbindung steht, daß durch Drehen der Verschlußteile (1, 2) gegeneinander das Mittelteil (3) in die erste oder zweite Stellung bewegt wird.

2. Verschluß, mit

(a) einem Unterteil (1), das eine Entnahmeöffnung (4a) aufweist,

(b) einem Oberteil (2) mit einer korrespondierenden Entnahmeöffnung (4b), wobei eines der Verschlußteile (1 oder 2) gegen das andere verdrehbar ist, und

(c) einem Mittelteil (3), das in eine erste Stellung, in der die Entnahmeöffnungen (4a, 4b) frei sind, und eine zweite Stellung, in der es die Entnahmeöffnungen (4a, 4b) verschließt, bewegbar ist,

wobei

(d) das Unterteil (1) oder das Oberteil (2) eine erste Umfangsfläche aufweist,

(e) das Mittelteil (3) eine zweite Umfangsfläche aufweist, und

(f) die erste und zweite Umfangsfläche derart kraftschlüssig, vorzugsweise mit einer zahnradartigen Verbindung (9), in Eingriff stehen, daß durch Drehen der Verschlußteile (1, 2) gegeneinander das Mittelteil (3) in die erste oder zweite Stellung bewegt wird.

3. Verschluß, mit

(a) einem Unterteil (1), das eine Entnahmeöffnung (4a) aufweist,

(b) einem Oberteil (2) mit einer korrespondierenden Entnahmeöffnung (4b), wobei eines der Verschlußteile (1 oder 2) gegen das andere verdrehbar ist, und

(c) einem Mittelteil (3), das in eine erste Stellung, in der die Entnahmeöffnungen (4a, 4b) frei sind, und eine zweite Stellung, in der es die Entnahmeöffnungen (4a, 4b) verschließt, bewegbar ist,

wobei

(d) das Oberteil (2) drehbar an dem Unterteil (1) gehaltert ist und die Entnahmeöffnungen (4a, 4b) einen Durchlaß (6) ausbilden können,

(e) das Oberteil (2) und das Unterteil (1) gegeneinander elastisch vorspannbar sind,

(f) das Mittelteil (3) zwischen dem Unterteil (1) und dem Oberteil (2) angeordnet ist und durch eine Drehung des Oberteils (2) in die erste oder zweite Stellung des Verschlusses bewegbar ist, und

(g) das Mittelteil (3) in der zweiten Stellung zwischen den beiden Öffnungen (4a, 4b) angeordnet ist und durch die Vorspannung zwischen der Drehkappe (2) und dem Grundkörper (1) den Durchlaß (6) zwischen ihnen abdichtet.

4. Verschluß nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß das Oberteil (2) und das Unterteil (1) gegeneinander elastisch vorspannbar sind.

5. Verschluß nach Anspruch 1, 3 oder 4, dadurch gekennzeichnet, daß das Mittelteil (3) als Pendelschieber (3a, 3c) ausgebildet ist, der in Führungsschienen (15) geführt wird.

6. Verschluß nach Anspruch 5, dadurch gekennzeichnet, daß der Pendelschieber (3a; 3c) einen U-förmigen Querschnitt aufweist und mit seinen Schenkeln (25) in den Führungsschienen (15) geführt wird.

7. Verschluß nach Anspruch 1, 3 oder 4, dadurch gekennzeichnet, daß das Mittelteil (3) als Schwenkteil (3d) ausgebildet ist, das um einem auf dem Unterteil (1) befestigten Zapfen (16) schwenkbar ist.

8. Verschluß nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß das Mittelteil (3) auf seiner Unterseite und/oder Oberseite mindestens eine Erhabenheit (3f) aufweist, die in Form und Größe an die jeweils zugehörige Entnahmeöffnung (4a, 4b) angepaßt ist und in der zweiten Stellung in die Entnahmeöffnungen rastend und dichtend eingreift.

9. Verschluß nach Anspruch 8, dadurch gekennzeichnet, daß zur Originalitätssicherung eine Blockierung (17) zwischen dem Oberteil (2) und dem Mittelteil (3) angeordnet ist, die eine Sollbruchstelle (17a) aufweist.

10. Verschluß nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß in der Entnahmeöffnung (4a) ein Ventileinsatz (13) angeordnet ist.

11. Verschluß nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, daß das Unterteil (1) durch eine Verschraubung (18) oder ein Prellverschlußgestell mit einem Behälter (19) verbunden ist oder bei tubenförmigen Behältern vorzugsweise am Behälter (19a) angespritzt ist.

12. Verschluß nach einem der Ansprüche 1 bis 11, dadurch gekennzeichnet, daß das Oberteil (2) einen ovalen Querschnitt aufweist.

13. Verschluß nach einem der Ansprüche 1 bis 12, dadurch gekennzeichnet, daß zwischen dem Mittelteil (3) und dem Unterteil (2) eine Führungsplatte (20) oder ein Führungsring (21) angeordnet ist, auf dem das Mittelteil (3) gleitet.

14. Verschluß nach Anspruch 13, dadurch gekennzeichnet, daß die Führungsplatte (20) mittels Stiften (22) im Unterteil (1) gehaltert ist.

15. Verschluß nach einem der Ansprüche 1 bis 14, dadurch gekennzeichnet, daß das Mittelteil (3) eine keilförmige Verdickung (10) an der Ober- und Unterseite aufweist, die das Unterteil (1) und das Oberteil (2) beim Übergang in die geschlossene Stellung des Verschlusses auseinanderpressen.

16. Verschluß nach einem der Ansprüche 1 bis 15, dadurch gekennzeichnet, daß das Mittelteil (3) kreisförmig ist und ein nierenförmiges Langloch (11) aufweist.

17. Verschluß, gekennzeichnet durch eine beliebige Kombination von einzelnen Merkmalen der Ansprüche 1 bis 16.

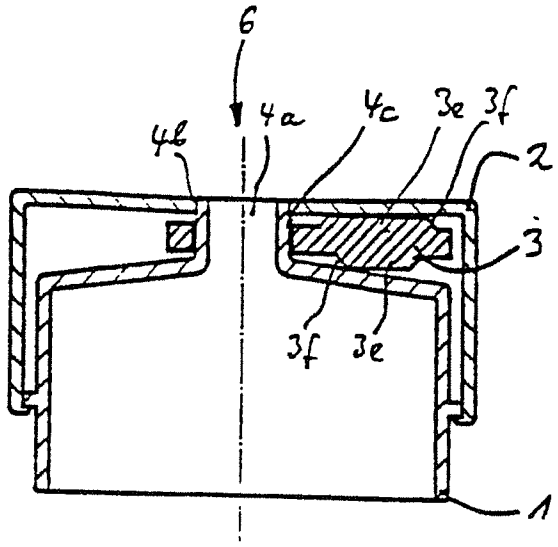


Fig. 1

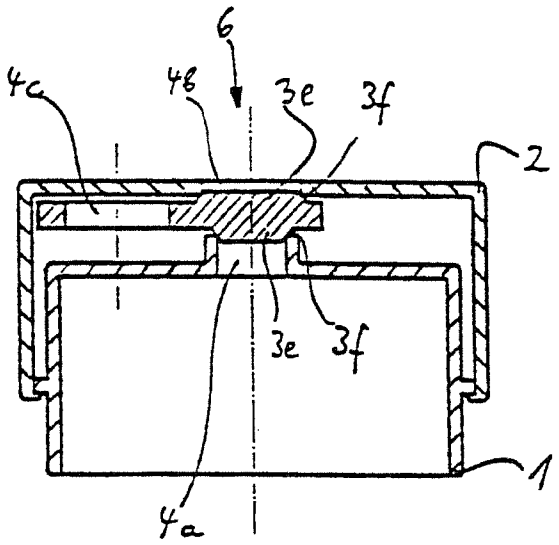


Fig. 2

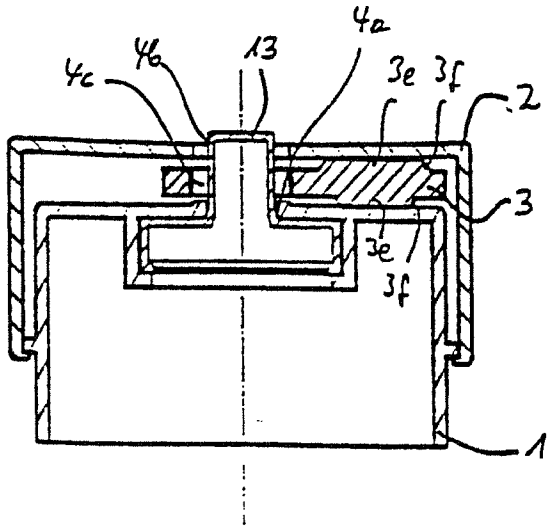


Fig. 3

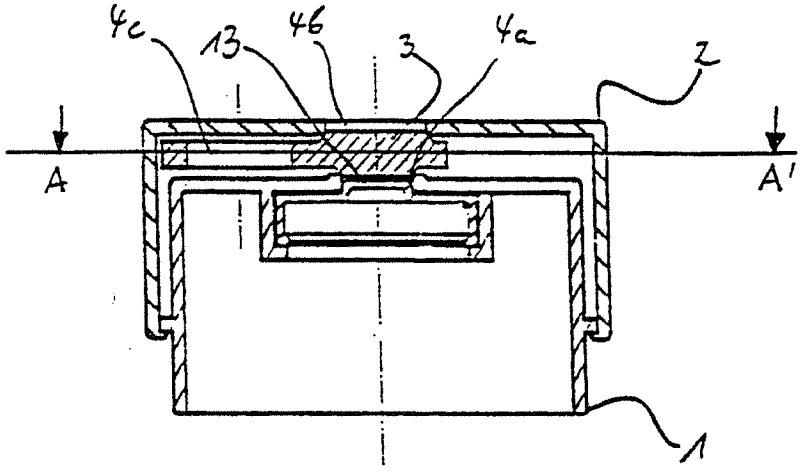


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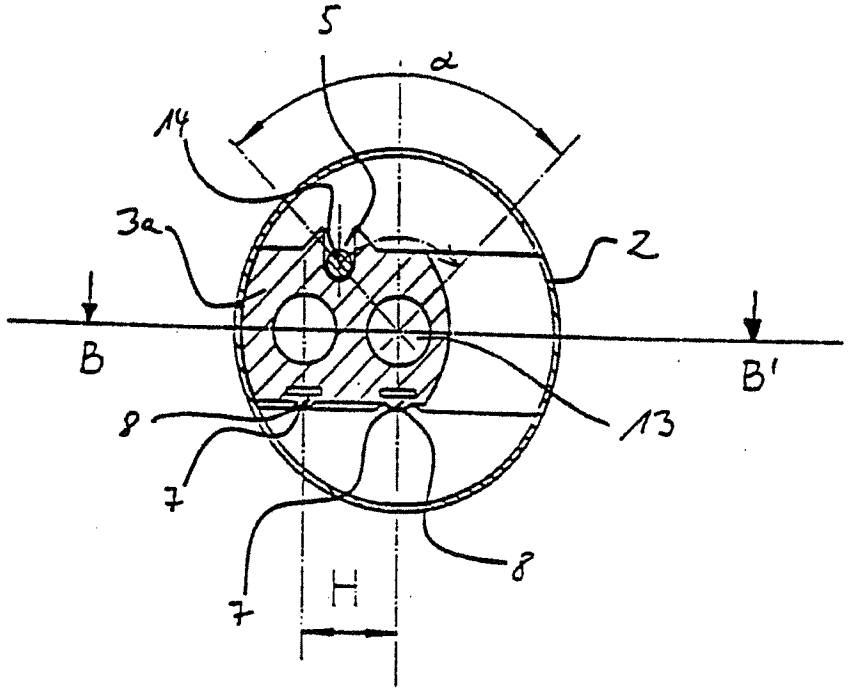


Fig. 5

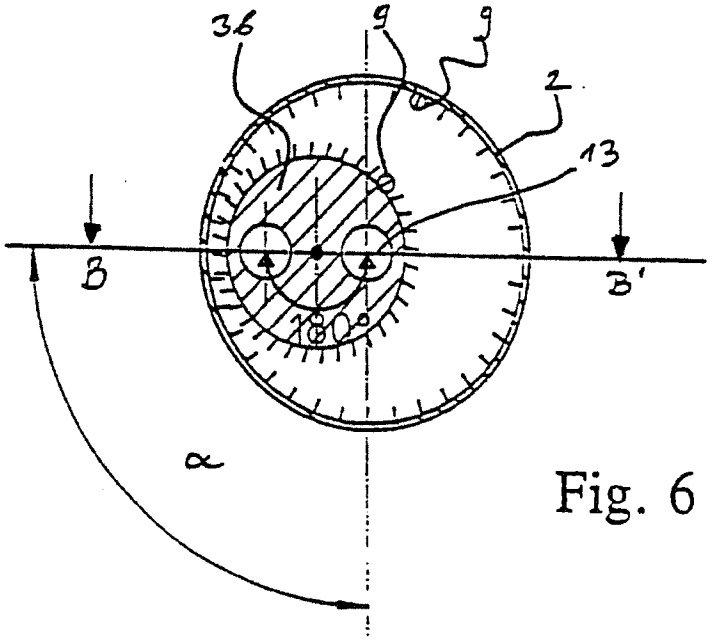


Fig. 6

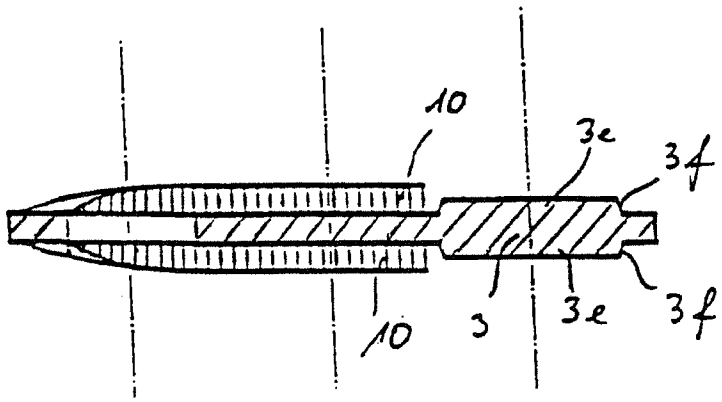


Fig. 7

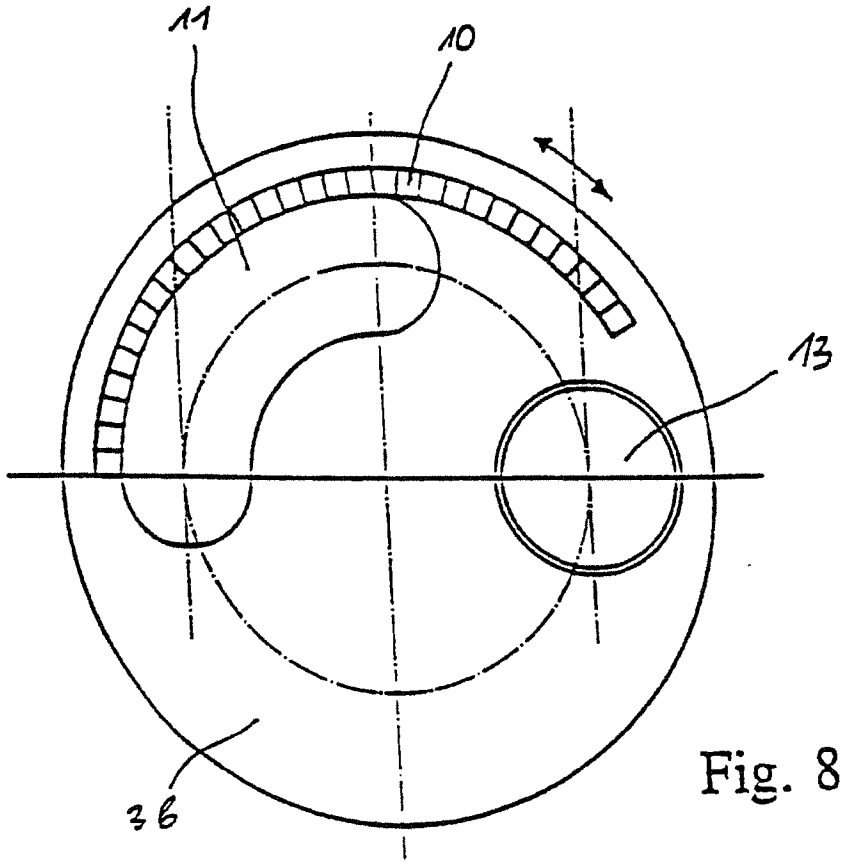


Fig. 8

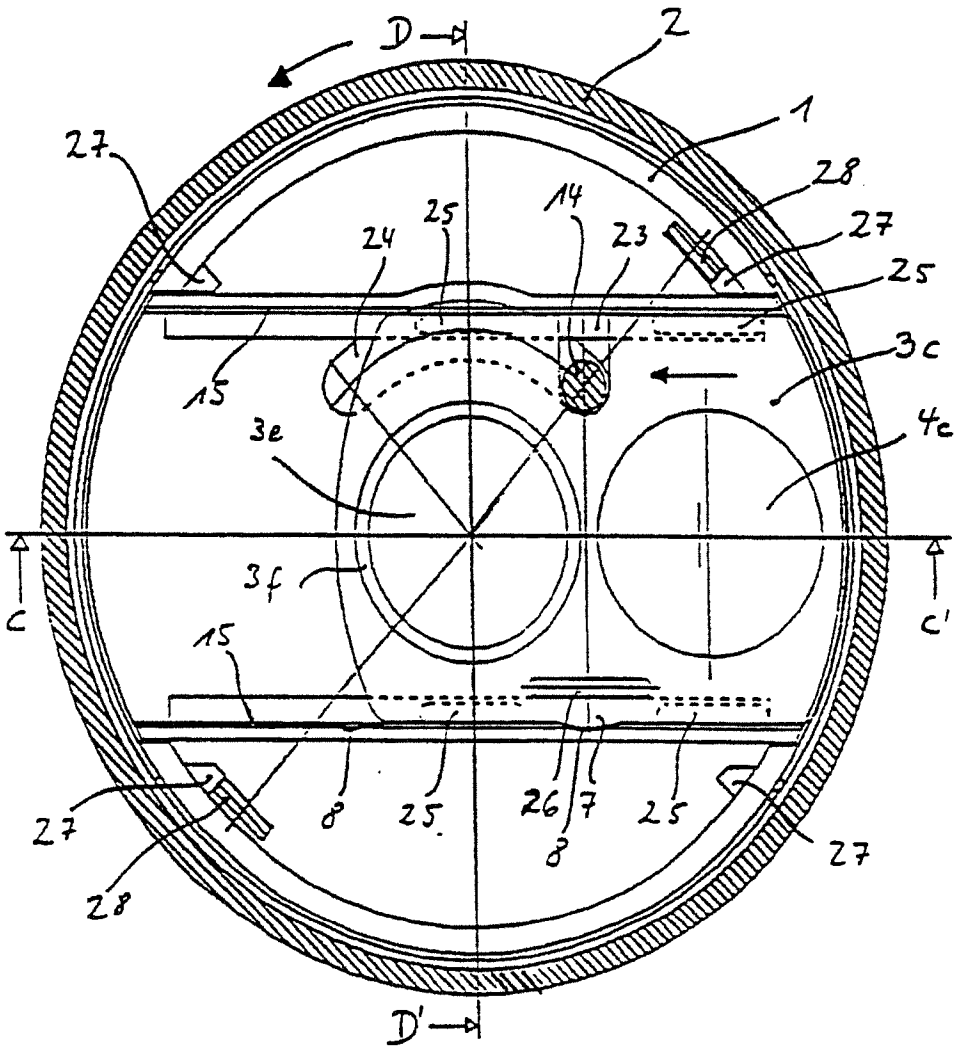


Fig. 9

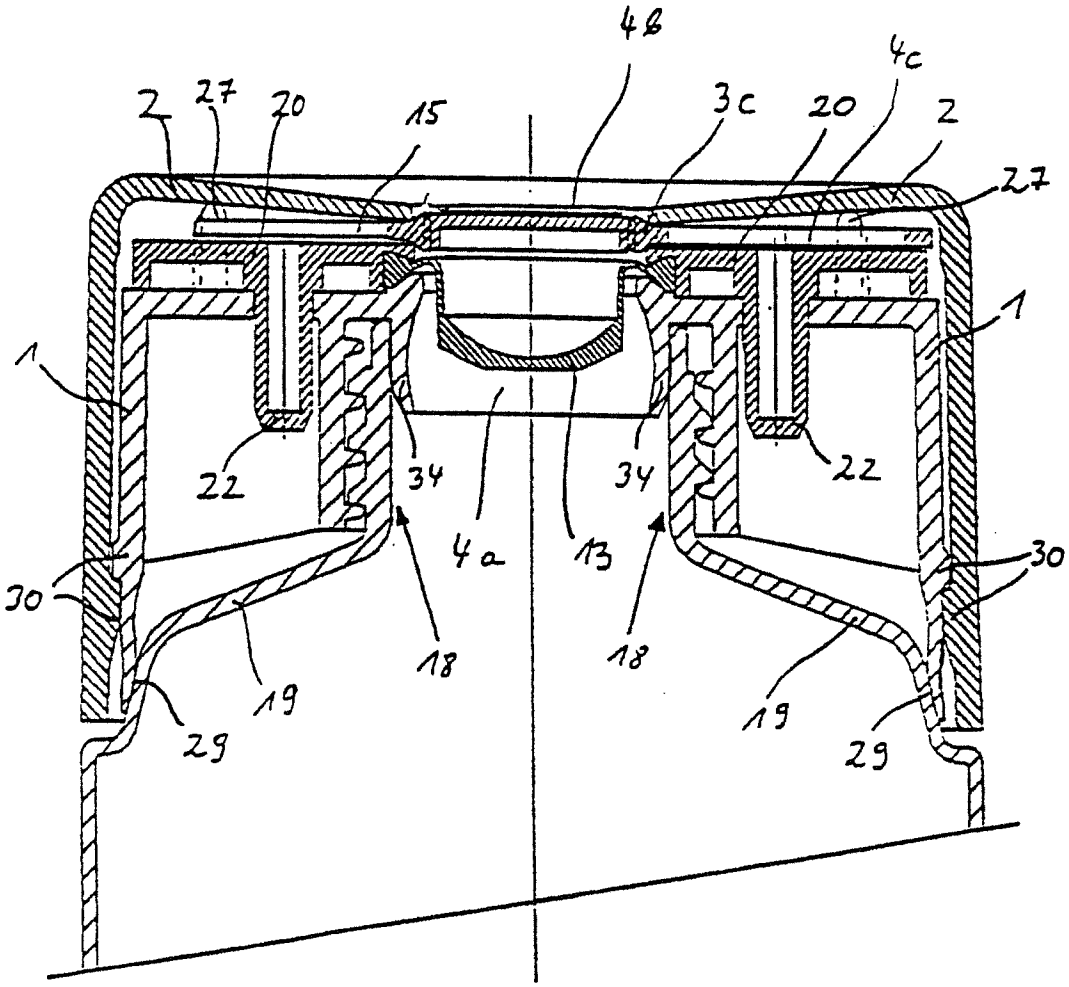


Fig. 10

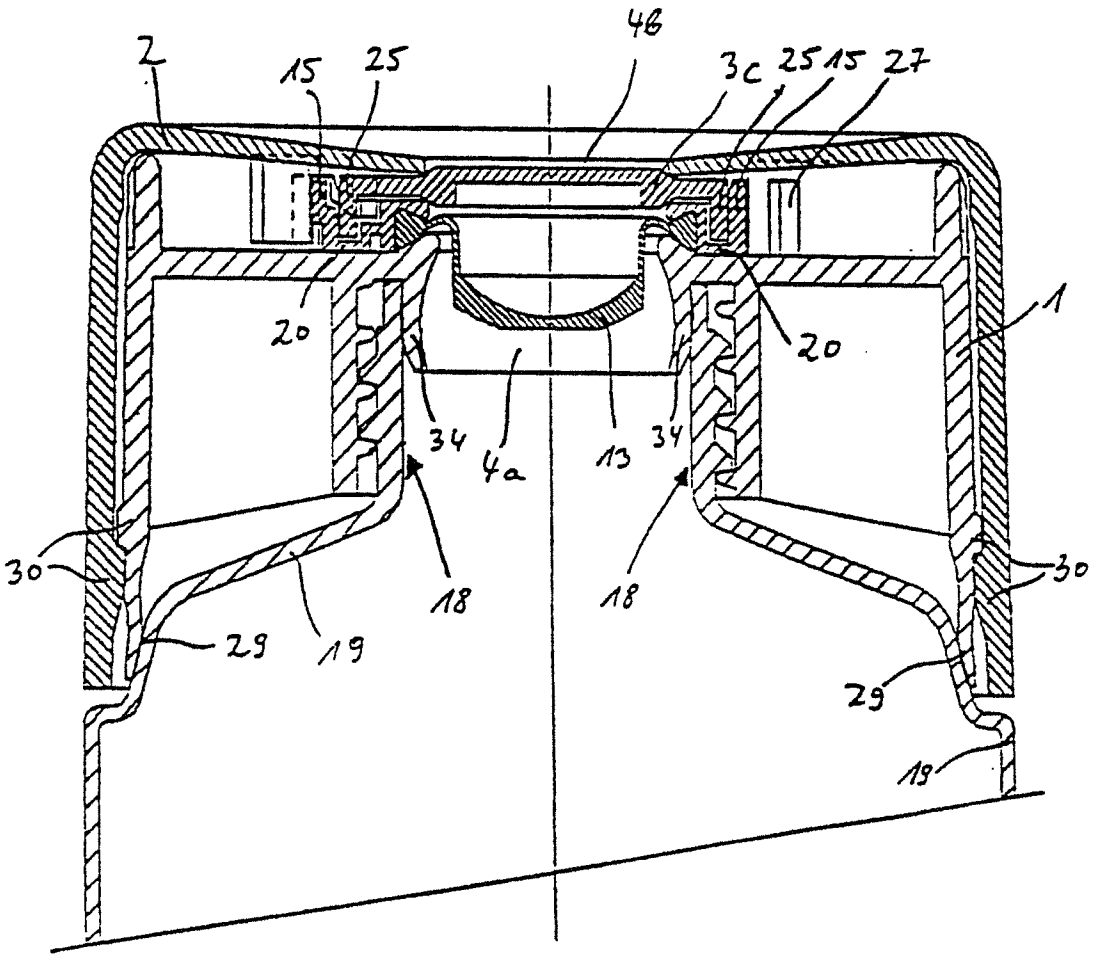


Fig. 11

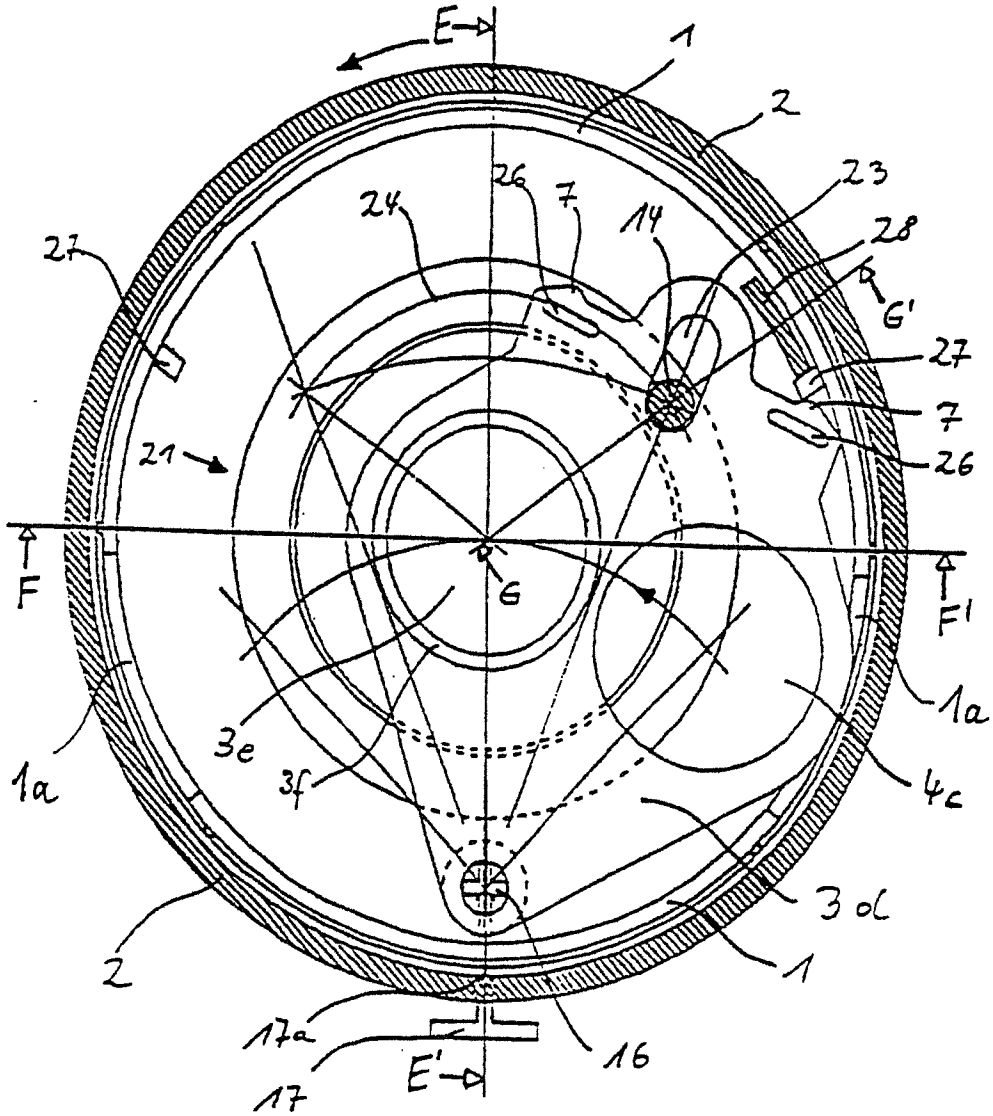

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Fig. 12

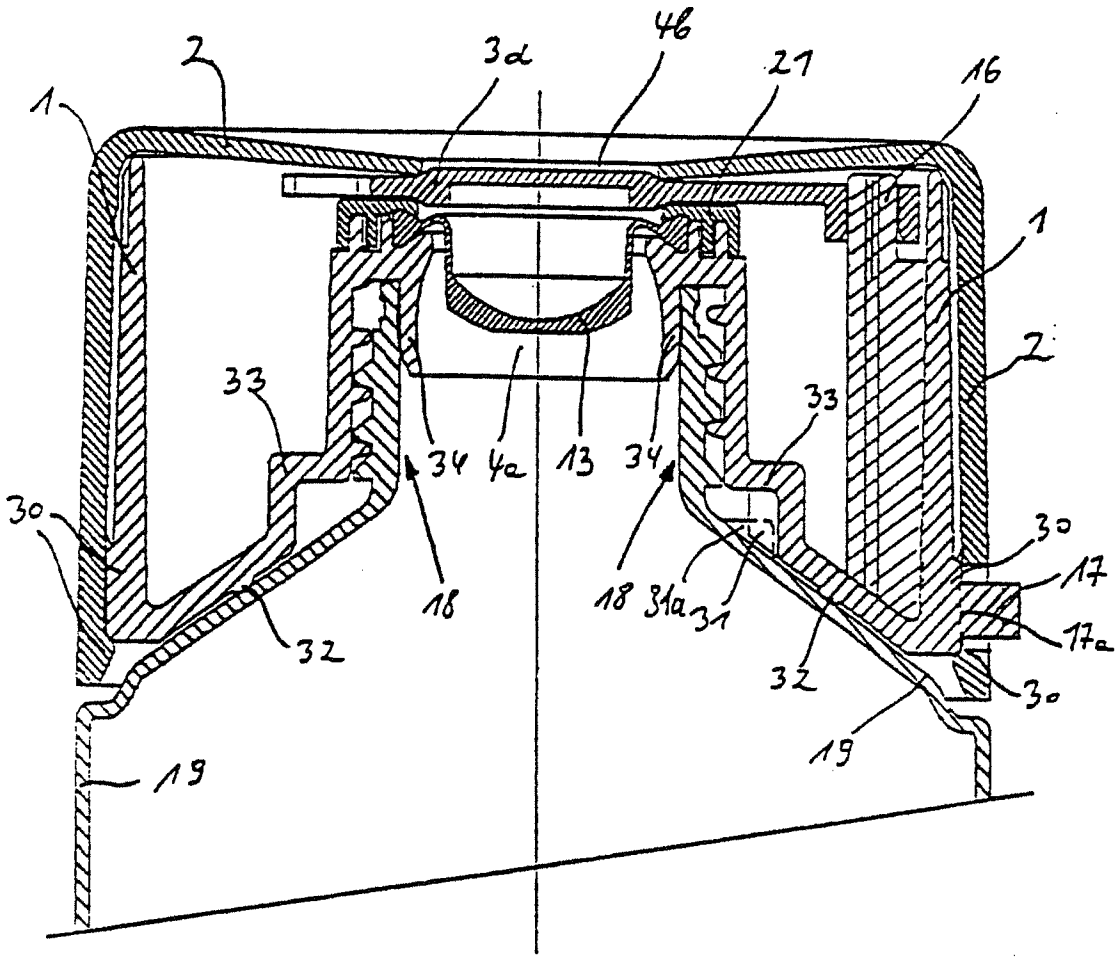

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Fig. 13

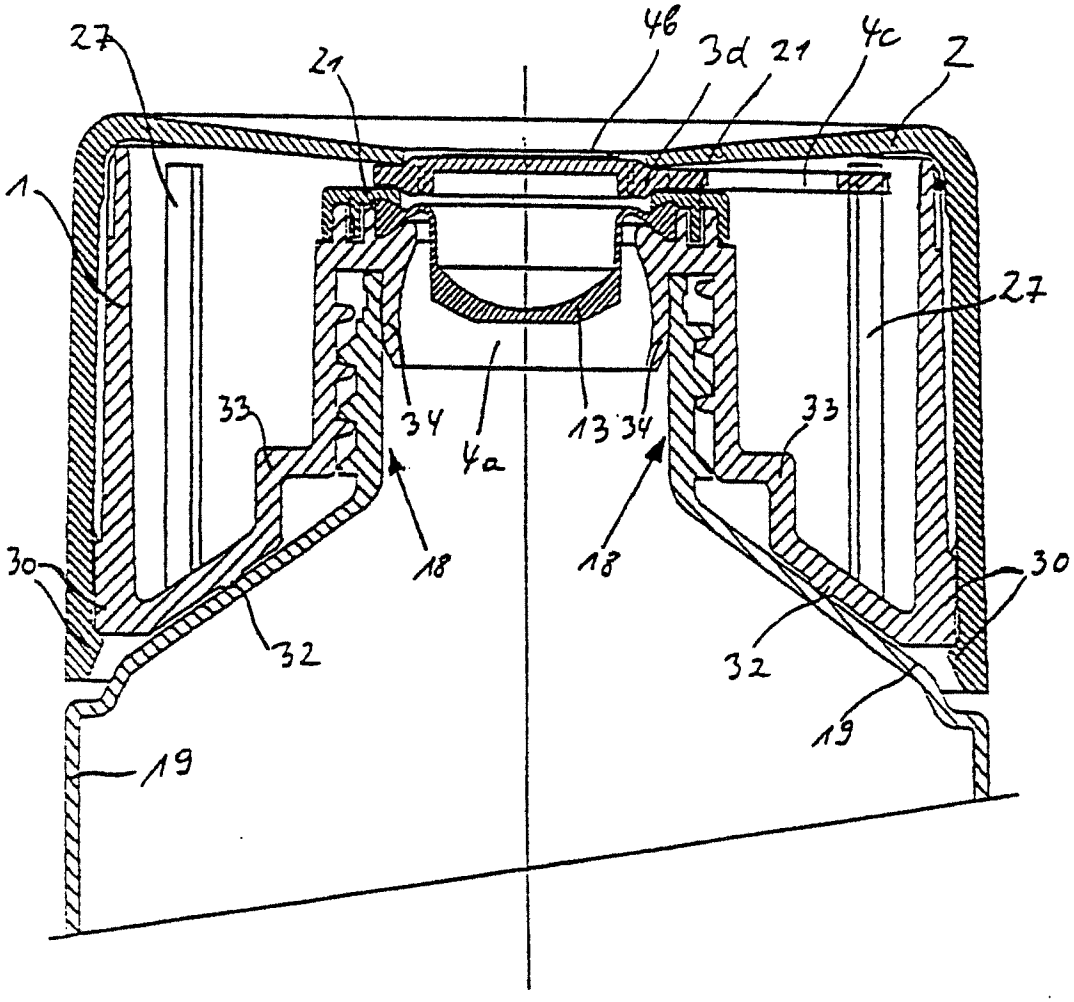


Fig. 14

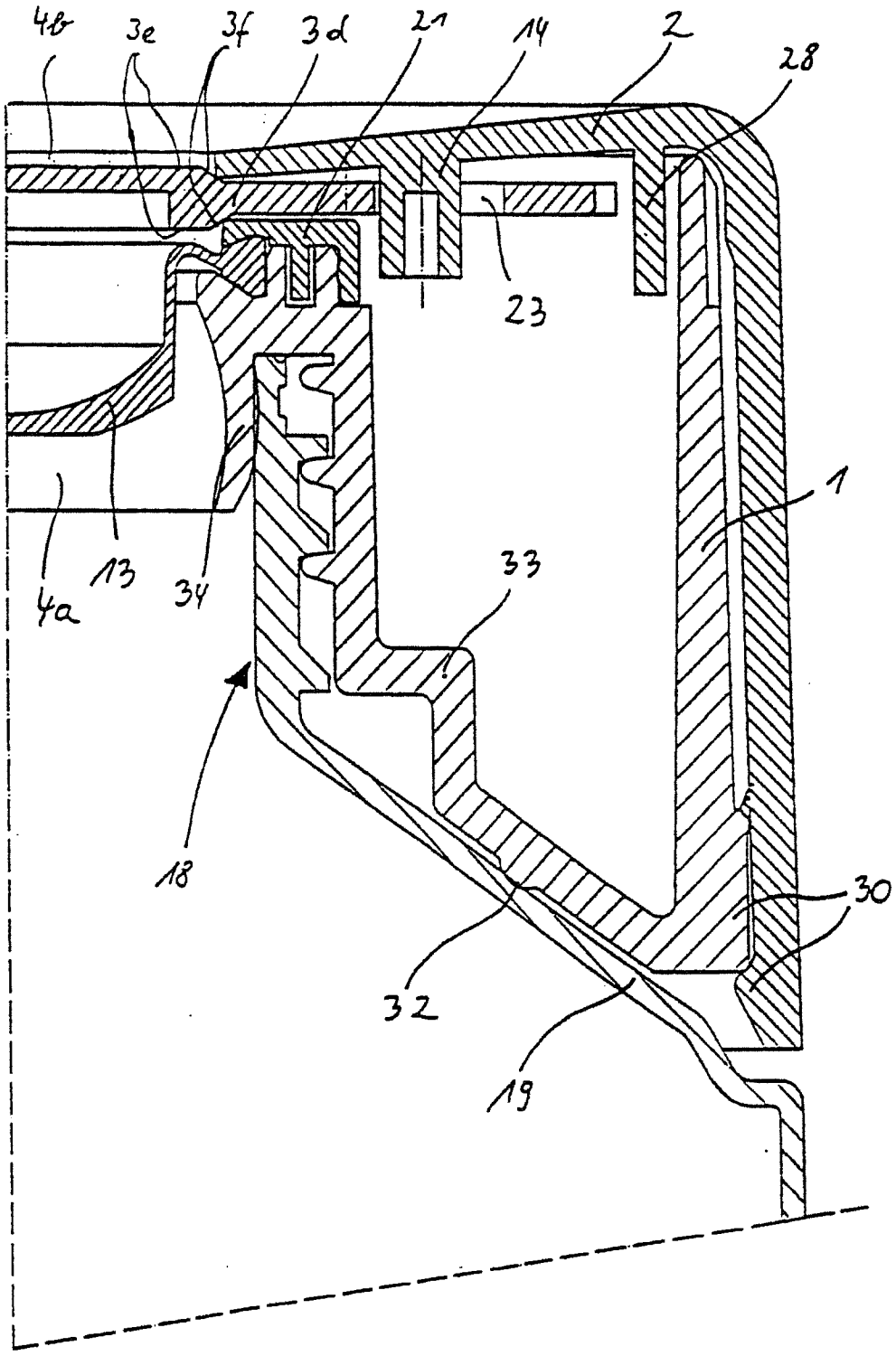


Fig. 15

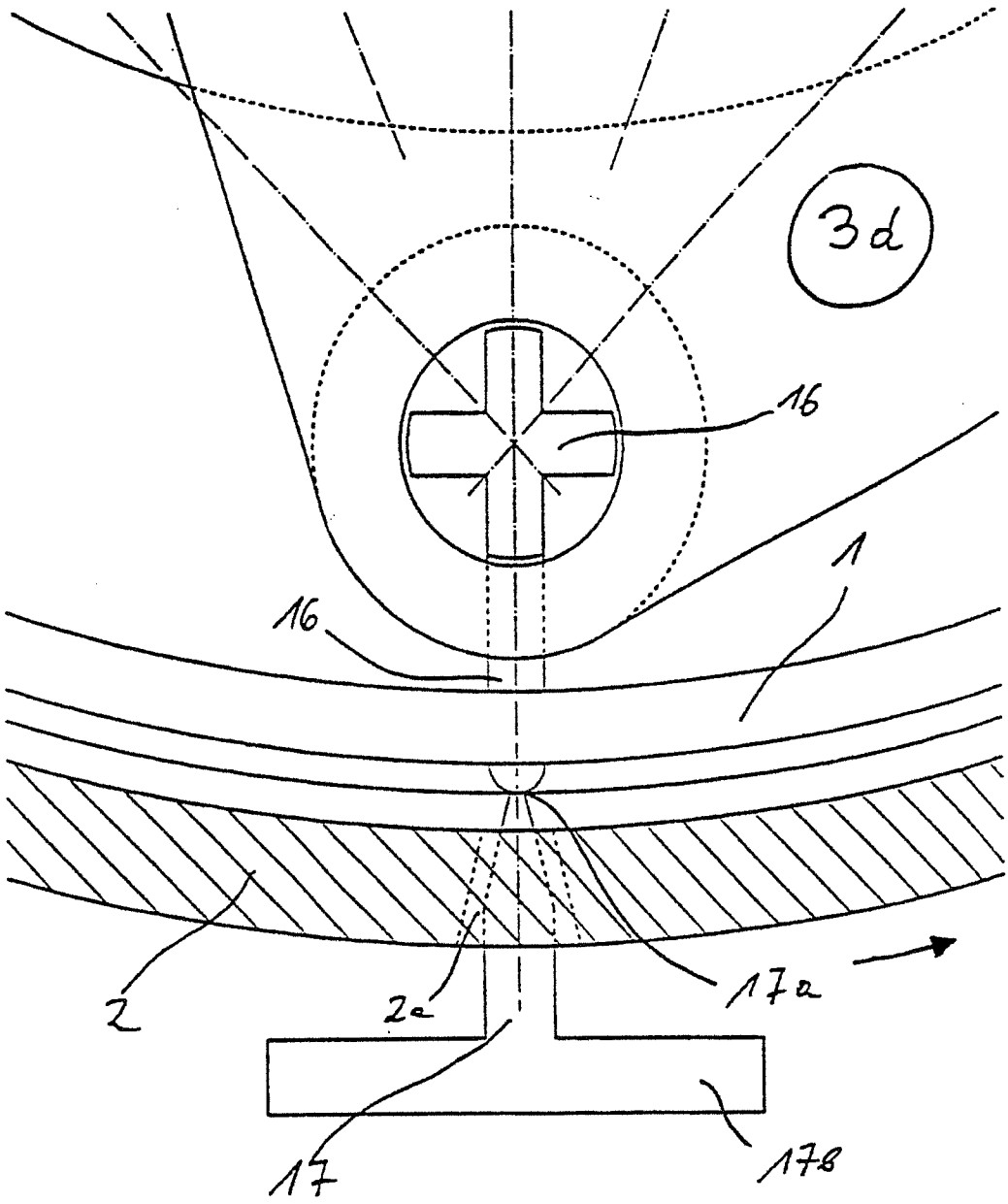


Fig. 16

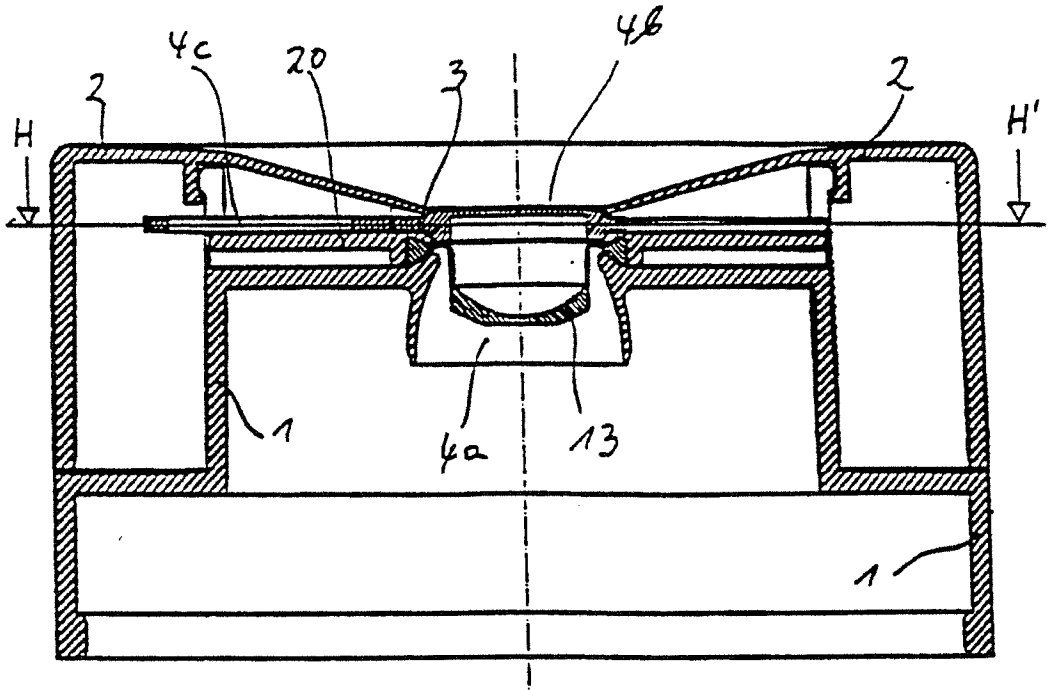


Fig. 17 a

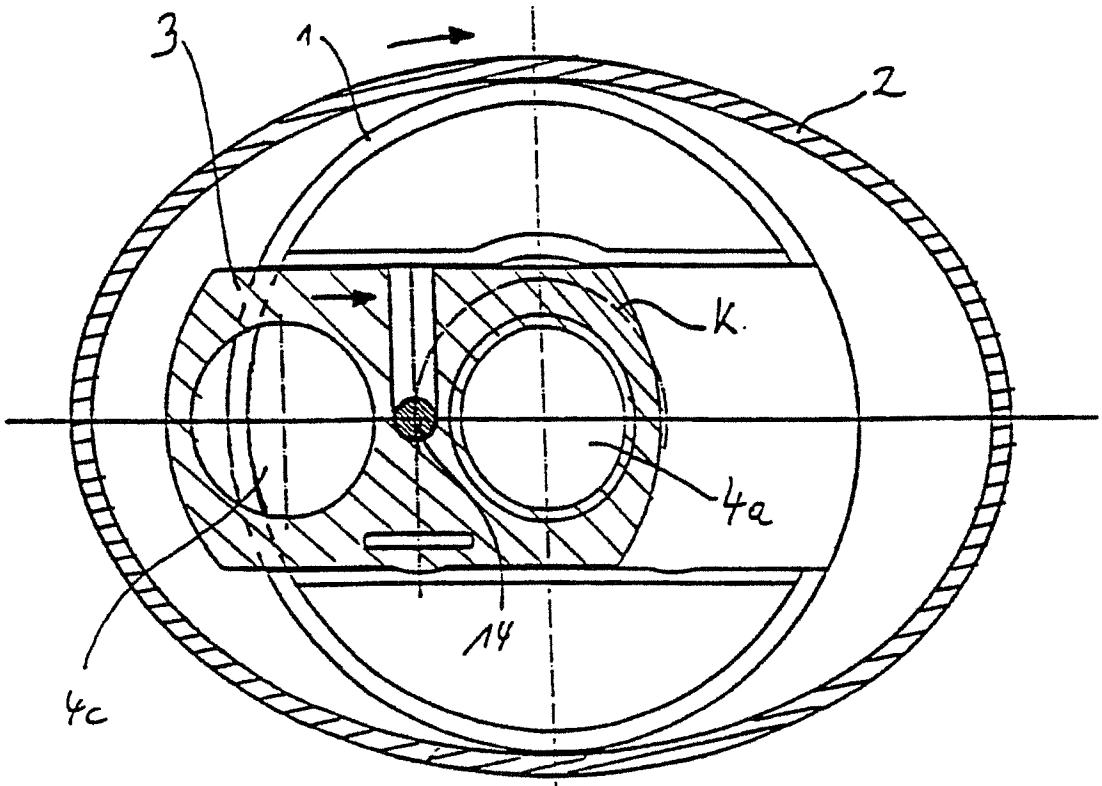


Fig. 17 b

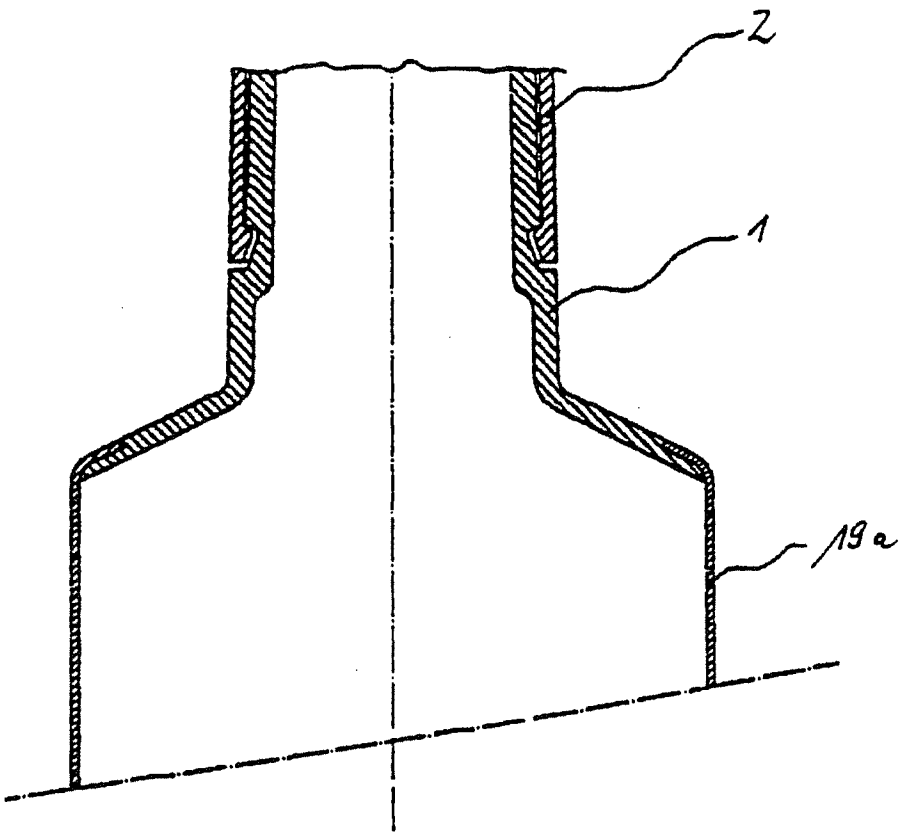


Fig. 18

INTERNATIONAL SEARCH REPORT

Interm al Application No
PCT/EP 94/01695

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 B65D47/26 B65D47/24 B65D47/20

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 B65D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,2 082 691 (FARRELLY) 1 June 1937	1,2,5-7, 11,13, 14,17
Y	see page 1, right column, line 38 - page 3, left column, line 11; figures 1-12	9,16
X	US,A,5 199 617 (BENNETT) 6 April 1993	1,2,7,8, 11,17
	see figures 1-8	
X	GB,A,521 672 (THORN) 28 May 1940	1,2,7, 11,17
	see figures 1-6	
	-/--	

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Date of the actual completion of the international search	Date of mailing of the international search report
30 September 1994	11. 10. 94

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Berrington, N

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X	US,A,3 446 406 (TROTT) 27 May 1969 see column 5, line 55 - column 7, line 35; figures 1-19	1-4,7,8, 11,13, 15,17
X	DE,C,924 857 (NEUGEBAUER) 9 May 1956 see page 2, line 9 - line 91; figures 1A,B	1,2,7, 10,17
X	US,A,2 106 364 (THORN) 25 January 1938 see figures 1-20	1,2,7,17
Y	DE,U,92 06 097 (COMBITOOL AG) 20 August 1992	9
A	see page 3, line 24 - page 4, line 19; figures 2,3	3,4
Y	FR,A,2 093 327 (HILCOSAN BECHER & DOSENFABRIK) 28 January 1972 see figure 3	16
A	GB,A,2 088 838 (DRDLIK) 16 June 1982	
A	DE,A,15 36 129 (LEITZ) 5 March 1970	

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-2082691		NONE	
US-A-5199617	06-04-93	NONE	
GB-A-521672		NONE	
US-A-3446406	27-05-69	NONE	
DE-C-924857		NONE	
US-A-2106364		NONE	
DE-U-9206097	20-08-92	NONE	
FR-A-2093327	28-01-72	NONE	
GB-A-2088838	16-06-82	NONE	
DE-A-1536129	05-03-70	NONE	

Intern ales Aktenzeichen
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A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
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Nach der Internationalen Patentklassifikation (IPK) oder nach der nationalen Klassifikation und der IPK

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Recherchierter Mindestprüfstoff (Klassifikationssystem und Klassifikationssymbole)
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Während der internationalen Recherche konsultierte elektronische Datenbank (Name der Datenbank und evtl. verwendete Suchbegriffe)

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Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
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X	US,A,5 199 617 (BENNETT) 6. April 1993 siehe Abbildungen 1-8	1,2,7,8, 11,17
X	GB,A,521 672 (THORN) 28. Mai 1940 siehe Abbildungen 1-6	1,2,7, 11,17

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[X] Weitere Veröffentlichungen sind der Fortsetzung von Feld C zu entnehmen

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PCT/EP 94/01695

C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	US,A,3 446 406 (TROTT) 27. Mai 1969 siehe Spalte 5, Zeile 55 - Spalte 7, Zeile 35; Abbildungen 1-19	1-4,7,8, 11,13, 15,17
X	DE,C,924 857 (NEUGEBAUER) 9. Mai 1956 siehe Seite 2, Zeile 9 - Zeile 91; Abbildungen 1A,B	1,2,7, 10,17
X	US,A,2 106 364 (THORN) 25. Januar 1938 siehe Abbildungen 1-20	1,2,7,17
Y	DE,U,92 06 097 (COMBITOOL AG) 20. August 1992	9
A	siehe Seite 3, Zeile 24 - Seite 4, Zeile 19; Abbildungen 2,3	3,4
Y	FR,A,2 093 327 (HILCOSAN BECHER & DOSENFABRIK) 28. Januar 1972 siehe Abbildung 3	16
A	GB,A,2 088 838 (DRDLIK) 16. Juni 1982	
A	DE,A,15 36 129 (LEITZ) 5. März 1970	

Im Recherchenbericht angeführtes Patentdokument	Datum der Veröffentlichung	Mitglied(er) der Patentfamilie	Datum der Veröffentlichung
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GB-A-521672		KEINE	
US-A-3446406	27-05-69	KEINE	
DE-C-924857		KEINE	
US-A-2106364		KEINE	
DE-U-9206097	20-08-92	KEINE	
FR-A-2093327	28-01-72	KEINE	
GB-A-2088838	16-06-82	KEINE	
DE-A-1536129	05-03-70	KEINE	

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(51) International Patent Classification 6 :
B32B 5/16, B24D 3/00, 3/02, C09C 1/68, C09K 3/14, C30B 23/00, 25/00, 28/12, 29/04, 31/00, H01L 29/04, 31/0312, 31/036

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(11) International Publication Number: WO 96/06732

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(22) International Filing Date: 11 August 1995 (11.08.95)

(30) Priority Data:
08/299,240 31 August 1994 (31.08.94) US
08/322,681 12 October 1994 (12.10.94) US

(71)(72) Applicant and Inventor: ROBERTS, Ellis, E. [US/US]; P.O. Box 6310, Los Osos, CA 93412 (US).

(74) Agent: COSTELLO, Leo, F.; 1308 Broad Street, No. 14, San Luis Obispo, CA 93401 (US).

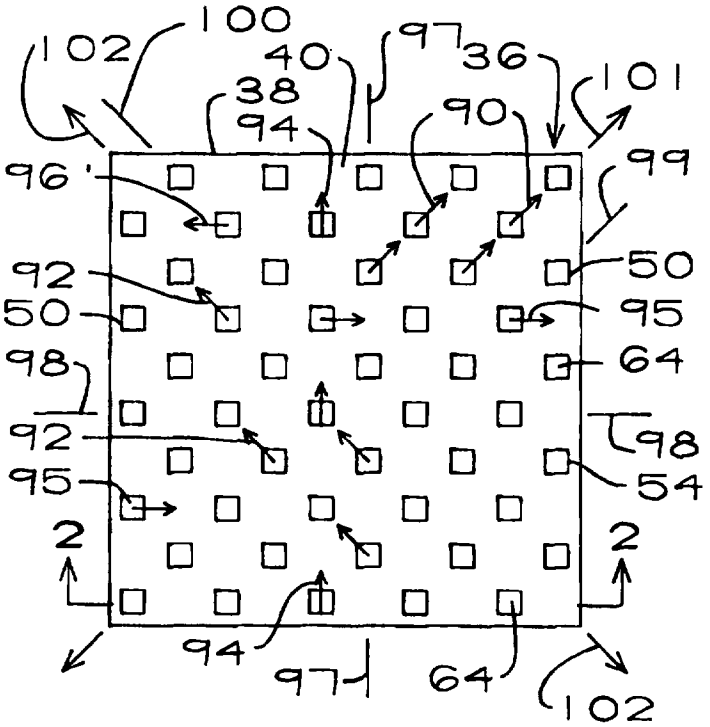
(81) Designated States: AU, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
With amended claims.

(54) Title: ORIENTED CRYSTAL ASSEMBLIES

(57) Abstract

An article of manufacture comprising synthetic single crystals (50, 60, 350) of uniform size and shape selected from the group consisting of diamond or cubic boron nitride and held in a formation (figs. 1, 10, 19, 33) with selected crystallographic directions of the crystals oriented in the same direction so that the crystals as a group exhibit a common crystallographic direction (101, 102, 248, 360, 670, 672) which may selectively be the hardest or near-hardest direction, and a method of making such an article. Such orientation takes advantage of the hardness properties of the individual crystals by imparting such properties to the assembly. Various embodiments of the article are thus useful as an abrasive, a bearing, a heat sink or a semiconductor.



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Description

Oriented Crystal Assemblies

Technical Field

This invention relates to oriented crystal assemblies and more particularly to an article of oriented single synthetic crystals and to a method for making such an article.

Diamond has numerous physical properties that are well known and which have great utility for industrial purposes but which in the past have not been fully exploited. These properties include abrasion and wear-resistance, thermal conductivity, electrical insulation, and receptivity to the deposit of a layer of diamonds by chemical vapor deposition.

The very high degree of abrasion resistance exhibited by diamond varies with the crystallographic direction of hardness by a factor of as much as about one hundred times, and this most resistant direction is along the diagonal of a cubic face in the plane of the face. Diamond crystals also have another direction of high hardness along a line tangential to an edge of the crystal; crystals of cubic boron nitride (CBN) have a similar direction of high hardness.

Until the present invention, however, it has not been recognized how to take advantage of such crystallographic directions of hardness of diamond , CBN, and perhaps other materials, when these materials are employed to make an article having wear-resistant or abrasive qualities and other desired characteristics. Thus, the prior art devices have not optimized the hardness characteristics of a hard surface including particles of diamond and CBN.

Background Art

In abrasives, for example, the grits or particles of the prior art have been incorporated in a backing member in either a random manner or an oriented manner. The prior art orientation has been to disperse the grits uniformly (U.S. Patent No. 4,925,457), to arrange planar faces of the grits so they seat flat against a workpiece (U.S. Patent No. 3,230,672), or to orient the grit particles by electrostatic or electromagnetic means (U.S. Patent Nos. 4,240,807 and 5,203,881).

Although these orientations may provide useful abrasive articles, these and like prior art abrasive or wear-resistant articles have failed to take advantage of the maximum hardness available in the abrasive materials used, such as diamond and CBN. The concept of orienting particles in a backing member so as to transfer to the abrasive or wear-resistant surface as a whole the hardness qualities of the individual particles per se has not been recognized. Thus, it has not been known how to control the hardness of the surface either to insure that the resulting surface would have the maximum hardness possible or to provide a predetermined degree of hardness for abrasive or bearing applications.

For semiconductor applications, the Geis et al. PCT application and related article (WO 92/01827 published 6 February 1992, and Geis et al. "Large-Area Mosaic Films Approaching Single-Crystal Quality," *Applied Physical Letters*, Vol. 58, No. 22 (3 June 1991), 2485-2487) recognize that diamond's excellent electrical properties have not been fully utilized. These references teach the placing of synthetic diamond seed crystals of 0.10 mm diameter or less in spaced complementary pits or grooves, and subsequently growing a film about the seeds by chemical vapor deposition. Geis et al. intentionally separate the seed crystals to enable the CVD crystal growth to envelope the seeds. Thus, although Geis et al. state that such placement orients the crystallographic directions, their method creates spaces or gaps between adjacent seed crystals. They state that at the point where adjacent crystals merge, there is the possibility that crystal defects may occur. Moreover, Geis et al. is concerned with electrical applications and thus does not teach how to produce an abrasive or bearing surface having a crystallographic direction of maximum abrasive resistance.

Disclosure of the Invention

The present invention involves an article of manufacture comprising synthetic single crystals of uniform size and shape selected from the group consisting of diamond or cubic boron nitride and held in a formation with selected crystallographic directions of the crystals oriented in the same direction and to a method of making such an article. The article is useful as an abrasive, a bearing, a heat sink or a semiconductor.

It is an object of the present invention to maximize the characteristics of a surface composed of hard materials such as diamond, CBN, and perhaps other materials, to produce an article having various industrial uses, such as abrasives, bearings, heat sinks and semiconductors.

Another object is to provide an article composed of synthetic single crystals of diamond, CBN, and perhaps other materials, having their crystallographic directions oriented in the same direction.

It is a further object of this invention to take advantage of the fact that synthetic single crystals of diamond and CBN have predetermined crystallographic directions lying along lines in contact with certain portions of their crystals, by aligning these directions when the crystals are positioned in a working formation.

It is also an object to take advantage of the fact that diamond and CBN are commercially synthesized in shapes and sizes that permit single crystals of these materials to be oriented with their crystallographic directions aligned.

A further object is to provide an article including a formation of synthetic single crystals for abrading a workpiece which, as contrasted with prior art tools: abrades faster; lasts longer; requires less frequent replacement and adjustment; is less costly to operate; maintains tolerances longer; saves abrasive material; requires less power; and minimizes dulling or flatting of grains.

Another object is to provide a method for making the article of the present invention.

Brief Description Of The Drawings

Fig. 1 is a plan view of one embodiment of an abrasive article made in accordance with the present invention but showing the article on a greatly enlarged scale from actual size.

Fig. 2 is a cross-sectional view taken along line 2-2 of Fig. 1.

Fig. 3 is an isometric view of a single, synthetic, cubic crystal of diamond as used in the article of Fig. 1 but greatly enlarged from Fig. 1.

Fig. 4 is an isometric view of a single, synthetic, predominately cubic crystal of diamond, but with small octahedral facets, as used in the present invention and also greatly enlarged from actual size.

Fig. 5 is an enlarged view of a face of the cubic crystal of Fig. 3 showing directional lines of hardness and the Miller indices of the cube face and hardness directions.

Fig. 6 illustrates a step of the method of the present invention and specifically is an isometric view of a corner of a template containing three cubic crystals oriented by the template into desired positions.

Fig. 7 illustrates a portion of an alternate form of template used in practicing the method referred to in regard to Fig. 6.

Fig. 8 illustrates another step of the method of the present invention and specifically is a cross section of the template and crystals therein, as if taken along line 8-8 of Fig. 6 when the template is full of crystals, and further showing a backing member of epoxy overlaying the crystals and the template.

Fig. 9 is a cross-section taken along the same plane as Fig. 8 but showing the backing member and the crystals, that is the abrasive article, removed from the template.

Fig. 10 is a plan view of another embodiment of an abrasive article made in accordance with the present invention and also shown on a greatly enlarged scale from actual size.

Fig. 11 is a cross-sectional view taken along line 11-11 of Fig. 10.

Fig. 12 is an edge view of the cubic diamond crystal of Fig. 3, although on a reduced scale from Fig. 3, showing its orientation as used in the article of Fig. 10, but enlarged from Fig. 10, and further showing its second hardest directional line of hardness and Miller index.

Fig. 13 is a face view of the diamond crystal of Fig. 12.

Fig. 14 illustrates a step of an embodiment of the present method used to make the article shown in Fig. 10 and specifically is an isometric view of a corner of a template containing two cubic crystals oriented by the template into desired positions which differ from the positions of Fig. 6.

Fig. 15 illustrates a step similar to that illustrated by Fig. 8 but pertains to the method of making the article shown in Fig. 10 and specifically is a cross-section of the template and crystals therein, as if taken along line 15-15 of Fig. 14 when the template is full of crystals, and further showing a backing member of epoxy overlaying the crystals and the template.

Fig. 16 is a cross-section along the same plane as Fig. 15 but showing the article of Fig. 10 removed from the template.

Fig. 17 is a plan view of a portion of a variation of the second embodiment of an abrasive article made in accordance with the present invention.

Fig. 18 is an isometric view of part of a template for use in making the variation shown in Fig. 17.

Fig. 19 is a plan view of a third embodiment of an abrasive article made in accordance with the present invention using tetrahedral cubic boron nitride crystals and also shown on a greatly enlarged scale from actual size.

Figs. 20 and 21 are partial cross-sectional views taken along lines 20-20 and 21-21, respectively, of Fig. 19.

Fig. 22 is a greatly enlarged isometric view of a tetrahedral crystal of cubic boron nitride as used in the article of Fig. 19 but greatly enlarged from Fig. 19 and showing Miller notations for two of the faces of the crystal.

Fig. 23 is a face view of the crystal of Fig. 22 on a reduced scale and also showing a Miller notation.

Fig. 24 is an edge view of the crystal of Fig. 23 but turned ninety degrees therefrom and again showing a Miller notation.

Fig. 25 is a fragmentary isometric view similar to Fig. 18 but showing a template used to make the article of Fig. 19.

Figs. 26 and 27 are cross-sectional views similar to Figs. 15 and 16 but showing steps for making the article of Fig. 19 and taken along the same plane as Fig. 21.

Fig. 28 is an isometric view of a corner of a template used to make a variation, not shown, of the embodiment shown in Fig. 19.

Figs. 29 and 30 are schematic views showing how the articles of the present invention are used in a tool to surface a workpiece along a linear path but specifically showing the article of Fig. 19.

Figs. 31 and 32 are schematic views showing how the articles of the present invention are used in a tool to surface a workpiece along a rotary path but specifically showing articles made in accordance with the embodiment of Fig. 17.

Fig. 33 is a plan view, enlarged approximately two times actual size, of an assembly of synthetic cubic crystals of diamond, or like material, made in accordance with the present invention.

Fig. 34 is an elevation or edge view of the assembly of Fig. 33.

Fig. 35 is an isometric view of formation of synthetic cubic diamond crystals illustrating the aligned crystallographic directions of hardness by directional arrows and Miller indices. Again, the crystals and thus the assembly are enlarged from actual size. It is

also noted that the crystals shown in Fig. 35 are in fact cubic, although they may not appear so because of the rules of isometeric projection.

Fig. 36 is an isometric view of a corner of the assembly of Fig. 35 showing a binder applied to the crystals and showing in dashed lines the edges of crystals under the binder.

Fig. 37 is also an isometric view of the initial steps of assembling cubic diamond crystals into an integrated formation by placing the crystals in side-by-side contact on the bottom flat surface and in the corner of a tray inclined toward the corner. The scale is reduced from Fig. 35 but is still much larger than actual size.

Figs. 38a-38d are enlarged schematic views which illustrate additional steps of the method of this invention.

Figs. 39a-39f are also enlarged schematic views which illustrate additional steps of the method of this invention.

Detailed Description

Article of Manufacture- First Embodiment

The first embodiment of the present invention is a wear-resistant or abrasive article 36 (Figs. 1 and 2) which includes a square backing member 38 of plastic or metal that has a mounting surface 40 and a back surface 42. A plurality of single synthetic cubic crystals 50 of diamond have first portions 52 individually embedded in a backing member formation and second portions 54 projecting outwardly from the mounting surface.

The use of single, synthetic diamond crystals, 50 in Fig.3 and 60 in Fig.4, is important to the present invention, and thus reference is now made to certain details about such crystals. In general, these crystals are regular polyhedrons but are produced in various specific shapes, namely, perfect cubes (Fig. 3); a range of cubo-octahedrons where the crystal faces vary from predominately cubic and minimally octahedron (Fig. 4) to predominately octahedron and minimally cubic (not shown); and perfect octahedrons (not shown). It is preferred to use perfectly cubic crystals, as shown in Fig. 3, or predominately cubic crystals where the cubic faces predominate and the octahedral facets are minimal in size, as shown in Fig. 4. The principles of this invention, however, apply to other shapes of the cubic crystal system, to which diamond belongs, as will be understood in the subsequent description of the third embodiment of this invention using cubic boron nitride (CBN).

The cubic crystal 50 (Fig. 3) represents the described commercially available synthetic single diamond crystals which are up to about 1 mm in size. The crystal 50 has six side faces 64, twelve edges 70, and eight corners 74. These faces are of course square and are referred to in the art and herein as cubic faces or as being in cubic planes.

The cubo-octahedral crystal 60 (Fig. 4) also represents commercially available synthetic single diamond crystals and has six faces 82, which are commonly referred to as cubic faces since that is their predominate shape, and eight smaller octahedral facets 84 at the corners. Crystal 21 is thus referred to as a predominately cubic crystal since the octahedral facets are relatively small as compared to the cubic faces.

With reference to Fig. 5, a brief description is set forth of certain known crystallographic characteristics of a synthetic single diamond crystal, as 50 and 60, which are fully exploited in the present invention. Fig. 5 shows one of the faces 64 of the crystal 50. The crystal has crystallographic directions of maximum abrasive resistance or hardness in the plane of this cube face along the diagonal lines 90, 90 ′ and 92, 92 ′ of the face. It also has crystallographic directions of minimum abrasive resistance or hardness along lines 94, 94 ′ and 95, 95 ′ which are forty-five degrees from the diagonals or directions of maximum resistance. Therefore, the crystal exhibits degrees of directional hardness ranging from the diagonal maximum directional lines to the right-angular minimum directional lines. These lines of hardness may also be described as being tangential to their respective faces of the crystal. The appropriate Miller notations for the face and directional lines are denoted in Fig. 5. In view of the symmetry of the crystallographic structure of diamond crystals, each face of the crystal has the same crystallographic directions of hardness within the plane of its face.

Brief reference to certain nomenclature regarding the symmetry of crystals, as 50 or 60, (Figs. 3 and 4) will be useful in the subsequent description. As is known, the crystal has several planes of symmetry. One such plane is referred to in the art as a cubic plane which is an orthogonal plane which cuts through the crystal between and parallel to a pair of opposite faces, as 64. Another plane of symmetry is referred to in the art as a dodecahedral plane and is a diagonal plane that cuts through the crystal and contains a pair of opposite edges, as 70. The crystal also has several axes of symmetry one of which is represented, for example, by the letter y in Fig. 3 and passes through the center and

opposite faces of the crystal and is perpendicular to such faces. Reference will be made to these planes and axes in the following description and claims.

Having described known characteristics of single synthetic cubic diamond crystals 50, 60, the present invention is primarily concerned with the orientation of these crystals in a predetermined manner in the article 36, one embodiment of which is shown in Figs. 1 and 2. It is to be noted that Fig. 1 is drawn about four times actual size since the single synthetic cubic diamond crystals available are up to about 1 mm in size. It is also noted that for ease of illustration only perfectly cubic crystals are shown in Fig. 1 although in actual practice some of the crystals may be predominately cubic, as 60, and thus may have small octahedral facets 84.

In Figs. 1 and 2, each crystal 50 is individually mounted in the backing member 38, with its first or mounting portion 52 (Fig. 2), which is approximately half of the crystal, embedded in the backing member, and its second or abrading portion 54, which the other approximate half of the crystal, outside of the backing member. Another way of expressing the orientation of each crystal in the assembly is to state that each crystal is mounted in the formation with one of its cubic planes parallel to the mounting surface 40. The face 64 of each crystal at the extremity of the abrading portion 54 is referred to as an abrading face and is parallel to the mounting surface 40 and coplanar with the abrading faces of all the other crystals. These coplanar abrading faces thus define a working surface 96 for the article 36.

Incidentally, the amount of extension of the crystals 50 into or out of the backing member 38 is important to proper functioning of the article 36, but it is not a feature of the present invention. In the embodiment shown in Fig. 1, it is preferred that the mounting portions 52 of the crystals 50 are embedded in the backing member a distance of about 0.6 mm, sufficient to hold the crystals securely in the backing member so as to prevent their dislodgment when force is applied to the crystals upon workpiece engagement, while providing sufficient workpiece engaging surfaces. Specific techniques for bonding abrasive particles, such as the crystals 50, 60, in a plastic or metal backing member are well-known but are subsequently briefly generally described herein as a part of the subject method.

The crystals 50 in the embodiment of Fig. 1 are preferably uniformly distributed about the backing member 38 in a checkerboard pattern and for this reason are arranged in orthogonal rows, indicated by lines 97, 98, and diagonal rows indicated by lines 99,

100, relative to the square backing member. The rows are in spaced relationship, and adjacent crystals in each row are spaced from each other. It is to be understood that the specific square shape of the backing member, the specific checkerboard pattern or row formation, the specific crystal spacing, and the density or concentration of crystals shown in Fig. 1 are not essential to the invention and may be varied depending on the application of the article 36.

Of prime significance to the invention, however, is the orientation of the crystals 50 relative to each other. With reference to Fig. 1, the crystals are individually fixed in the backing member 38 with their maximum directions of crystallographic hardness, as 90, 90 ', aligned along parallel diagonals of the formation which run in NE/SW directions, to use a compass analogy. Likewise, the directions 92, 92 ' are aligned along the NW/SE diagonals. It will of course be apparent that orientation of the crystals is not limited to such specific compass directions nor to the orientation of the article on the drawing sheet. With such an orientation, the lines of maximum hardness directions of the crystals in each diagonal row 99 are aligned along common lines, as 101, 102, and these common lines of all the diagonal rows are parallel with each other. Stated otherwise, corresponding lines of maximum hardness directions of individual crystals are either in alignment, or parallel, with corresponding lines of maximum hardness of all the other crystals. Also, these lines 90, 90 ' and 92, 92 ' of maximum hardness are tangential to their respective face extremities 64, lie in the working surface 96, and are parallel to the mounting surface 40 of the backing member 38.

It is to be observed that as used herein and in crystallographic terminology, the words "align" and "aligned" mean pointing in the same direction, but can also mean being coincident with a single line. Thus, the lines of maximum hardness 90 of the crystals 50 in Fig. 1 are "aligned" in the sense that they all point in a NE direction in Fig. 1, whereas those directional lines 90 of the crystals in a given diagonal row are "aligned" in that they are coincident along a common line.

Conversely, corresponding lines, as 94, of minimum hardness directions of all the crystals 50 (Fig. 1) in each of the NS orthogonal rows 98 are in alignment, as represented by common lines, as 104 and 106, and all of the corresponding minimum hardness lines in each such row are parallel with those in the other NS rows. The same is true for the EW

rows. The lines of minimum hardness are thus also tangential to their respective face extremities 64, lie in the working surface 96, and are parallel to the mounting surface 40.

Therefore, it will be understood that the array, group, backing member, or formation of crystals 50 (Fig. 1) exhibits common directional lines, as 101 and 102, of maximum hardness which run diagonally of the backing member 38 and are parallel to the mounting surface 40. If the working surface 96 (Fig. 2) is moved across a workpiece (Figs. 29-32) in one of these diagonal directions, such as NE/SW, the crystals will exhibit their maximum hardness to the workpiece. Conversely, if the working surface is moved relative to a workpiece in the direction at forty-five degrees from common line 102, that is in a NS or EW direction, the surface will exhibit its minimum hardness to the workpiece. The working surface formed by the crystals thus exhibits common directions of maximum and minimum hardness and all the degrees of hardness in between, just like an individual crystal. With the present invention, then, the characteristics of an single crystal are imparted to the entire array of crystals.

With reference to Fig. 2, since the abrading portions 54 of the crystals 50 project outwardly of the backing member 38 equidistantly from the mounting surface 40 with their faces 64 defining the planar working surface 96, the crystals are able to contact a workpiece, not shown, simultaneously and thus apply force to the workpiece in an even manner. Wear on the crystals, and abrasion action on a workpiece, are therefore uniformly distributed.

Method of Making the First Embodiment of the Article

The method for making the first embodiment of the article 36 (Fig. 1) of the present invention is described with reference to Figs. 6-9. The method employs a template 120, only a portion of which is shown in Fig. 6. The template has a top surface or plate 122 and a plurality of half-cubic shaped recesses, wells, or pockets 124 extending downwardly into the body of the template from the top surface and serving as receptors for the crystals 50. Each recess may be described as having the shape of a part of a cube cut along one of its cubic planes. Since only a portion of the template 120 is shown, only a few of the recesses are shown. It will be understood, however, that a complete template is slightly larger than the abrasive article 36 and has the same number and formation of recesses as there will be crystals in the article to be made. Thus, a complete template for making the article shown in Fig. 1 includes fifty recesses in ten rows of five each, running

in both the length and the width of the template, with the recesses in adjacent rows offset from each other.

The recesses 124 (Fig.6) in the template 120 are of uniform shape and size. Each recess has a length and width (that is, the dimensions which lie in the plane of the surface 122) slightly greater than the edge dimensions of a cubic crystal 50, and a depth not quite as deep as such edge dimension. Thus, in this embodiment of the method, the recesses are slightly larger than 1 mm square and are about 0.6 mm deep. Each recess has a bottom wall 126, and side and end walls 128 and 130 which are at right angles to the bottom wall. The recesses may be configured with slightly beveled inside corners, not shown, similar to the shape of the facets 84 of the predominately cubic crystals 60 (Fig. 4) that have minor octahedral facets.

Significantly, the recesses 124 (Fig. 6) are oriented in the template 120 in positions which will orient the crystals 50, 60 so that their corresponding crystallographic maximum hardness directions, as 90, are aligned. Thus, all of the side walls 128 are parallel with each other, and all of the end walls 130 are parallel with the other end walls. To achieve equidistant projection of the crystals from the backing member mounting surface 40, all of the bottom walls 126 are in a common plane 138 (Fig. 8).

Alternatively, a modified template 120a (Fig. 7) with modified recesses 124a may be used. Here, the bottom wall 126a of each recess 124a is angled upwardly a few degrees from the common plane 138. More specifically, the bottom wall 126a is angled diagonally upwardly from one bottom corner of the recess to the diagonally opposite corner. It will be understood that corresponding corners, for example, all the NE corners, are similarly tilted upwardly so as to make the angulation uniform throughout the template 120a.

The templates 120 or 120a (Figs. 6 and 7) are made of plastic, such as polyethylene or tetrafluoroethylene, or of metal, such as steel or aluminum, and are shaped by casting the plastic or metal against a master form, not shown, having cube-shaped protrusions. Alternatively, the template is made by stamping or pressing plastic or metal stock with an appropriately shaped master multiple projection die or a single cube-shaped die, again not shown since such metal-working techniques are well known in the art.

In carrying out the method of the present invention, a supply of synthetic single diamond crystals 50, 60 of cubic or predominately cubic shapes and of approximately the

same size, currently about 1 mm, is selected. It is important to size the crystals by precision screening, preferably using screens with square openings. Further shape control by automated single crystal weighing or settling in a fluid using Stokes Law may be used.

With the top surface 122 (Fig. 6) of the template 120 maintained in a generally horizontal plane, crystals 50, 60 are deposited on the top surface and spread thereover and thus lie in random orientation about the top surface. More crystals are deposited than there are recesses 124 so as to insure a quantity sufficient to fill all the recesses. The template is vibrated or tapped and, if necessary, slightly tilted to cause the crystals individually to gravitate into and be received by the recesses. Because of the complementary shapes of the recesses and the crystals and the slightly larger recess size relative the crystal size, crystals are individually accommodated into the recesses where they each stabilize, with one bottom face 64 of each crystal lying flat on the bottom wall 126 of its recess and with its side faces 64 in adjacent parallel relation to the side and end walls 128 and 130. The crystals project from the top surface 122 of the template a distance less than their edge dimension, preferably about 0.4 mm in the illustrated embodiment. If the template 120a using inclined bottom walls 126a is employed, as shown in Fig. 7, corresponding top corners 74 of the crystals 50 are tipped up relative to their diagonally opposite top corners along a diagonal, as 99 (Fig. 1), of the template. While all of the recesses are being filled or after they are filled, the template is inclined slightly and again vibrated or tapped in order to remove excess crystals from between the rows, so that the top surface 122 is clean of crystals while maintaining the crystals in the recesses into which they were received and in their oriented positions therein.

Each recess 124 or 124a (Figs. 6 and 7) is thus temporarily filled with a crystal 50 or 60, and the crystals are thus oriented with all of their corresponding crystallographic directions of maximum hardness 90, 90 ′ and 92, 92 ′aligned and the corresponding directions of minimum hardness, as 94, 94 ′ and 96, 96 ′, likewise aligned. The bottom faces 64 of the crystals lie flat against the bottom walls 126 of their recesses and thus coplanar with plane 138, and the first or mounting portions 52 of the crystals protrude outwardly from the template.

The subject method next involves steps for fixing the crystals 50, 60 in the described orientation and for removing them from the template, as 120 (Fig. 6). The template used has a non-adhesive top surface 122 and non-adhesive recess walls 126, 128

and 130, which can be accomplished by making the template of polyethylene or tetrafluoroethylene as previously suggested. A layer 150 (Fig. 8) of uncured plastic, such as an epoxy resin, is applied over the top surface 122, covering and completely immersing the mounting portions 52 of the crystals in the plastic. This layer is then cured and upon curing, this overlay of plastic becomes the backing member 38 fixing the crystals in their positions of crystallographic alignment with the faces 64 resting against the bottom walls 126 of the recesses 124 in their coplanar relationship. The backing member and the array of crystals are then removed as a unit from the template thereby yielding the article 36 (Fig. 9).

In its basic form, the article 36 (Figs. 1, 2 and 9) comprises only one layer of crystals 50 and may be of any practical surface area with any practical number of crystals, limited only by the particular use or application of the article. By way of example only, the article 36 includes fifty crystals, each measuring about one millimeter square, in a backing member 38 measuring about 25 mm x 25 mm x 5 mm.

If desired for some applications, multiple articles, as 36, may be bonded together in edge-to-edge coplanar relation to form a much larger surface area, not shown. Also, multiple articles may be bonded together in stacked, layered relation, also not shown. In any case, all the crystals are positioned so that their crystallographic directions are oriented in the same direction, in accordance with the principles of this invention.

Article of Manufacture-Second Embodiment

The second embodiment of the article is identified by numeral 236 in Figs. 10 and 11. This article also conveniently includes a square backing member 238 having a mounting surface or area 240. Synthetic single diamond crystals 50, and/or 60, are used for this embodiment and are the same as used for the first embodiment in Fig. 1. As before, the crystals are preferably uniformly distributed about the mounting surface and are positioned in orthogonal and diagonal rows in a checkerboard pattern. The second embodiment differs from the first embodiment, however, in the orientation of the crystals, but this different orientation still aligns selected hardness directions.

Again, it is helpful to set forth certain crystallographic principles as a foundation for understanding the second embodiment. With reference to Fig. 12 and 13, it is known that the second hardest crystallographic direction of hardness of a diamond crystal 50 or 60 is along a line 248 which is tangential to an edge 70 of the crystal and also

perpendicular to the diagonal 249 (Fig. 13) of the crystal which intersects such edge. The appropriate Miller notation for this second hardness directional line is denoted in the drawings. It will be understood that there is a similar second hardest directional line tangential and perpendicular to each edge of the crystal. It is also to be noted that the crystal 50 has another axis of symmetry represented by the diagonal 249, and that this axis passes through one edge of the crystal, through the center of the crystal, and through the opposite edge and is perpendicular to such edges.

To take advantage of this second hardest direction, the crystals 50 (Figs. 10 and 11) are individually mounted in the backing member 238 so that a dodecahedral plane of each crystal is co-planar with the mounting surface 240, or is slightly on one side or the other of such mounting surface and parallel to it. It follows, then, as best visualized in Fig. 11, that the dodecahedral plane which is perpendicular to the first-mentioned dodecahedral plane is perpendicular to said mounting surface. With such mounting, the approximate half of each crystal on one side of the mounting surface is embedded in the backing member, and the other approximate half is outside the backing member. Of greatest significance, all the exposed edges 70a, which are referred to as abrading edges, of the crystal-halves are parallel to, or in alignment with, each other; are equidistant from and parallel to the mounting surface; and together define a working surface 250 (Fig. 11). Thus, the crystals are oriented in the backing member so that their crystallographic directions of hardness as indicated by the lines 248 (Fig. 10) are aligned with, or parallel to, such directional lines of all the other crystals, depending on whether their crystals are in the same EW row 252 or in a parallel EW row.

Thus, when the abrading edges 70a (Figs. 10 and 11) of the article 236 are in contact with and moved relatively to a workpiece, not shown, in the direction of the lines 253, 254 (that is, the EW direction in Fig. 10), the combined effect of aligned hardness directions of the crystals 50 is presented to the workpiece. Although the hardness direction 248 is not the hardest direction of the crystal, it is the next-to-the-maximum hardness direction and thus allows an improved abrasive force to be applied by the crystals, as contrasted with non-aligned directions of hardness of grits, particles or crystals which are randomly positioned with regard to crystallographic direction, as practiced by the prior art.

Method of Making the Second Embodiment of the Article

The article 236 (Fig. 10) is made in a manner similar to the article 36 (Fig. 1), except that a different template 260 (Fig. 14) is utilized to accommodate the different orientation of the crystals 50. In template 260, only a portion of which is shown in Fig. 14, recesses 264 are in the shape of an approximate cube-half, when the cube is cut along a dodecahedral or diagonal face-plane thereof. In other words, the recesses are V-shaped with a ninety degree included angle. In general, the parameters for constructing the template and the recesses are the same as for template 120 (Fig. 6). That is, the recesses are slightly larger than the crystals so as to facilitate accommodation of the crystals therein, and they have end walls 265 and side walls 266 that meet at bottom corners or edges 268 which are tangent to and lie in a common plane 270 (Fig. 15).

An alternative template 280 (Fig. 18) may be used with the second embodiment of the method. This template has V-shaped recesses, grooves or troughs 282 having side walls 284, end walls 286, and bottom edges 288, which are the same shape as the recesses 264 except that they extend almost the full length or width of the template, being enclosed by the end walls 286.

As with the method described with reference to Figs. 6-9, a similar method is followed to make the article 236 (Fig. 10). In brief, sorted, substantially uniformly sized crystals 50 are distributed in a random manner over the template 260, or 280, and the template is vibrated to cause the crystals to fall into the recesses 264, or 282. In the recesses 264, there is one crystal per recess, but with recesses 282, a line of crystals is accommodated with adjacent faces 64 of adjacent crystals preferably being in contact. Again, the templates 260 or 280 are inclined slightly and vibrated or tapped to remove excess crystals while maintaining the oriented crystals in the recesses.

Next, an uncured plastic layer 290 (Fig. 15) is placed over the template 260, or 280, to cover the protruding portions of the crystals 50 and then is allowed to cure and harden. When cured, the plastic layer becomes the backing member 238 with the crystals fixed therein and is removed from the template thereby resulting in the article 236 (Figs. 16 and 11).

Article of Manufacture- Third Embodiment

The third embodiment of this invention provides an article 336 (Figs. 19-21) similar in principle to the articles 36 and 236 of the first and second embodiments except

that the third embodiment uses single, synthetic crystals 350 of cubic boron nitride (CBN). The article includes a backing member or carrier 338 for the crystals which has a mounting surface 340 and a back surface 342.

Cubic boron nitride, like diamond, is in the cubic class of crystals, but, unlike diamond, has the sphalerite structure. The CBN crystal 350 (Fig. 22) is thus a regular polyhedron like diamond but, unlike diamond, has a tetrahedral shape. Individual crystals of CBN of good quality are commercially available, with planar triangular faces 352 meeting in sharp edges 354 and corners 356, and have dimensions of up to about 0.5 mm on an edge. It is important to emphasize that, like the embodiments 36 (Fig. 1) and 236 (Fig.11) of this invention utilizing diamond crystals, the CBN used for the third embodiment is in the form of single or individual crystals and not the CBN grains used in the prior art as abrasive grains or grit that are predominately crushed aggregates of intergrown, randomly-oriented crystals. Like the other embodiments, use of single, substantially uniform crystals allows predetermination of the crystallographic directions, manipulation of the crystals, and resultant orientation into the desired positions.

As is known, the tetrahedral crystal, as 350, has several planes and axes of symmetry. One such axis is referred to in Fig. 23 by the reference letter p and is useful in describing and claiming the present invention. The axis p passes through the center of one edge of the crystal, through its center and through the center of the edge opposite to the first edge, and is perpendicular to both such edges.

No careful work is known that has correlated the variation of abrasion-resistance of the CBN crystals, as 350 (Fig. 22), with crystallographic direction. The similarity, however, between the internal atomic configurations of CBN and diamond leads to the conclusion that the most abrasive-resistant direction of a CBN crystal is along a line, as 360 (Figs. 19, 22-24), which is perpendicular to an edge, as 354a, of the crystal. This directional line may also be described as tangential to the edge 354a and parallel to the opposite edge 354b, as best illustrated in Fig. 23. It is of course understood that the edge 354a is chosen by way of example only and that there is such a directional line of maximum hardness perpendicular and tangential to each of the edges 354. Miller notations for faces of a CBN crystal are shown in the Figs. 22-24.

The crystals 350 (Figs. 19-21) are mounted in the backing member 338 so that a plane cutting through each crystal and parallel to a pair of its opposite, perpendicularly related edges lies approximately in or close to the mounting surface 340 (Fig. 20) of the

backing member. Such a plane divides the crystal into two portions, so that with such a mounting, one of these portions is embedded in the backing member and the other portion is outside the backing member. In the preferred embodiment illustrated in Figs. 19-21, about sixty percent of each crystal is embedded in the backing member and the remaining forty percent protrudes out of the backing member. The important feature, however, is that the exposed edge 354a of said opposing pair of edges of each crystal is parallel with the corresponding exposed edges of all the other crystals, as is readily seen in Fig. 19, and with the mounting surface 340. Also, these edges 354a of crystals in the same NS row, as 366, are in alignment.

As previously mentioned with regard to the other embodiments, the third embodiment of the invention is not limited to the specific spacing or number of crystals 350 (Fig. 19) or rows, nor to the orthogonally formed rows, nor to the number or concentration of crystals. It is important to the invention, however, that the crystallographic lines 360 of maximum hardness of corresponding edges, as 354a, of all the crystals are in alignment, or are parallel, with each other. Such alignment or parallelism of the crystallographic lines follows from mounting the crystals with the exposed edges 354a in alignment or parallel with each other.

Method of Making the Third Embodiment of the Article

This embodiment of the method is similar to the other two method embodiments except that templates 390 and 392 (Figs. 25 and 28), similar to the templates 280 (Fig. 18) and 260 (Fig. 14), respectively, are constructed to accommodate the tetrahedral, CBN crystals. The article 336 illustrated in Fig. 19 is made using the template 390 in Fig. 25. The template 390 has elongated V-shaped recesses or troughs 394 with end walls 396, and side walls 398 meeting at predetermined angles in bottom corners or edges 400 which are all in a common plane 406 (Fig. 26).

As an example, the entire template 390, only a portion of which is shown in Fig. 25, may be approximately 32 mm x 15 mm x 5 mm in size and be made of high density polyethylene. The recesses 394 may be milled lengthwise of the template to a depth of about 0.5 mm and so that the side walls 398 have an included angle of about 70°32 ′, ±5°.

With the template 390 (Fig. 25) maintained in a horizontal position, crystals 350 of CBN of pre-sorted, substantially uniform size are sprinkled on the template and thus

randomly positioned thereon. By vibrating and slightly tilting the template, the crystals are caused to drop into the recesses 394 with an edge 354a (Fig. 26) of each crystal fitting against the bottom edge 400 of a recess, and thus being tangent to the common plane 406, and with two opposite side faces 352 (Fig. 25) resting against the side walls 398 of the recess and with slightly less than half of each crystal protruding outwardly from the template. Tilting the template toward one end while vibrating and tapping the same also causes excess crystals on the top surface of the template and between the recesses to drop off the template.

Epoxy resin (system three, phase two) is then poured over the template 390 so as to provide a layer 410 (Fig. 26) of about 5 mm depth covering the projecting portions of the crystals 350. The resin is then cured at about 60°C for about two hours, causing the resin to cure and harden and form the backing member 338. The crystals are thus individually fixed in the backing member in their oriented positions in the template. The backing member and its attached crystals are then removed from the template thus resulting in article 336 (Fig. 27) wherein all of the exposed edges 354a of the crystals are parallel to each other (Fig. 19), thereby causing the crystallographic directional lines 370 of maximum hardness to be either aligned or parallel to each other and lying in the common plane of the work surface 420 (Figs. 20, 21 and 27) defined by the edges 354a. It will be understood that the coplanar relation of the edges 354a results from the bottom edges 400 of the recesses 394 lying in a common plane 406 (Fig. 26).

It will now be understood how the template 392 (Fig. 28) having spaced V-shaped recesses or pockets 426 is used to create an article, not shown, with crystals 350 temporarily placed in the pockets, individually fixed in a backing member, not shown, and then removed, to produce such an article very similar to article 236 (Fig. 10), but with CBN crystals instead of diamond crystals.

The recesses, trough or grooves 394 and 426 (Figs 25 and 28) that act as receptors of the crystals 350 to align the crystals can be chosen to be of a length slightly longer than the length of an edge of a CBN crystal, in the case of the recesses of Fig. 28, or any multiple of this length in the case of the recesses of Fig. 25. Thus, the pattern and density of the crystals can be adjusted to make optimum use of the CBN crystals for workpiece treatment.

By now it will be understood that the template, as 120, 260, 280, 390, or 392, used in the present invention is not limited to the particular recess or well configurations

shown, but more broadly, the template is understood to have a receptor area shaped to accommodate and align the crystals 50 or 350, such receptor area including either a plurality of recesses or pockets or wells, as 124 or 264 or 426, or one or more troughs, as 282 or 426 or 394.

In all the embodiments of this invention, it will be understood that bonding agents other than epoxy resin or other plastic formulations may be used, as are well known in the art. Briefly, with the templates 120, 260, 280, 390, or 392 made of graphite, a powdered infiltration metal or a powdered infiltrator alloy with abrasion-resistant particles, such as tungsten carbide, can first cover the crystals 50 or 350. The assembly can then be heated to fuse the metal and create the backing member 38, 238 or 338, fixing the crystals in their oriented positions. Also, metal, such as nickel, can be electrodeposited over the crystals in the template to serve as the backing member by a well known process. Still further, any of the templates may be made of a refractory material not bondable to fired ceramic bodies, such as graphite or silicon carbide. An unfired plastic ceramic could then be layered over the crystals in the template and subsequently heated to a temperature suitable to sinter the ceramic body, whereby a vitreous backing member embeds the crystals in their oriented positions.

Figs. 29 and 30 show one of the articles, as 336, constituting part of a tool 500 which moves relatively to a workpiece 510 along a linear path 520. It will be noted that the edges 354a contact the workpiece together since they are tangential to a common plane or work surface 420. Also, the crystals all move across the workpiece perpendicularly of the edges 354a or, in other words, along the common lines 360 (Fig. 30) of directional hardness of all of the crystals. Each individual crystal engages the workpiece so that its predetermined line of maximum hardness 360 is aligned with the path 520 of movement of the crystal. Therefore, a maximum amount of abrasive action is exerted by the crystals.

Figs. 31 and 32 illustrate the principles of the present invention for use in a tool 600 which surfaces a workpiece 610, shown in phantom outline in Fig. 31, along a rotary path 602. The tool comprises a sleeve 604 having an annular end 606, and a plurality of crystals, as 50, mounted on the end so that the sharp edges, as 70a, are oriented radially of the sleeve. In this manner, the crystals engage the workpiece so their individual lines 248 of high hardness are aligned with the rotary path 602 of the crystals. Although the drawing shows groups of crystals mounted at each quadrant at the end of the sleeve, the

crystals can be spaced or mounted in a continuous formation about the circumference. The important point is that the crystals are mounted so that each crystal contacts the workpiece with its line of high hardness aligned with the path of movement of the crystal.

Article of Manufacture- Fourth Embodiment

The fourth embodiment is useful as a bearing, heat sink or semiconductor. This embodiment provides an assembly 650 (Figs. 33 and 34) of synthetic single crystals 50 (or 60, although only the numeral 50 will be used in the following description) of diamond secured together in a formation by a binder 658 which forms a backing member. The crystals are oriented so as to provide the assembly with enhanced physical properties similar to what has been previously described. Full advantage of these properties cannot be realized with an individual crystal because of its minute size.

The assembly 650 of the synthetic single diamond crystals 50 shown in Figs. 33 and 34 as approximately twice actual size. In order to explain the principles of this invention as incorporated in the fourth embodiment, however, it is necessary to use illustrations considerably more enlarged from actual size than even Figs. 33 and 34. Such an enlarged assembly is indicated in Fig. 35 by reference numeral 660 and may be regarded as merely a segment of the assembly of Fig. 33.

The crystals 50 are placed in the assembly or formation 660 (Fig. 35) in an integrated, tightly packed mosaic pattern. The crystals are in side-by-side and edge-to-edge relationship with adjacent side faces 64 of adjacent crystals in mating congruent contact so as to eliminate or at least greatly reduce any gaps between the crystals and to restrict intrusion of contamination or foreign material. In the assembly, all the top faces 64 of the crystals are in a common plane which thus creates a top, outwardly directed surface 662 of the assembly, and all of the bottom faces 64 of the crystals are coplanar and define a bottom, outwardly directed surface 664.

The crystals 50 are integrated or bonded together in the formation 660 by one or more of several bonding techniques, as subsequently described in greater detail. One of these bonding techniques is an adhesive coating 666 over either the top surface 662, as shown in Fig. 36, or over the bottom surface, not shown.

Of greatest significance, the crystals 50 (Fig. 35), by virtue of their substantially same size and predominately cubic shape and by virtue of their described assembly 660, are oriented with their crystallographic directions of maximum abrasive resistance either

aligned with, or parallel to, each other. Alignment occurs because the crystallographic directions 90, 90 ′ of each crystal (Fig. 5) are aligned with the corresponding directions 90, 90 ′ of all the other crystals lying in a row along one of the principal diagonals 670 (Fig. 35) of the assembly. Likewise, the crystallographic directions 92, 92 ′ (Fig. 5) of the crystals lying in a row along the other principle diagonal 672 (Fig. 35) of the assembly are aligned. Parallelism occurs because these directions, as 90, 90 ′, are parallel to such directions of the crystals in other shorter, diagonal rows, one of which is indicated by line 674 in Fig. 35.

Furthermore, the directions of minimum abrasive resistance 94, 94 ′ (Fig. 5) are aligned and parallel to each other in a similar manner and as represented by line 676 in Fig. 35, and this line is at forty-five degrees separation from the lines of maximum resistance 670, 672.

In its basic form, the assembly or formation 650 (Fig. 33), or 660 (Fig.35), comprises only one layer of crystals 50 and may be of any practical surface area, that is, any practical number of crystals, limited only by the assembly space and the particular use or application of the assembly. By way of example only, the assembly in Fig. 33 includes two-hundred twenty-five crystals with an actual size of approximately fifteen millimeters by fifteen millimeters square and slightly in excess of one millimeter thick allowing for the thickness of the binder 658. In contrast, the assembly of Fig. 35 includes sixty-four crystals and would measure about 8 by 8 by 1 mm in actual size.

The perimeter or outside edge of the assembly 650 need not be rectangular and may have other regular or irregular configurations since the principles of the invention still apply along the diagonals of the assembly as governed by the cubic crystal faces 64 (Fig. 35) within the margins of the assembly. Again, reference to top and bottom surfaces 662 and 664 does not imply use of the assembly in any particular orientation but is for convenience in describing the assembly of the crystals 50. If desired for some applications, multiple assemblies, not shown, may be bonded together in edge-to-edge coplanar relation to form a much larger surface area. Also, multiple assemblies may be bonded together in stacked, layered relation, also not shown. In any case, the crystals are assembled so that their crystallographic directions are oriented in the same direction, in accordance with the principles of this invention. Multiple layers also occur upon chemical vapor deposition, as subsequently described.

Method of Making the Fourth Embodiment of the Article

In general, the method of making the fourth embodiment may be divided into two parts for descriptive purposes, namely, initially assembling the crystals 50 so as to form the assembly 650, and secondly, binding the crystals in the assembly. Figs 37 illustrates the steps of assembling the crystals, and Figs. 38 and 39 illustrate two embodiments of binding the crystals in the assembly.

The initial part of the method, namely, placing the diamond crystals 50 in an assembly 660a is thus described by reference to Fig. 37. One of the first tasks is to select the crystals to be used. Synthetic single diamond crystals of subtantially cubic shape, or of cubo-octahedral shape where the cubic faces predominate, are chosen. Also, the crystals used should be of substantially the same size. Currently, crystals are available up to about 1 mm on an edge, but as synthetic growing techniques improve, larger crystal sizes may become available. If not already accomplished, and as discussed above, the supply acquired should be sized to insure that the crystals used are of substantially the same size, preferably from 0.75 mm to 1 mm or larger if available. As previously noted, only perfectly cubic crystals 50 are shown in Fig. 37, but the method described is equally applicable to the cubo-octahedral crystals 60 with predominately cubic faces 82.

Synthetic, single diamond crystals 50 are dropped (Fig. 37) one at a time or in limited numbers into a tray or receptacle 680 having a planar bottom surface 682 and side walls 684 defining a corner 686 of the tray which has the shape of a corner of a cube. The tray is tilted toward the corner and is gently shaken, vibrated or tapped in the plane of the bottom surface. When the crystals land on the bottom surface 682, they attain a stable position on one of their faces 64. Stability occurs because of the cubic shape of each crystal; the angle of tilt of the tray; the mass of the crystal; and the material of the tray, more particularly the bottom surface 682. Then, because of the tilt and vibration of the tray, the crystals slide toward the corner. The angle of tilt of the tray and the vibrating action are adjusted to achieve this stabilization and sliding action. In the described embodiments, the tray is preferably made of high density polyethelene, PTFE, graphite, a refractory, or other material which has a coefficient of friction to promote the described stabilty and sliding action of the diamond crystals.

As the crystals 50 slide into the corner 686 of the tray 680 (Fig. 37), they align themselves with the side walls 684 of the tray or with the side faces 64 of crystals that are already in oriented positions in the corner and thereby build up the assembly 660a of

crystals in a layer, one crystal thick. Use of needle point tweezers, not shown but commonly available, may be used to reposition any errant crystals. The side faces of adjacent crystals are in congruent contact with each other, and the top faces of all the crystals in the assembly form the common planar surface 662. This results in all the crystals being oriented in the same crystallographic direction, as explained above in describing the assembly 660 in Fig. 35.

After the crystals 50 are positioned in the assembly 660a (Fig. 37), they are bound together in accordance with the second part of the method, now described with reference to the two embodiments shown in Figs. 38 and 39. In describing these embodiments, all of the crystals are shown as cubo-octahedral crystals 60 with predominately cubic faces 82, but it is understood that in actual use, the crystals may be a mixture of cubic crystals 50 and such cubo-octahedral crystals 60. Only cubo-octahedral crystals are shown in Figs. 38 and 39 because of illustrative convenience and because it facilitates description of the binding and grinding steps.

With reference first to Fig. 38a through 38d, the steps are described for binding crystals 50 in an assembly 660b which has utility for abrasion resistance in bearings and heat sink purposes. It is noted that Figs. 38 and 39 are schematic views involving only a few crystals and are intended primarily to show the principles of the method. Cubo-octahedral synthetic single diamond crystals 60 (Fig. 38a) with large cubic faces 82 and relatively small octahedral facets 84 and approximately one millimeter in size are contained and oriented in a tray 680b, for example in the manner discussed with reference to Fig. 37. The crystals in the tray are then covered with a metal infiltration powder 690, such as Macrofil, a product available from Kennametal Inc. of Latrobe, Pennsylvania, USA that is capable of wetting the crystals upon heating. The powder is then heated to melting temperature to fuse the metal to the surface of the crystals and to draw it by capillary action into interstices between the top corners or octahedral facets 84 of the crystals. It is to be understood that the tray is made of a heat-resistant material, such as graphite, which is not wetted by the metal. The molten metal is then allowed to cool and solidify to form a binder coating 692 (Fig. 38b), whereupon the crystal assembly is removed from the tray (Fig. 38c). Finally, the bottom surface 664b of the assembly is ground to remove the octahedral facets and to produce a smooth coplanar surface.

The embodiment of the method described and illustrated in Figs. 37 and 38a-38d produces the bearing surface 664b which has a maximum abrasive resistant direction along

the aligned diagonals of the crystals 60, as fully described above in discussing Fig. 35. Using the principles of Figs. 37 and 38a-38d, an article, as 650 (Fig. 33), is produced which is useful as a bearing member with an exceptionally high abrasion resistance along the defined direction. It is significant to note, however, that the method also causes, and the article exhibits, a direction of minimum abrasive resistance, and it is along this line that the grinding occurs in achieving the smooth planar surface 664b. Thus, by following the principles of this invention, both maximum and minimum abrasive directions are fully achieved and exploited.

In addition, the article of the fourth embodiment is useful as a heat sink since the cubic faces 82 of the crystals 60 are in intimate contact and allow maximum heat conductivity across the interfaces of the crystals. The metal binder 692 enters essentially only the interstices between the octahedral facets 84 of the crystals and thus does not contaminate the main body of the assembly and interfere with the excellent thermal conductivity of diamond. The bearing surface or heat sink can be enlarged by including more crystals in the assembly 650 or by duplicating the assembly and mounting the assemblies so provided in contiguous edge-to-edge generally coplanar relationship to form a larger assembly of crystals, as will be understood although not shown.

Figs. 39a through 39f are referred to in describing another embodiment of the binding part of the method of the present invention so as to provide an article of manufacture suitable for electronic, heat sink, or abrasion-resistant uses. In Fig. 39a, the crystals 60 are assembled as previously described in a tray or box 680e which is temperature resistant to about 1000° C and chemically resistant to chemical vapor deposition (CVD) of diamond. For this purpose a suitable tray material is refractory cement. A first coat 710 (Fig. 39b) of diamond is deposited by CVD on the upper surface 662d which binds the crystals 60 together in assembly 660e. While the assembly is still in the tray (Fig. 39c), a rigid backing 712, which may be made of plate glass or aluminum, is temporarily cemented, for example by lapidarist's cement such as stick shellac, to the first coat 710 of diamond to hold the assembly 660e rigidly together to allow grinding. Next, the assembly of diamond crystals as held together by the rigid backing is removed from the tray (Fig. 39d), and the lower surface 664e is finished by a grinding tool, by chemical milling, or by laser machining to provide a smooth coplanar surface 664e with any octahedral facets 84 destroyed.

In the next step (Fig. 39e), the backing 712 and the cement used to attach it are removed by dissolution with a solvent, such as alcohol, or by heating to a temperature of approximately 200°C. Many other temporary cements could also be used and dissolved. A second coat 715 (Fig. 39f) of diamond is then deposited by CVD over the planar surface 664e. It is to be understood that the diamond in both the first and second coats 710 and 715 inherits the orientation of the atomic arrangement of the oriented diamond crystals in the assembly 660e so that the final article is an assembly of pure, single crystal diamond, with all of the crystallographic directions oriented in the same direction. The article 660e is thus ideally suited for the semiconductor, heat sink and bearing purposes discussed herein.

In summary of the present invention and its advantages, each of the described embodiments comprises synthetic single crystals of diamond or CBN, as 50, 60 and 350, held in a formation with selected crystallographic directions of the crystals oriented in the same direction. In the first three embodiments, a plurality of single synthetic crystals of diamond or CBN of substantially uniform size and shape are mounted in a backing member, as 38, 238 and 338, so that all the crystals are oriented with corresponding hard-to-abrade directions aligned. With the first and third embodiments in Figs. 1 and 19, the hardest-to-abrade directions are aligned, whereas with the second embodiment of Fig. 10, the next-to-the hardest directions are aligned. In all four embodiments the exposed workpiece-engaging extremities, as 64, 70a, 354a, 64b of the crystals lie in a common plane for simultaneous workpiece engagement even though some of the crystals are of slightly differing sizes. With the second and third embodiments of Figs.10 and 19, sharp edges, as 70 and 354, are presented to a workpiece, and with the variation of the first embodiment (Fig. 7), sharp corners, as 74, are presented. In the embodiments of Figs. 7, 10, 19, therefore, the sharp edges or sharp corners are in a saw-tooth formation which together with the aligned hardness directions produce an especially effective abrading action. It is also to be noted that the spacing between the crystals facilitates removal of abraded material as a workpiece is being processed.

From the foregoing, the following advantages, inter alia, of the first three embodiments will be understood. Since only the hardest-to-abrade directions are presented to a workpiece, the abrasive article: has increased life thus saving abrasive material; abrades faster; requires less frequent replacement of parts; maintains dimensional tolerances longer; minimizes adjustment for wear compensation; reduces dulling and

flatting; and allows variation of abrasive concentration and thus facilitates its optimization. Furthermore, since all of the workpiece-engaging extremities of the crystals lie in a common plane, even though the individual crystals may vary somewhat in length, the crystals engage the workpiece simultaneously and uniformly thereby enabling uniform removal of material from the workpiece and avoiding the problems of grains which stand high and slow the abrasive action. All of the above stated features and advantages have the effect of reducing cost, time and labor and improving abrasive action.

The terms "abrasive" and "abrading" are sometimes used in the art in a very specific sense to mean a very specific type of workpiece treating action. It is to be understood, however, that as used herein, these terms are not limited to such a specific meaning but include cutting, grinding, dressing, lapping, sawing, or otherwise treating or engaging workpieces in the multitude of ways in which a hard surface or tool is used. It is also to be noted that the principles of the invention are more broadly applicable to wear-resistant surfaces which are useful not only as workpiece-treating elements but as bearing elements.

In addition, it will be understood from the foregoing that the fourth embodiment yields the following advantages. The alignment of the hardest-to-abrade direction, that is the cube face diagonal of diamond crystals, gives superior wear surface, as compared to bonded aggregations of randomly oriented diamond crystals, because of the presentation of the one hundred percent hardest directions and the absence of a softer bonding agent. This is an advantage in sliding-surface bearings or thrust bearings especially in applications with abrasive contamination between the wear surfaces. The reduction in wear lengthens the time between bearing replacement or adjustment, retains the dimensional tolerances between bearing surfaces for longer periods, and retains the smoothness of bearing surfaces for longer periods of service. Friction values of the hardest-to-abrade diamond directions on each other are lower than friction values for random diamond directions. The result is less heat generation, lower power consumption, and less stress on the bearing parts.

The high heat conductivity of diamond makes a superior heat sink to conduct heat away from the heat source. The subject invention produces an extended assembly 650 with almost one hundred percent diamond content, and thus a continuous homogeneous content of diamonds without the diluting effect of binders used in binding diamond crystals.

The fourth embodiment produces an extended, voidless assembly 650 of diamond crystals with identical crystallographic directions. Chemical vapor deposition on the assembly results in a thin layer of diamond with one crystallographic direction because of the epitaxial relationship between the chemically-vapor deposited layer and the substrate of oriented diamond crystals. It is important to regognize that the assembly has one crystallographic direction yielding single crystal quality because the contacting adjacent crystals avoids spaces between the crystals which would otherwise produce defects at the growth boundaries.

Following the principles of the fourth embodimen thus makes possible improved exploitation of diamond's semiconductor properties. Chemically-vapor deposited single-crystal assemblies, as 660e, can be made insulating in character by using pure diamond or can be doped with impurities to yield P or N carriers to make diodes, transistors, radiation detectors, or photo conductor devices. The diamond substrate forms an integral heat sink to allow increased electric current capacity to the devices, and diamond's high temperature and chemical immunity permit devices to function in hostile environments.

In attrition grinding of hard materials to reduce particles to smaller sizes, the wear of machine surfaces by the abrasive action of the particles is costly because the parts wear rapidly and must be replaced, and the parts that wear produce particles that contaminate the product being ground. By applying to the wear surfaces, assemblies or layers 650 of aligned diamond crystals that present the hard-to-abrade directions of the crystals to the abrading directions of the particles being ground, machine wear can be drastically reduced thus saving the cost of new wear surfaces and the cost of replacing them. The great reduction of impurities from wear surfaces is often of critical importance in quality control, and the minuscule contamination by diamond wear surfaces is of a highly inert nature.

The present invention takes advantage of the inherent properties of diamonds and particularly synthetic diamond crystals in the manner described, but it is to be understood that the principles of this invention are equally applicable to other materials that have similar or equivalent crystalline properties.

In addition to the terms "assembly" and "formation," the terms "array," "sheet," "mosaic," "block," and "matrix" are used to describe the article of manufacture provided by the present invention. Other terms could be used without affecting the principles

described herein. It is understood that the use of these terms does not imply any particular surface area or size of the various assemblies shown in Figs. 1, 10, 19 or 33.

Furthermore, although preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to understood that the present invention has been described by way of illustration and not limitation.

Claims

1. An article of manufacture comprising synthetic single crystals held in a formation with selected crystallographic directions of the crystals oriented in the same direction.

2. The article of claim 1 wherein the crystals are polyhedral in shape.

3. The article of claim 2 wherein the shapes are selected from the group consisting of cubic, cubo-octahedral and tetrahedral.

4. The article of claim 2 wherein the crystals are of uniform size and shape.

5. The article of claim 4 wherein the crystals are at least about 0.5 mm to 1 mm in size.

6. The article of claim 1 wherein the crystals are selected from the group consisting of diamond and cubic boron nitride.

7. The article of claim 6 wherein the crystals are of uniform size and shape, wherein each of the crystals has face portions and edge portions, wherein one of said portions of each crystal faces outwardly of the formation, wherein said selected crystallographic direction of each crystal lies along a line in contact with its outwardly directed portion, wherein all of said selected crystallographic directions have substantially the same degree of hardness, and wherein said outwardly directed portions thereby exhibit a common crystallographic direction of hardness.

8. The article of claim 7 wherein the crystals are spaced from each other.

9. The article of claim 8 wherein all of the outwardly directed portions project equidistantly outwardly from said formation.

10. The article of claim 8 wherein said outwardly directed portions are faces of the crystals.

11. The article of claim 8 wherein said outwardly directed portions are edges of the crystals.

12. The article of claim 11 wherein said outwardly directed edges are coplanar.

13. The article of claim 11 wherein said outwardly directed edges are at an angle to a common plane and terminate in sharp corners which are in said common plane.

14. The article of claim 7 wherein the crystals are closely packed together with said outwardly directed portions being faces of the crystals and forming a continuous common surface.

15. The article of claim 7 including a binder of plastic or metal holding the crystals in said formation.

16. The article as in any one of claims 7-13 or 15 wherein said outwardly directed portions are abrading portions whereby the article is an abrasive article.

17. The article of claim 14 wherein said continuous common surface is a bearing surface, a heat sink or a semiconductor substrate.

18. The article of claim 7 or 14 wherein the formation is a semiconductor substrate, and wherein a layer of diamond crystals is deposited on said outwardly directed portions by chemical vapor deposition whereby the deposited layer has the same crystallographic direction as the assemblage.

19. The article of Claim 18 wherein the deposited layer is doped with impurities to provide P or N carriers and wherein the formation is an integral heat sink for the doped layer.

20. The article of claim 7 wherein the formation is a layer of said crystals in a common plane.

21. A method for producing an article of oriented crystals comprising the steps of selecting synthetic single crystals of substantially uniform size and of polyhedral shape and wherein each of said crystals has at least one portion with a crystallographic direction which is substantially the same in all of the crystals, positioning the crystals in a formation so that all of said crystallographic directions are oriented in the same direction and said portions collectively exhibit a common crystallographic direction of hardness, and securing the crystals together in said formation.

22. The method of claim 21 wherein said selecting step invloves selecting the crystals from the group consisting of diamond and cubic boron nitride.

23. The method of claim 21 or 22 wherein the crystals are positioned in said formation in spaced relation to each other.

24. The method of claim 21 or 22 wherein the crystals are positioned in said formation in contacting, closely packed relation to each other.

25. The method of claims 21 or 22 wherein said one portion of each crystal is an abrasive portion, wherein said positioning step includes introducing the crystals into a template having receptor means shaped to position and align said abrasive portions to collectively exhibit said common crystallographic direction of hardness and wherein said abrasive portion of each crystal protrudes from said template, said method including the further step of vibrating the template to stabilize the crystals in the receptor means and to remove excess crystals, wherein said securing step involves applying a binder to the crystals protruding from the template whereby the crystals are fixed in the positions in which they were aligned in the template and at least partially curing said binder, and including the additional step of removing the crystals and binder from the template.

AMENDED CLAIMS

[received by the International Bureau on 05 February 1996 (05.02.96); original claims 1,5,7,20 amended; new claim 21 added; original claims 21-25 renumbered as claims 22-26 remaining claims unchanged (2 pages)]

1. An article of manufacture comprising a formation of synthetic single crystals each having a predetermined crystallographic direction of hardness, said crystals being held in the formation with said predetermined crystallographic directions oriented in the same direction, said formation being created by physically moving the crystals from disoriented positions into their oriented positions in said formation.

2. The article of claim 1 wherein the crystals are polyhedral in shape.

3. The article of claim 2 wherein the shapes are selected from the group consisting of cubic, cubo-octahedral and tetrahedral.

4. The article of claim 2 wherein the crystals are of uniform size and shape.

5. The article of claim 4 wherein the size of the crystals ranges from about 0.5 mm to about 1 mm or more.

6. The article of claim 1 wherein the crystals are selected from the group consisting of diamond and cubic boron nitride.

7. The article of claim 6 wherein the crystals are of uniform size and shape, wherein each of the crystals has face portions and edge portions, wherein one of said portions of each crystal faces outwardly of the formation, wherein said predetermined crystallographic direction of each crystal lies along a line in contact with its outwardly directed portion, wherein said crystals have substantially the same degree of hardness along their respective predetermined crystallographic directions, and wherein said outwardly directed portions thereby exhibit a common direction of hardness.

8. The article of claim 7 wherein the crystals are spaced from each other.

9. The article of claim 8 wherein all of the outwardly directed portions project equidistantly outwardly from said formation.

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20. The article of claim 7 wherein the formation is a coplanar layer of said crystals.

21. The article of Claim 1 wherein the formation is a matrix of rows and columns of crystals, each of said rows and columns being completely filled with crystals, said crystal formation having a common crystallographic direction of hardness.

22. A method for producing an article of oriented crystals comprising the steps of selecting synthetic single crystals of substantially uniform size and of polyhedral shape and wherein each of said crystals has at least one portion with a crystallographic direction which is substantially the same in all of the crystals, positioning the crystals in a formation so that all of said crystallographic directions are oriented in the same direction and said portions collectively exhibit a common crystallographic direction of hardness, and securing the crystals together in said formation.

23. The method of claim 22 wherein said selecting step involves selecting the crystals from the group consisting of diamond and cubic boron nitride.

24. The method of claim 22 or 23 wherein the crystals are positioned in said formation in spaced relation to each other.

25. The method of claim 22 or 23 wherein the crystals are positioned in said formation in contacting, closely packed relation to each other.

26. The method of claims 22 or 23 wherein said one portion of each crystal is an abrasive portion, wherein said positioning step includes introducing the crystals into a template having receptor means shaped to position and align said abrasive portions to collectively exhibit said common crystallographic direction of hardness and wherein said abrasive portion of each crystal protrudes from said template, said method including the further step of vibrating the template to stabilize the crystals in the receptor means and to remove excess crystals, wherein said securing step involves applying a binder to the crystals protruding from the template whereby the crystals are fixed in the positions in which they were aligned in the template and at least partially curing said binder, and including the additional step of removing the crystals and binder from the template.

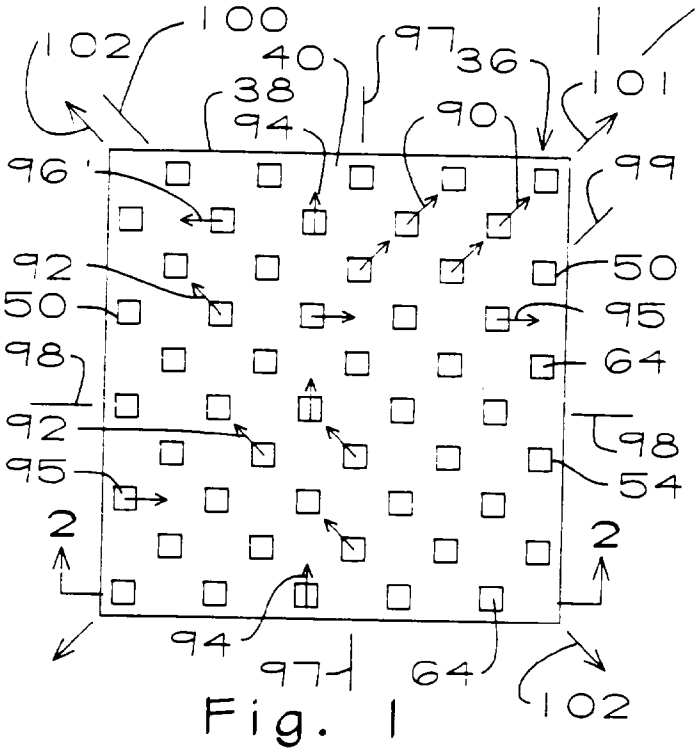


Fig. 1

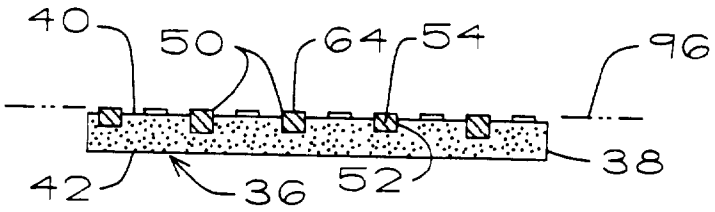


Fig. 2

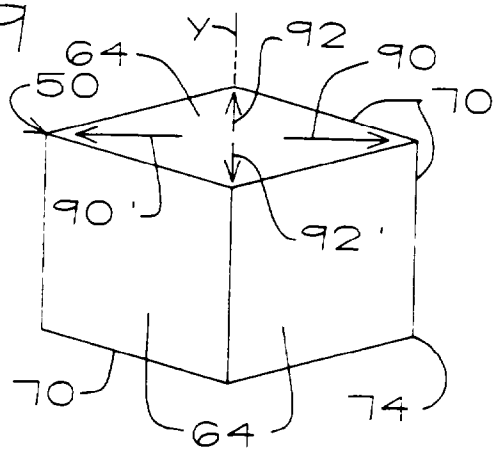


Fig. 3
PRIOR ART

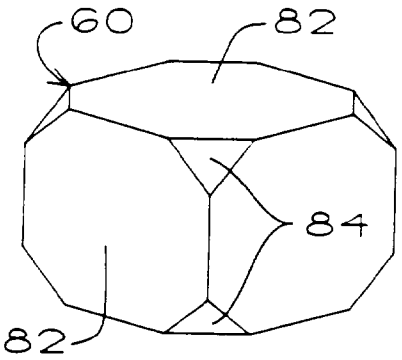


Fig. 4
PRIOR ART

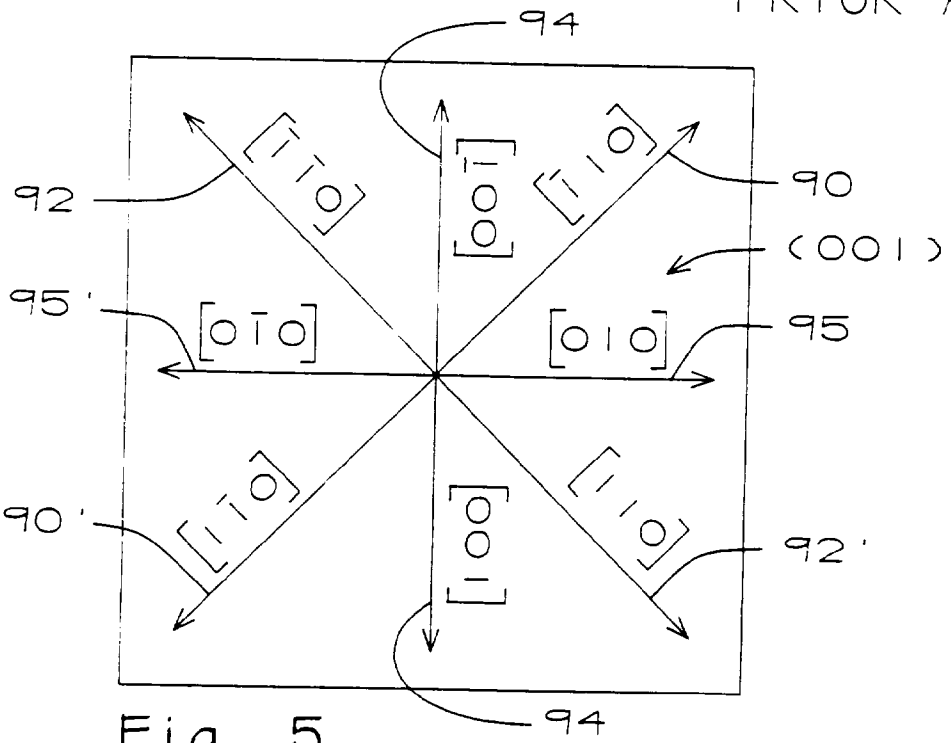


Fig. 5
PRIOR ART

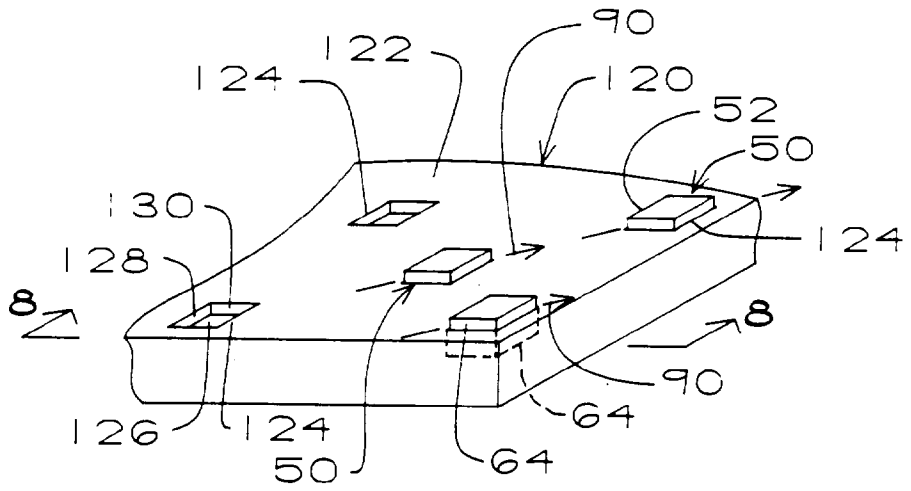


Fig. 6

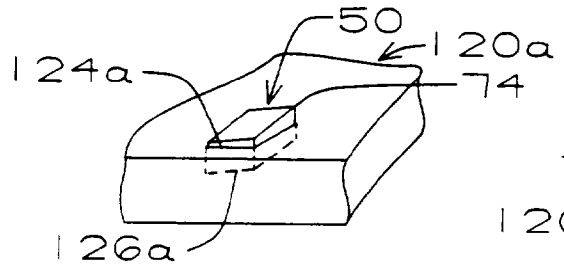


Fig. 7

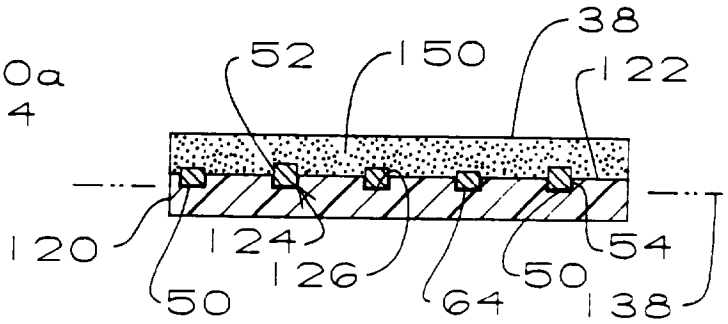


Fig. 8

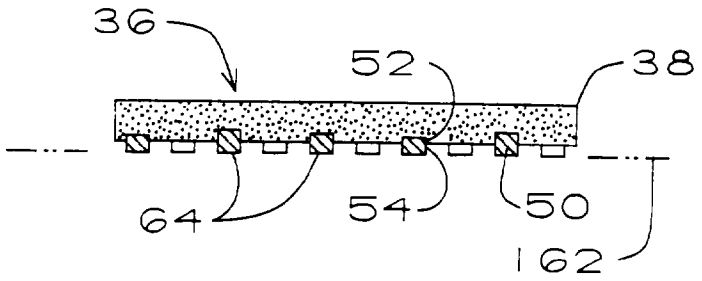


Fig. 9

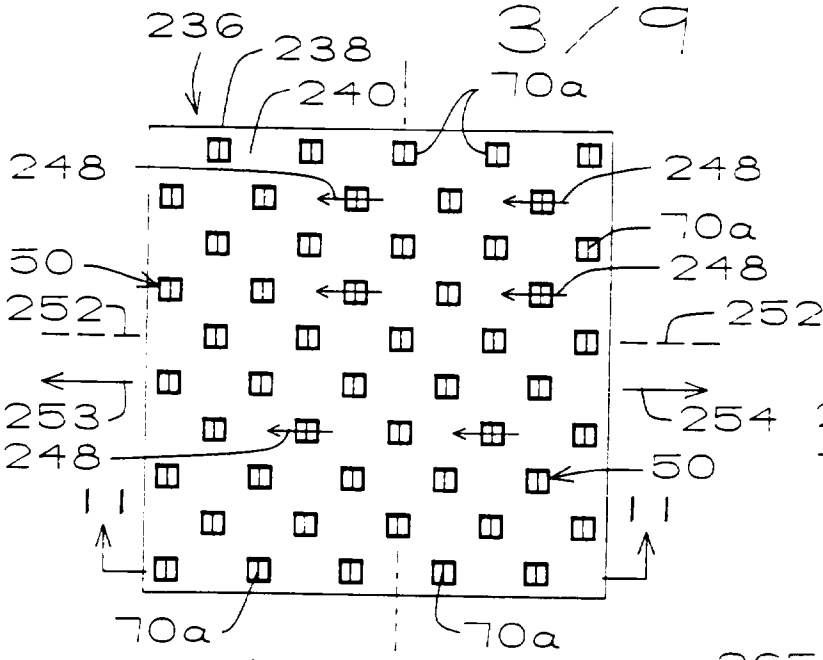


Fig. 10

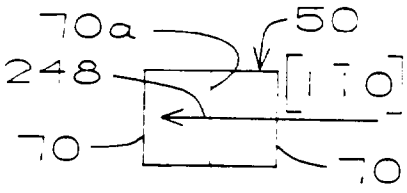


Fig. 12

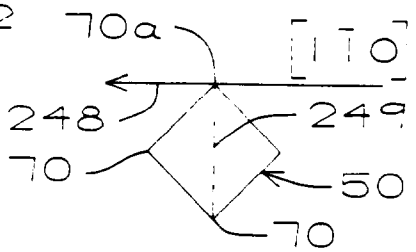


Fig. 13

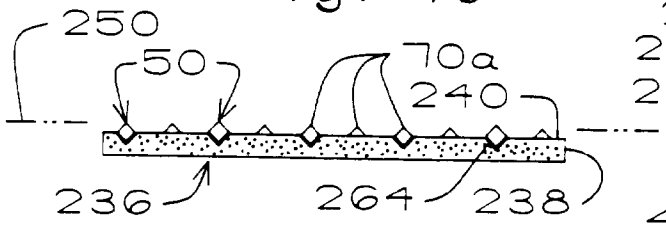


Fig. 11

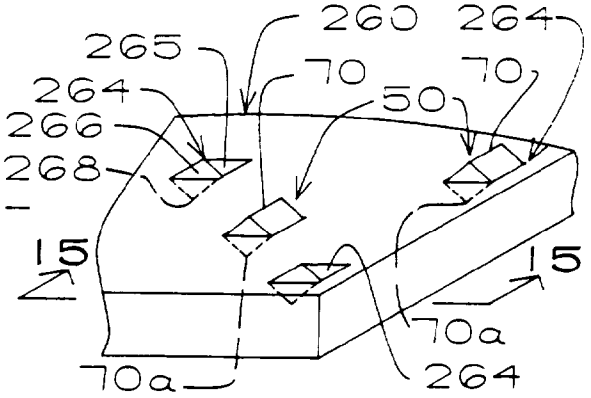


Fig. 14

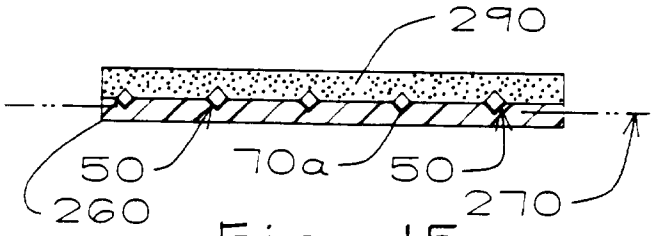


Fig. 15

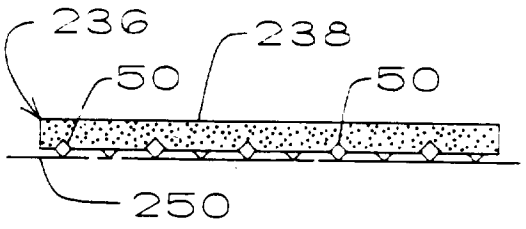


Fig. 16

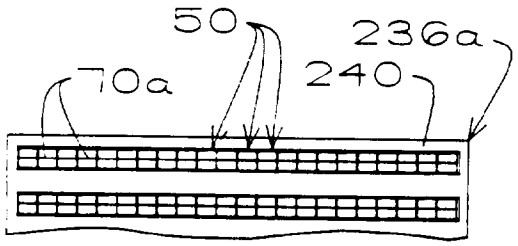


Fig. 17

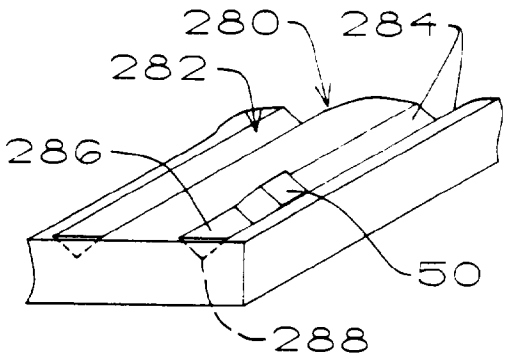


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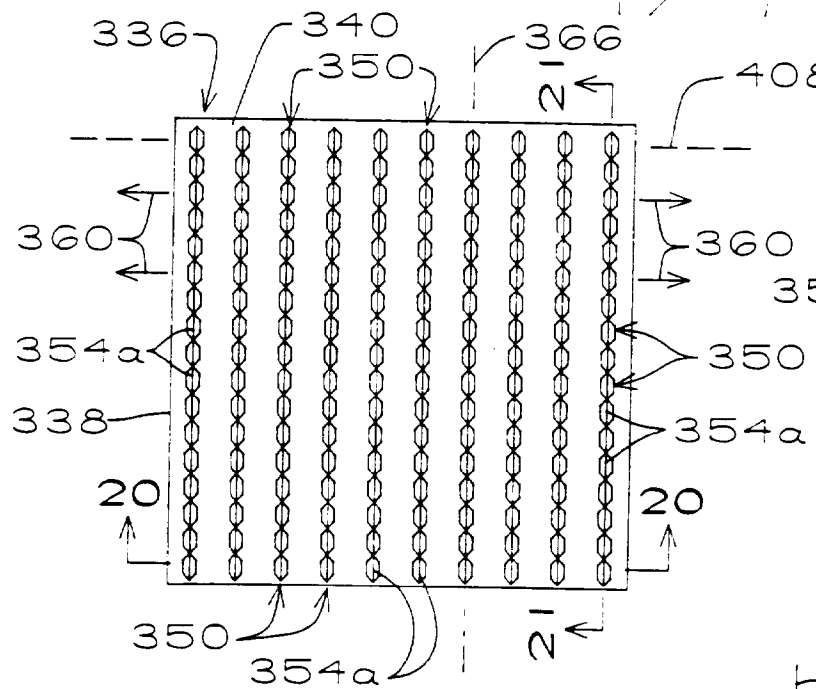


Fig. 19

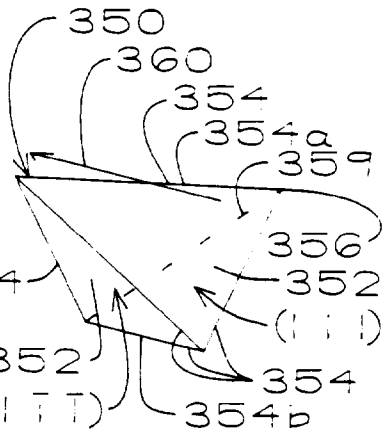


Fig. 22

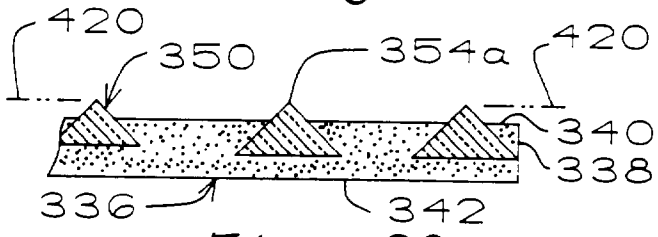


Fig. 20

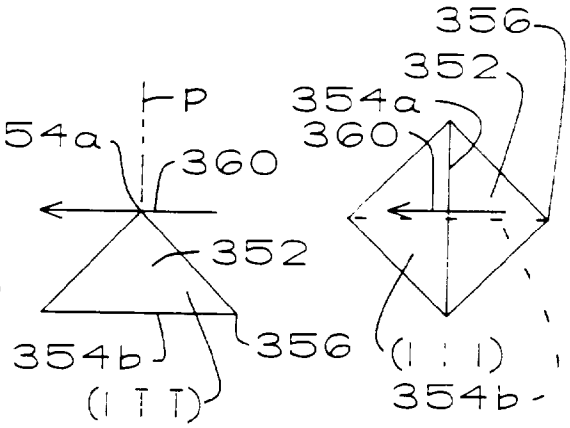


Fig. 23 Fig. 24

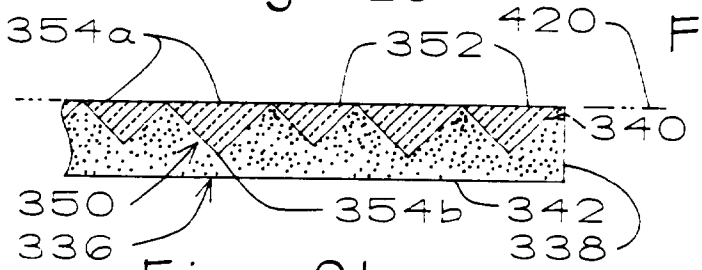


Fig. 21

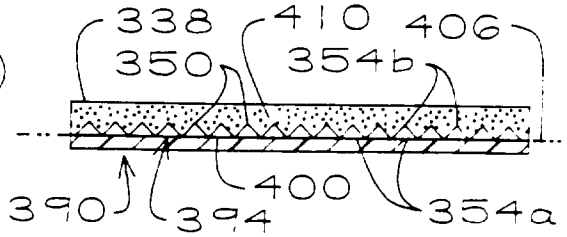


Fig. 26

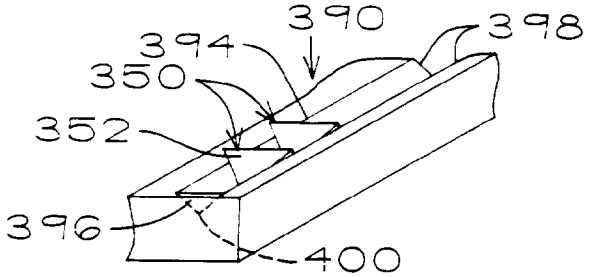


Fig. 25

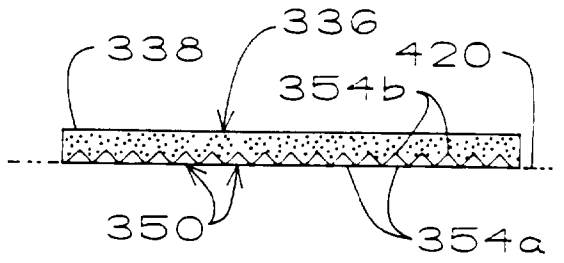


Fig. 27

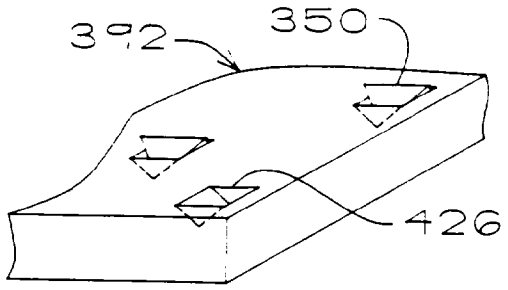


Fig. 28

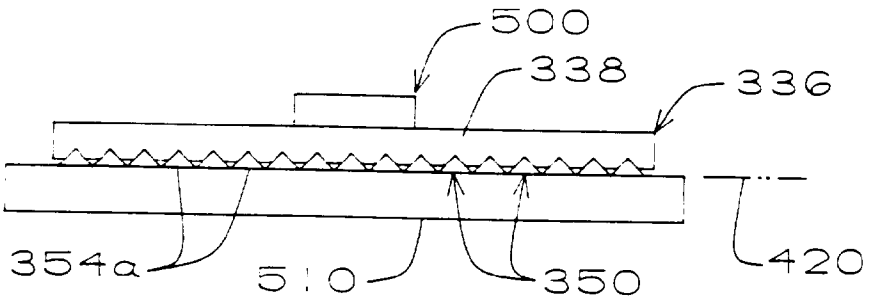


Fig. 29

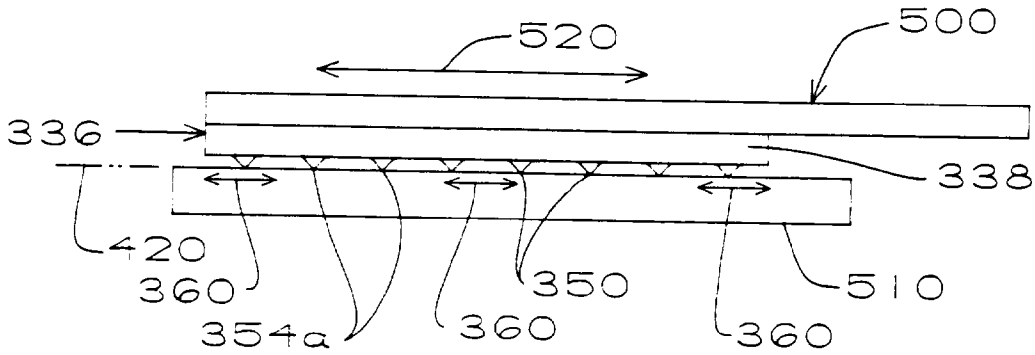


Fig. 30

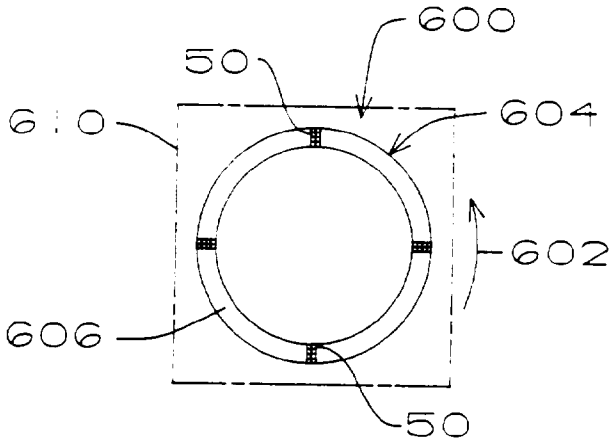


Fig. 31

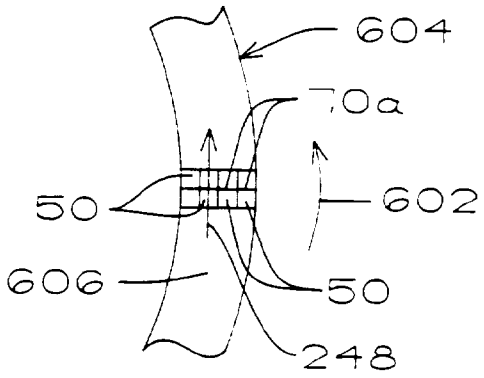


Fig. 32

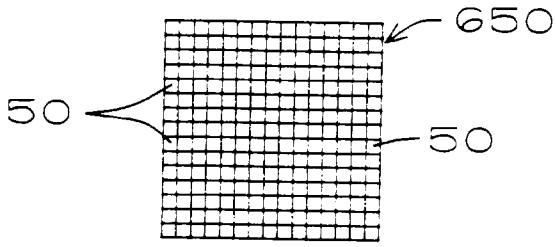


Fig. 33

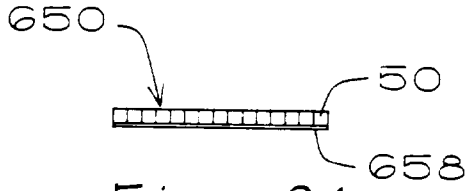


Fig. 34

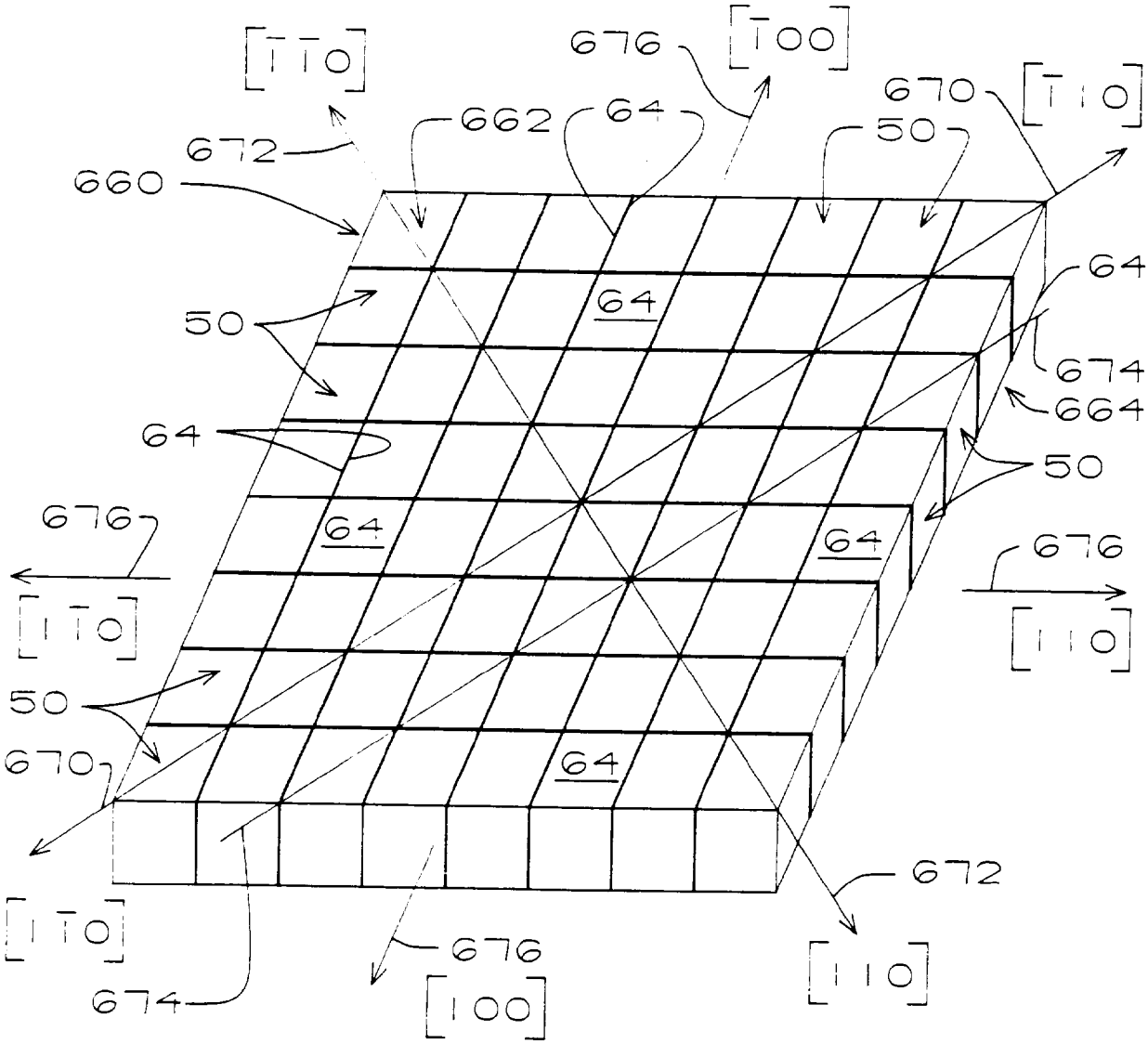


Fig. 35

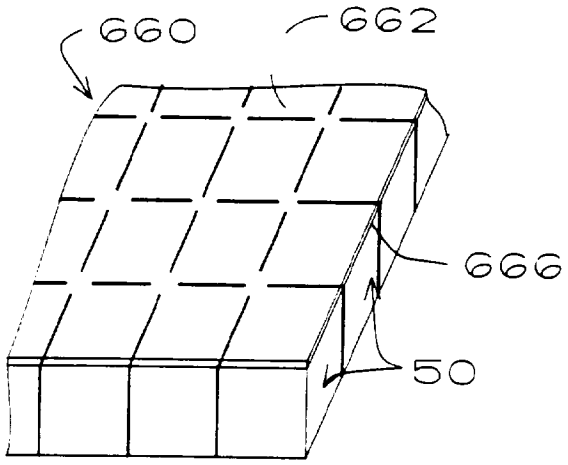


Fig. 36

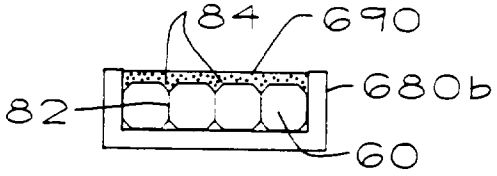


Fig 38a

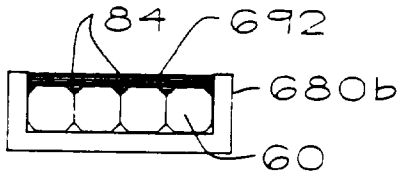


Fig 38b

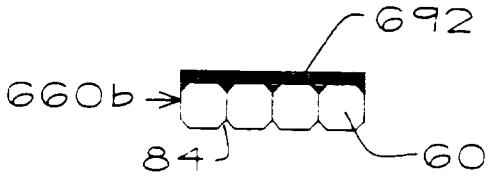


Fig 38c

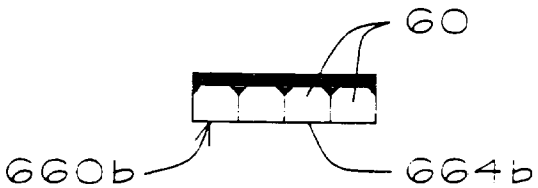


Fig 38d

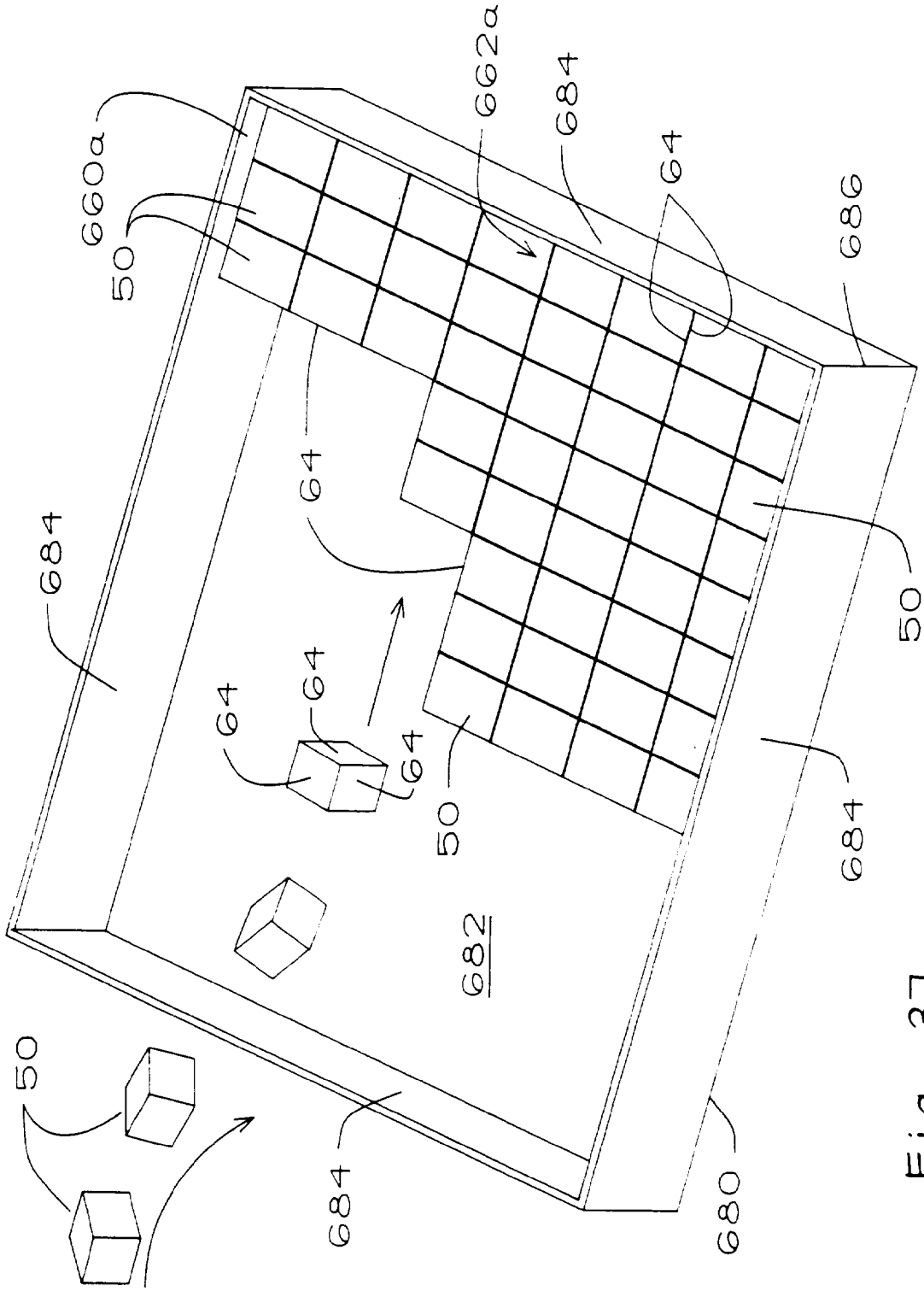


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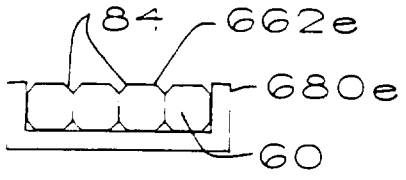


Fig 39a

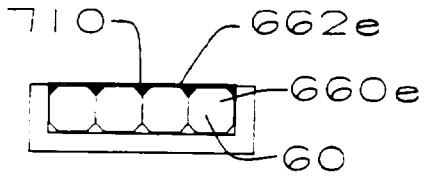


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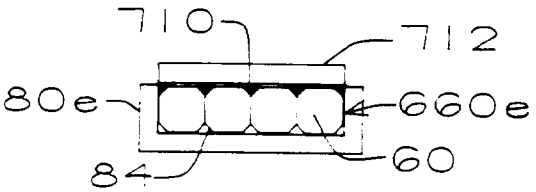


Fig 39c

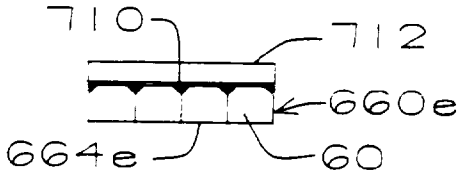


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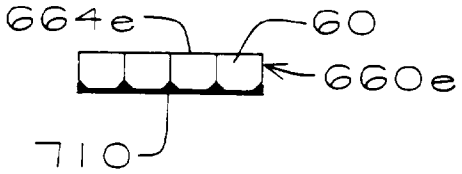


Fig 39e

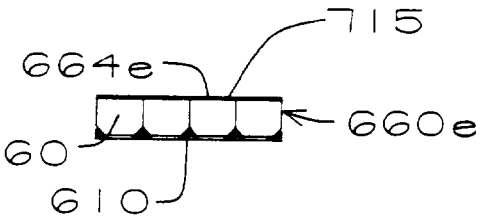


Fig 39f

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/10195

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :Please See Extra Sheet.
US CL :428/141, 143, 217, 323, 408; 51/295, 307; 257/64, 77, 627, 628; 117/84, 95, 101
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 428/141, 143, 217, 323, 408; 51/295, 307; 257/64, 77, 627, 628; 117/84, 95, 101, 902, 924

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

APS: diamond, orientation, heat sink, abrasive.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO, A, 92/01827 (MASSACHUSETTS INSTITUTE OF TECHNOLOGY) 06 February 1992, see entire document.	1-4, 6-7, 14, 17-22, 24
Y	Applied Physical Letters, Volume 58, Number 22, issued 03 June 1991, Geis et al, "Large-area Mosaic diamond films approaching single-crystal quality", pages 2485-2487, see pages 2485-2487.	1-4, 6-7, 14, 17-18, 20-22, 24
Y	US, A, 3,895,313 (SEITZ) 15 July 1975, see Figure 8; columns 3-4; column 7, line 63 - column 8, line 60.	1-4, 6-7, 14, 17, 20-22, 24
Y, P	US, A, 5,371,383 (MIYATA ET AL) 06 December 1994, see column 2, lines 34-68; column 4, lines 38-45; column 5, lines 20-23.	1-4, 6-7, 14, 17-22, 24

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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"E"	earlier document published on or after the international filing date	"Y"	document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
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"P"	document published prior to the international filing date but later than the priority date claimed		

Date of the actual completion of the international search 27 OCTOBER 1995	Date of mailing of the international search report 07 DEC 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer VIVIAN CHEN Telephone No. (703) 308-2351

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C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US, A, 4,925,457 (DEKOK ET AL) 15 May 1990, see entire document.	2, 6-13, 15-16, 22-23, 25
Y	US, A, 5,107,626 (MUCCI) 28 April 1992, see Figure 1; column 1, line 60 to column 2, line 50.	1-4, 6-13, 15-16
Y	US, A, 5,304,223 (PIEPER ET AL) 19 April 1994, see column 2.	1-4, 6-13, 15-16
Y	US, A, 5,152,917 (PIEPER ET AL) 06 October 1992, see column 2.	1-4, 6-13, 15-16
A	US, A, 5,296,207 (LUX) 22 March 1994, see entire document.	17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/10195

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (6):

B32B 5/16; B24D 3/00, 3/02; C09C 1/68; C09K 3/14; C30B 23/00, 25/00, 28/12, 29/04, 31/00; H01L 29/04, 31/0312, 31/036

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A1

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(22) International Filing Date: 5 September 1997 (05.09.97)

(30) Priority Data:
08/711,636 10 September 1996 (10.09.96) US

(71) Applicant: NORTON COMPANY [US/US]; 1 New Bond Street, Box Number 15138, Worcester, MA 01615 (US).

(72) Inventors: HOLDEN, Robert, L.; 12 Stillwater Heights Drive, West Boylston, MA 01583 (US). MC NAMARA, John, P.; 56 Berlin Street, Clinton, MA 01510 (US).

(74) Agents: GORDON, David, P.; 65 Woods End Road, Stamford, CT 06905 (US) et al.

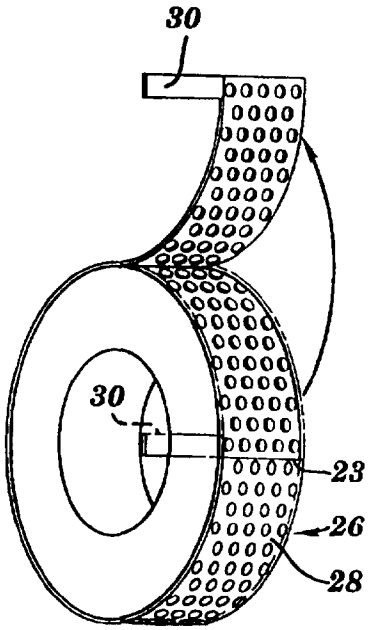
(81) Designated States: AU, BR, CA, CN, JP, KR, MX, RU, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: GRINDING WHEEL

(57) Abstract

A molded bonded abrasive grinding wheel adapted for relatively rough grinding operations is provided with a plurality of protuberances spaced in a predetermined pattern along the peripheral surface thereof and extending substantially orthogonally therefrom to define a textured grinding face. The protuberances are molded integrally with the grinding wheel and are perfomed by placing a perforated, or textured annular insert in a grinding wheel mold during molding wherein the insert is molded in-situ about the peripheral surface of the grinding wheel. The insert is removed from the peripheral surface after molding or during grinding to expose the protuberances defined by the perforations of the insert.



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GRINDING WHEEL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to grinding wheels and more particularly, to a grinding wheel molded with a textured grinding face to facilitate use in rough grinding or conditioning operations.

2. Background Information

The grinding wheel art is highly developed and includes a wide range of wheel constructions and wheel fabrication processes adapted to optimize specific grinding operations and/or applications. One specific operation to which consideration has been given is known as conditioning. Conditioning is generally the removal of surface defects from ingots, blooms, billets and slabs of steel prior to further processing. Types of defects include cracks, folds, scale, scabs, seams, cinder patches and burned steel. Conditioning operations are generally characterized as "rough grinding" operations and utilize relatively large contact pressures between the wheel and the workpiece. Typically, grinding wheels optimized for these conditioning operations, commonly referred to as conditioning wheels, are fabricated from relatively heavy duty abrasive particulate, such as aluminum oxide, alumina zirconia, silicon carbide, or combinations thereof, of relatively large size (usually corresponding to an industry standard "grit size" of 4 through 46). Moreover, the particulate utilized for these wheels tends to be relatively hard or durable to provide resistance to the aforementioned relatively high grinding pressures. This particulate is generally maintained in a three-dimensional matrix of organic bonds, such as those provided by, for example, resinoid or phenolic resin bond material. Examples of conventional conditioning wheels are known as "BZZ Conditioning

Wheels" available from Norton Company of Worcester, Massachusetts.

As discussed hereinabove, the durability of the abrasive used in conditioning wheels serves to resist the relatively high pressures associated with the conditioning operation. The rough grinding face provided by the relatively large grit size, moreover, serves to effectively reduce the surface area of contact between the wheel and the workpiece to provide a relatively high pressure per unit area of contact therebetween. In this manner, contact pressure exerted between the exposed cutting edges of the abrasive and the workpiece is relatively high to facilitate the rough grinding or conditioning operation, while minimizing undesirable effects of excessive wheel pressure, such as uneven wheel wear or wheel breakage, as will be discussed hereinafter.

Conditioning wheels, like most other types of grinding wheels, are generally fabricated by hot or cold pressed molding operations. Disadvantageously, however, this fabrication method tends to produce wheels that emerge from the mold having substantially smooth peripheral grinding faces in which relatively few, if any, of the cutting edges of the abrasive are exposed. Thus, in the event such a smooth surface were brought into contact with a workpiece in a conditioning application, the increased contact area provided thereby would tend to reduce the contact pressure per unit area. To compensate for this condition, additional wheel pressure would generally be required to provide sufficient contact pressure between the wheel and workpiece to char or break the bonds of the grinding face and expose the cutting edges of the abrasive. Disadvantageously, however, this increased wheel pressure tends to generate non-uniform bond attrition which may lead to the wheel breaking or alternatively, becoming out of round and out of balance causing vibration during operation.

To overcome these disadvantages, most conventional conditioning wheels are subjected to an additional post-mold

operation commonly referred to as "dressing." Dressing generally includes applying a sharp implement, such as crush dressing, shot facing, or conical cutter, to the smooth face of the wheel during wheel rotation to remove the outer layer of bond material therefrom. This serves to expose the relatively course texture defined by the abrasive particulate to facilitate conditioning operations. Once the abrasive particulate has been exposed, the grinding wheel will wear away during subsequent grinding operations in a conventional manner, thus continually exposing new abrasive particulate in the bond matrix.

Although this dressing operation may serve to ameliorate the problem generated by the molding process, it is not without disadvantages. In particular, this additional operation contributes disadvantageously to the manufacturing cost, as well as to the length of time or lead time required to manufacture the wheel.

Thus, a need exists for an improved grinding wheel which overcomes the disadvantages of the prior art.

SUMMARY OF THE INVENTION

According to an embodiment of this invention, a molded grinding wheel includes bonded abrasive particulate, a substantially curved peripheral surface and a plurality of surface irregularities spaced in a predetermined pattern along the substantially curved peripheral surface to define a textured grinding face.

According to a second aspect of the present invention, an insert is adapted for use in conjunction with a grinding wheel mold having a mold cavity defined by at least one curved surface. The insert includes at least one liner sized and shaped for disposition in superimposed and concentric relation with the at least one curved surface of the grinding wheel mold. The at least one liner has a plurality of discontinuities disposed

therein and is adapted for being selectively molded in-situ with a grinding wheel in the grinding wheel mold, and removed from the grinding wheel, wherein the plurality of discontinuities define surface irregularities in a peripheral surface of the grinding wheel.

In a third aspect of the present invention, a method of forming a grinding wheel includes the steps of molding the grinding wheel to form a substantially curved peripheral surface and disposing a plurality of surface irregularities in a predetermined pattern along the substantially curved peripheral surface to define a textured grinding face.

In a fourth aspect of the present invention, a grinding wheel comprises a plurality of protuberances disposed on a peripheral surface thereof by providing at least one liner having a plurality of recesses disposed therein, molding the at least one liner in-situ about the peripheral surface and removing the at least one liner from the peripheral surface after molding.

The above and other features and advantages of this invention will be more readily apparent from a reading of the following detailed description of various aspects of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a grinding wheel of the subject invention;

FIG. 2 is a cross-section taken along 2-2 of FIG. 1;

FIG. 3 is a perspective view of a component utilized to fabricate the grinding wheel of FIG. 1; and

FIG. 4 is a perspective view, with portions in phantom, of

the grinding wheel of FIG. 1, during a step in the fabrication thereof.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Briefly described, as shown in FIG. 1, a molded, bonded abrasive grinding wheel 10 adapted for relatively rough grinding operations is provided with a plurality of surface irregularities, such as protuberances 20, spaced in a predetermined pattern along the peripheral surface thereof and extending substantially orthogonally or radially therefrom, to define a textured grinding face 18. Protuberances 20 are molded integrally with the grinding wheel and are formed by placing an annular insert 22 having a plurality of discontinuities, such as perforations 24, in a grinding wheel mold during molding of the wheel wherein the insert is molded in-situ about the peripheral surface of the grinding wheel. The insert is removed from the peripheral surface after molding to expose protuberances 20 defined by perforations 24.

For definitional purposes, throughout this disclosure, the term "axial" when used in connection with an element described herein, shall refer to a direction substantially parallel to the axis of a circular dimension thereof. The term "orthogonal" when used in connection with an element described herein, shall refer to a direction substantially perpendicular to a tangent of a curved surface at a point of intersection of the element with the curved surface.

Referring now to the drawings in detail, as shown in FIG. 1, grinding wheel 10 of the present invention is of conventional, generally disc-shaped construction, having a generally cylindrical inner surface or bore 12, planar side surfaces 14 and 16 (FIG. 2) and a substantially cylindrical outer surface or grinding face 18. The dimensions of the grinding wheel, including diameters of inner surface 12 and outer surface 18, as shown at a and b, respectively, as well as the thickness of the

wheel as shown at t (FIG. 2), are predetermined in a conventional manner, based in part on the particular grinding application for which wheel 10 is to be employed. The grinding wheel may be fabricated from a conventional bonded abrasive material such as, for example, the type mentioned hereinabove.

In a preferred embodiment, grinding wheel 10 is a "conditioning wheel" as generally described hereinabove. Outer surface 18 has a diameter preferably within a range of from approximately 14 inches (in) to 36 in, or approximately 35 centimeters (cm) to 91 cm. Thickness t (FIG. 2) is preferably within a range of from approximately 1.5 in to 6 in, or approximately 3 cm to 15 cm. Grinding wheel 10 also preferably comprises abrasive particulate having a grit size within a range of 4 to 46, or an average diameter within a range of .25 in (.65 cm) to .02 in (.05 cm). The abrasive is preferably maintained within hot or cold pressed phenolic resin or resinoid bonds.

As shown in FIGS. 1 and 2, outer surface 18 is provided with a series of surface irregularities such as protuberances 20 which, as shown, extend orthogonally or radially outwardly therefrom. Protuberances 20 are spaced at predetermined intervals from one another about outer surface 18 and serve to provide the outer surface with a relatively rough or "knobby" texture as shown.

Referring now to FIG. 3, a mold liner, insert or annulus 22 is provided to facilitate molding of protuberances 20. Mold band liner 22 comprises a generally cylindrical web of predetermined diameter d and width w sized to nominally define outer surface 18 of wheel 10 as will be discussed hereinafter. The liner is preferably provided with at least one axially extending scribe or cut 23, as shown in phantom, to facilitate removal of the insert from wheel 10 as will also be discussed hereinafter. Discontinuities such as apertures or perforations 24 are spaced at predetermined intervals throughout liner 22. The perforations serve to define protuberances 20 in a manner to be discussed in greater detail hereinafter. Liner 22 is adapted to slidingly

interfit in a superimposed and concentric manner with an outermost cylindrical surface of the cavity of a conventional grinding wheel mold (not shown). In this manner, liner 22 serves as a template for outer surface 18, including integral protuberances 20, of a grinding wheel 10 molded therein, as will be discussed in greater detail hereinafter with respect to the operation and fabrication of the present invention.

Liner 22 is preferably fabricated from a material capable of resisting deformation due to heat and pressure generated during hot pressed molding operations commonly employed to fabricate grinding wheels. In addition, the material is preferably relatively flexible to facilitate removal from wheel 10, as will be discussed hereinafter. In a preferred embodiment, the liner is thus fabricated from a relatively light gauge steel or aluminum, or from a paper product such as cardboard or chipboard.

In an alternate embodiment (not shown), the liner may comprise an inflatable bladder fabricated from a suitable material such as a heat resistant polymer. Such a bladder may include a plurality of discrete inflatable portions disposed on the generally cylindrical surface of the mold cavity as discussed hereinabove. It may thus be inflated during molding to define the textured grinding face 18 of the wheel and subsequently deflated to facilitate removal of the wheel from the mold in the manner to be discussed hereinafter.

A preferred embodiment of the invention having been fully described, the following is a description of the fabrication and operation thereof.

As discussed hereinabove, liner 22 is placed in concentric and superimposed orientation with the outermost cylindrical surface of the cavity of a conventional grinding wheel mold (not shown). A grinding wheel 10 is then molded in a generally conventional manner. Briefly described, a grinding wheel mixture, such as the above-described abrasive particulate and phenolic resin mixture, is deposited into the mold and

subsequently either hot or cold pressed. A post bake operation may be provided, in which the wheel is maintained for a predetermined period at typical elevated cure temperatures. During these molding operations, the grinding wheel mixture will enter and fill apertures 24 of liner 22, to effectively form a grinding wheel 10 having liner 22 molded in-situ with the peripheral surface thereof.

Once the molding process is complete, grinding wheel 10 and liner 22 are preferably removed from the mold as a single unitary wheel/liner assembly 26, in which liner 22 is disposed in concentric, superimposed relation with the wheel, as shown partially in phantom, in FIG. 4. As also shown, when so disposed, wheel 10 and liner 22 cooperate to provide assembly 26 with a substantially smooth, cylindrical outer surface 28 which serves to facilitate removal of wheel/liner assembly 26 from the mold without disadvantageously damaging either the wheel or the mold. In this regard, cylindrical outer surface 28 enables removal of wheel/liner assembly 26 simply by sliding the wheel/liner assembly in an axial direction out of the mold.

One skilled in the art will recognize that a molded wheel having an irregular or textured circumferential grinding face wholly defined by a wall of the mold cavity generally would not be removable from the mold simply by axial movement. Rather, irregularities in the grinding face, such as protuberances of the type described hereinabove, would tend to engage the corresponding recesses within the mold cavity and thus prevent such axial movement relative to the mold. Such a wheel would not be removable from the mold without damaging the mold and/or wheel. To avoid this problem, a segmented mold with muiltiple discrete sections may be used to mold wheels of the invention without using a perforated liner. Other mold types may be used. Such molds must be adapted to allow removal of the textured side walls of the mold without disturbing the grinding face of the wheel.

Once removed from the mold, liner 22 is removed from wheel 10. This may be accomplished by suitably engaging the liner proximate scribe or cut 23, such as at a tab 30, and peeling the liner away from outer surface 18 of wheel 10 as shown in FIG. 4 and continuing until the liner is completely removed from the wheel.

Once the liner has been so removed, grinding wheel 10 may then be utilized in grinding operations without further dressing operations. Indeed, the textured grinding face defined by the surface irregularities or protuberances 20 serves to effectively lower the area of contact between the wheel and workpiece. This lower contact area serves to increase the contact pressure per unit area between the wheel and workpiece to facilitate charring or breaking the bonds of the grinding face to expose the cutting edges of the abrasive as discussed hereinabove. Once cutting edges are exposed, the grinding wheel will wear away during subsequent grinding operations in a conventional manner, thus continually exposing new abrasive particulate in the bond matrix as also discussed hereinabove.

In an alternate embodiment, the liner may be fabricated from a cardboard or chipboard material as discussed hereinabove, either with or without tab 30. This material is advantageously flexible to facilitate fabrication and insertion into the cavity of the wheel mold, while it also tends to become relatively brittle when subjected to the elevated temperatures of typical post-bake operations. Accordingly, such a liner 22 may be left in-situ, in concentric orientation about wheel 10 until the wheel is used for grinding, whereupon the grinding operation itself will tend to disintegrate the liner to remove it from wheel 10. Such a cardboard or chipboard liner may thus advantageously enable elimination of the aforementioned liner removal step to further reduce manufacturing costs of wheel 10 of the subject invention.

In a further alternative embodiment, the inflatable bladder liner discussed hereinabove may be utilized to provide the

textured face. In this embodiment, the step of removing the liner from the wheel may be effected simply by deflating the bladder. Moreover, the bladder may be fastened to the mold wherein deflation may be accomplished while the wheel is disposed within the mold to facilitate removal of the wheel from the mold.

The use of liner 22 thus enables a grinding wheel to be molded with an irregular outer surface to eliminate the necessity of subsequent "dressing" operations of the type mentioned hereinabove, while enabling use of substantially conventional and relatively inexpensive molds and molding techniques. Elimination of these operations advantageously serves to reduce the manufacturing cost of grinding wheels such as "conditioning wheels." Moreover, elimination of the need for dressing serves to substantially reduce the length of time or lead time required to manufacture such grinding wheels. This reduced lead time may advantageously serve to reduce inventory costs for both the wheel manufacturer and wheel purchasers. The reduced lead time also tends to enable the wheel manufacturer to provide improved service to customers, by enabling orders such as for custom or particularly large numbers of wheels to be filled relatively quickly.

The discontinuities of insert 22 and the surface irregularities of wheel 10 have been shown and described herein as generally concave recesses 24 and generally convex protuberances 20, respectively. However, it should be recognized by those skilled in the art that the discontinuities of insert 22 may comprise generally convex protuberances of the type shown and described hereinabove with respect to wheel 10, and the surface irregularities of wheel 10 may comprise generally concave recesses of the type shown and described hereinabove with respect to insert 22, without departing from the spirit and scope of the present invention.

Moreover, those skilled in the art should recognize that the discontinuities of insert 22 may be of any configuration, such as a series of troughs, striations or other convex or concave

structures sufficient to provide a grinding wheel with a substantially textured grinding face, without departing from the spirit and scope of the present invention.

Although the present invention has been described herein with respect to a grinding wheel having a substantially cylindrical grinding face, the invention may be practiced with grinding wheels having a grinding face of any other substantially curved geometry, including but not limited to substantially frusto-conical, dome shaped, bowl shaped, or other concave or convex geometries, without departing from the spirit and scope of the present invention.

Although the present invention is described herein with respect to conditioning wheels, it should be understood by one skilled in the art that any type of grinding wheel may be provided with a textured grinding face as set forth herein without departing from the spirit and scope of the present invention.

The foregoing description is intended primarily for purposes of illustration. Although the invention has been shown and described with respect to an exemplary embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions, and additions in the form and detail thereof may be made therein without departing from the spirit and scope of the invention.

Having thus described the invention, what is claimed is:

CLAIMS

1. A molded grinding wheel adapted for rough grinding operations comprising:

bonded abrasive particulate;

a substantially curved peripheral surface; and

a plurality of surface irregularities spaced in a predetermined pattern along said substantially curved peripheral surface to define a textured grinding face.

2. The grinding wheel as set forth in claim 1, wherein said plurality of surface irregularities comprise protuberances extending substantially orthogonally from said substantially curved peripheral surface.

3. The grinding wheel as set forth in claim 1, wherein said grinding wheel comprises abrasive particulate dispersed in a phenolic resin bond material.

4. The grinding wheel as set forth in claim 1, wherein said plurality of surface irregularities are formed by selectively placing at least one insert in-situ about said substantially curved peripheral surface, in a grinding wheel mold having a cavity defined by at least one curved surface wherein said at least one insert is disposed within the cavity during molding of said grinding wheel, and removing said at least one insert from said substantially curved peripheral surface following molding.

5. The grinding wheel as set forth in claim 4, wherein said at least one insert comprises an annulus having a plurality of perforations.

6. An insert adapted for use in conjunction with a grinding wheel mold, the grinding wheel mold having a mold cavity defined by at least one curved surface, said insert comprising:

at least one liner sized and shaped for disposition in substantially superimposed and concentric relation with the at

least one curved surface;

said at least one liner having a plurality of discontinuities disposed therein;

said at least one liner adapted for being selectively molded in-situ with a grinding wheel in the grinding wheel mold and removed from the grinding wheel, wherein said plurality of discontinuities define surface irregularities in a peripheral surface of the grinding wheel.

7. The insert as set forth in claim 6, wherein said at least one liner is adapted for being removed from the mold unitarily with the grinding wheel.

8. A method of forming a grinding wheel adapted for rough grinding operations comprising the steps of:

molding abrasive particulate dispersed in a bond material to form a substantially curved peripheral surface; and

disposing a plurality of surface irregularities in a predetermined pattern along the substantially curved peripheral surface to define a textured grinding face.

9. The method as set forth in claim 8, wherein said step of disposing a plurality of surface irregularities further comprises molding the surface irregularities integrally with the grinding wheel.

10. The method as set forth in claim 9, wherein said plurality of surface irregularities comprises a plurality of protuberances.

11. The method as set forth in claim 9, wherein said step of disposing a plurality of surface irregularities further comprises the steps of selectively:

placing at least one insert for molding in-situ about the substantially curved peripheral surface; disposing the at least one insert about an inner curved surface of a grinding wheel mold during molding of the grinding wheel, and

removing the at least one insert from the substantially curved peripheral surface following molding.

12. The method as set forth in claim 11, wherein said at least one insert comprises a perforated annulus.

13. A grinding wheel comprising:

a plurality of regularly spaced surface irregularities disposed on a peripheral surface thereof by providing a at least one liner having a plurality of recesses disposed therein, molding the at least one liner in-situ about the peripheral surface and removing the at least one liner from the peripheral surface after molding.

14. The grinding wheel of claim 13, wherein said at least one liner is removed from the mold unitarily with the grinding wheel.

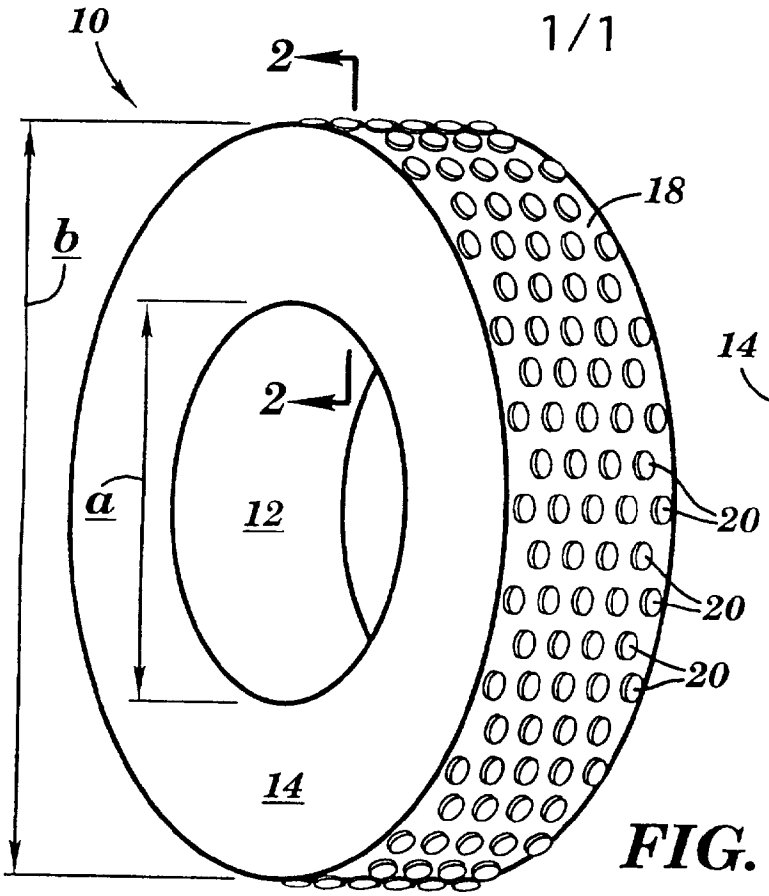


FIG. 1

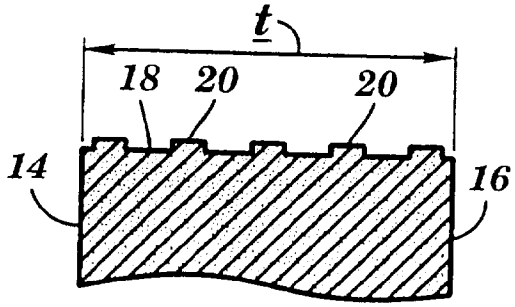


FIG. 2

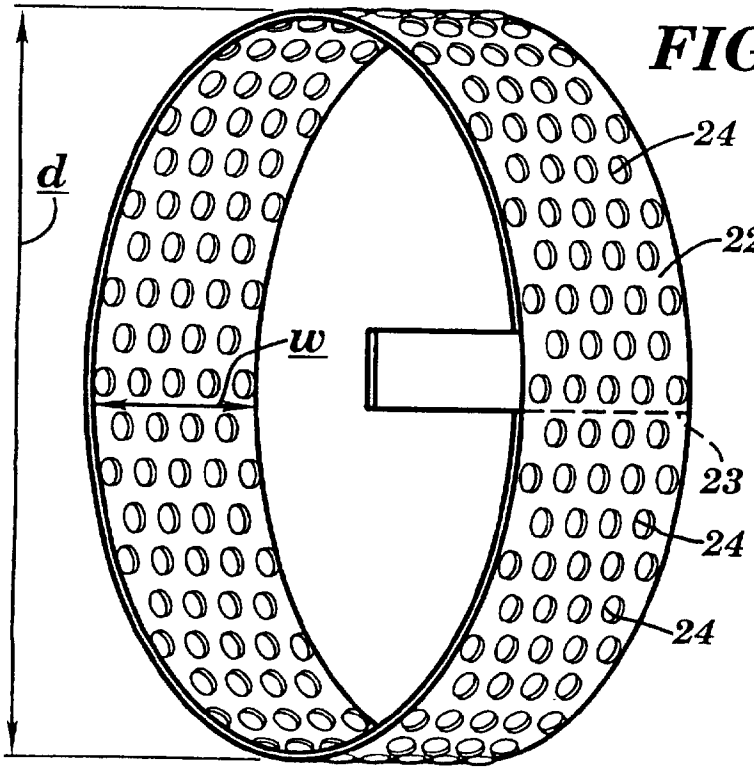


FIG. 3

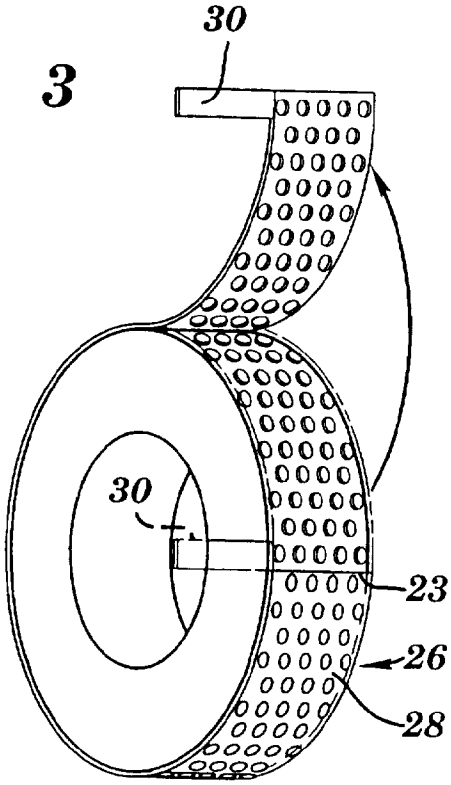


FIG. 4

INTERNATIONAL SEARCH REPORT

Int. .tional Application No
PCT/US 97/15724

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24D3/28 B24D18/00 B24D5/00

According to International Patent Classification(IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24D B24B C09K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
21 November 1997	28/11/1997

Name and mailing address of the ISA	Authorized officer
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Int ational Application No
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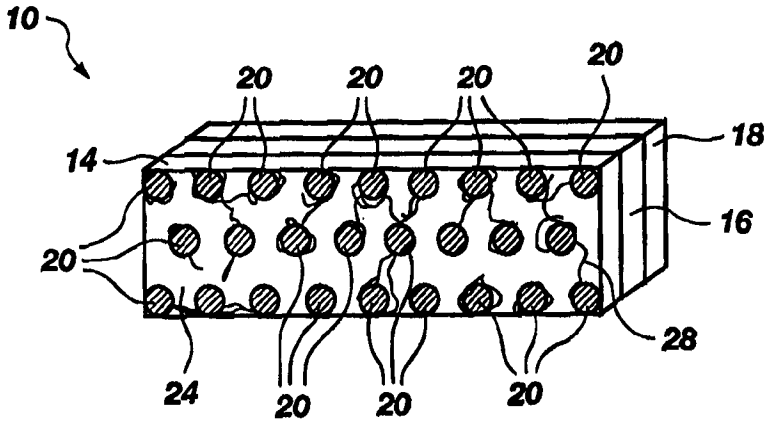
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(54) Title: BRAZED DIAMOND TOOLS BY INFILTRATION

(57) Abstract

The present invention describes a diamond tool with diamond bonded chemically by a braze that contains either Cr, Mn, SI, or Al or mixtures or alloys thereof. The diamond tool is made by infiltrating the braze into a matrix metal that contains diamond in either form of grits or polycrystalline bodies.



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BRAZED DIAMOND TOOLS BY INFILTRATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to tools having diamond particles formed thereon/therein, wherein the diamond particles are chemically bonded to matrix support material used to hold the diamond in place. More specifically, the diamond grit is bonded chemically in a matrix powder by a braze that can wet diamond. These tools are manufactured by the infiltration of the molten braze into a preform of matrix that contains diamond particles, thereby securing the diamond in place by a chemical bond.

2. State of the Art

Abrasive tools have long been used in numerous applications, including cutting, drilling, sawing, grinding, lapping and polishing materials. Because diamond is the hardest abrasive material, it is widely used as a superabrasive on saws, drills, and other devices which utilize the abrasive to cut, form or polish other hard materials. The total value of such tools consumed is believed to be over 5 billion U.S. dollars per year. More than half of the value of these tools is consumed in sawing applications such as cutting stones, concretes, asphalts, etc.

Diamond coated tools are particularly indispensable for applications where other tools lack the hardness and durability to be practical substitutes. For example, in the stone industry,

where rocks are cut, drilled, and sawed, diamond tools are about the only type which are sufficiently hard and durable to make the cutting, etc., economical. If diamond tools were not used, many such industries would be economically infeasible. Likewise, in the precision grinding industry, diamond tools, due to their superior wear resistance, are uniquely capable of developing the tight tolerances required, while simultaneously withstanding wear sufficiently to be practical.

Despite the prevailing use of diamond tools, these tools have suffered from several significant limitations which have placed unnecessary limits on the useful life of the tools. One such drawback is that the diamond grit is not attached to the matrix support material in a sufficiently strong attachment to maximize useful life of the cutting, drilling, polishing, etc., body. In fact, in most cases diamond grit is merely mechanically embedded in the matrix support material. As a result, diamond grit is often knocked out or pulled out prematurely during use. Moreover, the grit may receive inadequate mechanical support from the loosely bonded matrix under work conditions. Hence, the diamond particles could be shattered by the impact of the tool against the work piece to which the abrasive, etc., is applied.

It has been estimated that in a typical diamond tool, less than about one tenth of the grit is actually consumed in the intended application - i.e. during actual cutting, drilling, polishing, etc. The remainder of the diamond grit is either wasted by being leftover when the tool's useful life has expired, or is wasted by being pulled-out or broken during use due to poor attachment and inadequate support. Most of these diamond losses could be avoided if the diamond particles can be properly

positioned in and firmly attached to the surrounding matrix.

Furthermore, to ensure that the diamond grit is mechanically held sufficiently to remain in place, it must be buried deep in the matrix to prevent it falling out or being knocked free of the tool body during use. As a result, the protrusion of the diamond particle above the tool surface is insufficient. The low grit protrusion limits the cutting height for breaking the material to be cut. These limitations, in turn, limit the cutting speed of the cutting tool. If the diamond grit could be held more securely in the matrix, it could protrude higher from the matrix. The greater cutting depth would allow increased cutting speed and a greater useful life for the product. Moreover, due to the lower friction of the workpiece and tool matrix, the power required for cutting, drilling, etc., may also be reduced.

In order to anchor diamond grit firmly in the matrix, it is highly desirable for the matrix to form a carbide around the surface of the diamond. The chemical bond so formed is much stronger than the traditional mechanical attachment. The carbide may be formed by reacting diamond with a suitable carbide former such as a transition metal. Some examples of carbide forming transition metals are: titanium (Ti), vanadium (V), chromium (Cr), zirconium (Zr), molybdenum (Mo), and tungsten (W).

The formation of a carbide requires that the carbide former be deposited around the diamond and that the two subsequently be caused to react to form a carbide. Moreover, the non-reacted carbide former must also be consolidated by sintering or other means. All these steps require treatment at high temperatures. However, diamond may be degraded when exposed to a temperature above 1,000° C. The

degradation is due to either the reaction with the matrix material or the development of microcracks around metal inclusions inside the crystal. These inclusions are trapped catalysts used to synthesize the diamond.

Most carbide formers are refractory metals so they may not be consolidated below a temperature of about 1,200° C. Hence, refractory carbide formers are not suitable as the main constituent of the matrix support material.

There are, however, some carbide formers that may have a lower sintering temperature, such as manganese (Mn), iron (Fe), silicon (Si), and aluminum (Al). However, these carbide formers may have other undesirable properties that prohibit them from being used as the primary constituent of the matrix support material. For example, both manganese and iron are used as catalysts for synthesizing diamond at high pressure (above 50 Kb). Hence, they can catalyze diamond back to graphite during the sintering of the matrix powder at a lower pressure. The back conversion is the main cause of diamond degradation at high temperature.

Aluminum, on the other hand, has a low melting point (660° C), thus, making it easy to work with for securing the diamond particles. However, the melting point of aluminum can be approached when a diamond grit is cutting aggressively. Hence, aluminum may become too soft to support the diamond grit during the cutting operation. Moreover, aluminum tends to form the carbide Al_4C_3 at the interface with diamond. This carbide is easily hydrolyzed so it may be disintegrated when exposed to coolant. Hence, aluminum typically is not a suitable carbide former to bond diamond in a matrix.

To avoid the high temperature of sintering, carbide formers, such as tungsten, are often diluted

as minor constituents in the matrix that is made primarily, for example, of either cobalt or bronze. During the sintering process, there is a minimal amount, if any, of liquid phase formed. The diffusion of carbide former through a solid medium toward diamond is very slow. As a result, the formation of carbide on the surface of diamond is negligible. Therefore, by adding a carbide former as a minor matrix constituent, the improvement of diamond attachment is marginal at the best.

In order to ensure the formation of a carbide on the surface of diamond, the carbide former may be coated onto the diamond before mixing with the matrix powder. In this way, the carbide former, although it may be a minor ingredient in the matrix, can be concentrated around diamond to form the desired bonding.

The coating of diamond may be applied chemically or physically. In the former case, the coated metal is formed by a chemical reaction, generally at a relatively high temperature. For example, by mixing diamond with a carbide former such as titanium or chromium, and heated the mixture under a vacuum or in a protective atmosphere, a thin layer of the carbide former may be deposited onto the diamond. The thickness of the coating may be increased by increasing temperature. The deposition rate may also be accelerated by adding a suitable gas (e.g., HCl vapor) that assists the transport of the metal. For example, Chen and Sung (U.S. Patent No. 5,024,680) describes such a coating process.

Alternatively, the coating may be performed in a molten salt. For example, U.S. Patent No. 2,746,888 describes a method of coating a thin layer of titanium over diamond in a molten salt of chlorides.

A commonly used chemical method for coating diamond is chemical vapor deposition (CVD). In this

case, the deposited metal is produced by the reaction of gases at a high temperature. Thus, U.S. Patent No. 3,520,667 describes a technique to deposit a thin layer of silicon (Si) onto the surface of diamond. The temperature of this deposition is high enough so silicon carbide is formed instantaneously at the interface.

In order to prevent diamond from possible degradation by exposure to high temperatures, coating is produced at the lowest temperature possible. However, coating often becomes too thin when deposited at a low temperature. For example, the coating produced by a typical chemical method is about one micrometer thick. There are some commercial diamond grits that contain such thin coatings. For example, General Electric Company offers a saw grit that may be coated with a thin coating of either titanium or chromium.

However, when the thin coating is exposed to a high temperature, such as that which may be encountered during the sintering process, it can be easily oxidized in the atmosphere, or dissolved into the matrix metal. Thus, although a significant benefit is claimed for such commercially coated products, e.g., a one-third improvement in tool life, the ability for the thin coating to survive the manufacturing process is debatable.

In order to protect the thin metal coating, multiple layers of coating may be applied. Thus, U.S. Patent Nos. 5,232,469 and 5,250,086 described a second layer made of nickel, or another non-carbide former. The second layer may be deposited by an electroless process that is performed at a lower temperature. For more layers, Chen and Sung (U.S. Patent Nos. 5,024,680 or 5,062,865) describe a diamond grit with three layers of coating. In this case, the inner most layer is made of chromium, and it is overlaid by a secondary

metal layer such as titanium. The double layers are further wrapped in a third overcoat of a material such as tungsten. However, such a complicated coating system may be too costly to be economically feasible in the production of many cutting, drilling or polishing tools.

Alternatively, a chemical coating may be deposited relatively thick by a CVD method. For example, Sung, et al. (U.S. Patent Nos. 4,943,488 or 5,116,568) describes a fluidized bed system that can coat diamond with tungsten of a few tens of micrometers. But again, such a coating is expensive, and its application has not been widely used.

In contrast to chemical methods, a physical method may be inexpensive. Moreover, it may deposit a thick metal coating onto diamond at a very low temperature. For example, the author evaluated "Metal Coating of Saw Diamond Grit by Fluidized Bed" (see p267-273 of Fabrication and Characterization of Advanced Materials, edited by S. W. Kim and S. J. Park of The Materials Research Society of Korea 1995). The coating system is based on the method as described in U.S. Patent No. 4,770,907 (a similar concept is disclosed in U.S. Patent 5,143,523 or European Patent No. 0 533 443 A1). However, such a method, like many other similar processes, often produces coatings with different thickness. Moreover, only very fine (<5 micrometers) metal powders can be coated effectively onto the surface of diamond. Hence, although physical methods may be used to coat a diamond grit with an alloy that contains a carbide former, their benefits are limited.

When diamond is coated mechanically by a metal powder, as described in the above example, the powder is held loosely by an organic binder (e.g., PVA, or PEG). Such a coating may be easily rubbed off during the subsequent treatments, e.g., mixing or pressing.

Although heat treatment may increase the mechanical strength of the coating, it may not consolidate the coating to the full density. A porous coating lacks the mechanical strength necessary to support a diamond grit that is impacted repeatedly during the cutting operation.

Carbide formers may also be diluted in an alloy. If the alloy can melt below 1100° C, it may be used to braze the diamond without causing much degradation of the latter. Many diamond brazes are known in the art. Most are based on Group Ib solvents (copper, silver and gold) that contain one or more carbide formers, e.g., gold-tantalum (Au-Ta), or silver-copper-titanium (Ag-Cu-Ti). These brazes, however, are typically too expensive for commercial use. Moreover, they are soft and unsuitable as ingredients for the matrix support material of diamond tools.

There are some high temperature filler metals that may be used to braze diamond. Such brazes may be hard enough to hold a diamond grit in place during cutting. For example, U.S. Patent Nos. 3,894,673 and 4,018,576 describe diamond tools made by brazing a hard facing alloy that contains nickel-chromium (Ni-Cr) as the major constituent. However, these brazed diamond tools, although useful, are generally limited as surface set tools that contains only one layer of diamond. Such tools may not last when they are used to cut highly abrasive materials, e.g., granite. Moreover, the braze in these tools, in addition to holding the diamond, must also serve as the hard facing. The compromise of these dual-functions may not always be possible as the optimal wear resistance of the tool surface may need to be adjusted for specific applications.

Alternatively, a diamond bonding alloy may be used to infiltrate a high concentration (i.e greater than 40 % by volume) of diamond particles. Thus, Chen

and Sung (U.S. Patent Nos. 5,030,276 or 5,096,465) describe such a product and the process of making the same. However, the infiltration is very difficult due to the high concentration of diamond. Moreover, such products have limited applications, such as a drill bit. They are not applicable for most applications that require a lower concentration (i.e., less than 40 % by volume) of diamond, such as saw blades and grinding wheels.

The hard facing alloys may also be used as the matrix support material. For example, U.S. patent 4,378,975 describes a method to coat diamond with a very thin layer of chromium, and subsequently palletizing the coated grit with a nickel-chromium alloy. The palletized particles are then consolidated by sintering the alloy. However, as the consolidation process is taking place primarily in a solid phase, the bonding of matrix and diamond may not be sufficient.

In addition to sintering, infiltration is also a common technique for making diamond tools, in particular for drill bits and other specialty diamond tools that contain a large (i.e. greater than U.S. mesh 30/40) diamond grit. For example, U.S. Patent No. 4,668,522 describes a process to infiltrate a rotary drill bit with a copper alloy at a temperature lower than 850° C (preferably 750° C). Most commonly used infiltrants for these tools are copper based alloys. These infiltrants must flow and penetrate the small pores in the matrix powder. In order to avoid the diamond degradation at high temperature, the melting point of the infiltrant must be low. Hence, the infiltrant often contains a low melting point constituent, such as zinc (Zn). In addition to lowering the melting point of the infiltrant, the low melting point constituent also reduces the viscosity so the infiltrant can flow with ease. However, as

most carbide formers tend to increase the melting point of the infiltrant, they are excluded from most infiltrants. As a result, these infiltrants cannot improve the bonding of diamond.

Some infiltrants do contain a carbide former that may facilitate the bonding of diamond. U.S. Patent No. 5,000,273 describes an abrasive tool that is produced by infiltrating a matrix powder with an alloy that contains the major constituents of copper, manganese and zinc. However, as discussed above, zinc is added to increase the fluidity of the infiltrant, and it may not be suitable for making certain products that is produced under different environments. For example, if infiltration is performed under a vacuum, zinc may be vaporized. As a result the remaining alloy may become too viscous to infiltrate completely the matrix powder.

Thus, there is a need for an improved method of infiltrating the matrix powder to bond the diamond thereto. Such a method should be able to be accomplished at a sufficiently low temperature to avoid potential damage to the diamond. Additionally, such a method should be designed to improve the bonding of the diamond to the matrix support material.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved method for forming tools having diamond particles disposed therein/thereon.

It is another object of the present invention to provide such a method wherein the diamond particles are disposed in a matrix support material, and then the matrix support material infiltrated with a braze to bond the diamond particles to the matrix support materials.

It is yet another object of the present invention to provide such a method wherein the brazing occurs at

sufficiently low temperatures to prevent thermal damage to the diamond particles.

It is still another object of the present invention to provide such a method wherein the matrix support material is specifically selected to provide numerous pores through which the brazing material may flow and thereby facilitate chemical bonding of the diamond and matrix support material.

It is still yet another object of the present invention to provide such a method wherein the diamond particles are disposed in the matrix support material in some predetermined pattern, to thereby lengthen the useful life of the tool to which the diamond and matrix support material are attached.

The above and other objects of the invention are realized in specific illustrated embodiments of a novel method for forming brazed diamond tools, and for tools made by the novel method. The method includes forming a sheet of matrix support material, and then disposing a plurality of diamond particles in the matrix support material. Preferably, the amount of diamond particles to matrix support material is preferably less than 50 percent by volume, and most preferably less than 40 percent by volume. The diamond impregnated sheet is then infiltrated by a braze which is capable of wetting the diamond, so as to form a chemical bond with the diamond. The braze also bonds to the matrix support material, thereby creating a chemical bond connecting the diamond to the matrix support material, rather than relying on a simple mechanical attachment in accordance with the prior art. Although the technique is most suitable for making saw blades, its applications can extend to all diamond tools.

In accordance with one aspect of the present invention, the matrix support material may be made of common metal powder. Examples of such metal powder

are cobalt, nickel, iron, bronze or their alloys or mixtures (e.g., tungsten or its carbide). After formation of the matrix support material is then infiltrated by a diamond braze, such as Nicrobraz L. M. (made by Wall Colmonoy Company), either under a vacuum, typically about 10^{-5} torr, or in an inert atmosphere (e.g., argon (Ar) or nitrogen (N_2)) or a reducing atmosphere (e.g., hydrogen (H_2)). The braze, thus, facilitates bonding between the diamond particles and the matrix support material.

In accordance with another aspect of the present invention, the matrix support material is formed by coarse metal powder (i.e. greater 400 mesh U.S. or 34 microns). While conventional methods require the density of the green body be as high as possible so subsequent sintering can proceed rapidly, it has been found in accordance with the present invention, that it is preferable to use a precursor with a lower packing density to allow the easy flow of the diamond braze. In some situations, the porosity of the precursor body may be intentionally increased by using irregularly shaped matrix particles. This preference is again contrary to the conventional wisdom that requires the particles be as spherical as possible so the packing density can be increased.

In accordance with yet another aspect of the present invention, the diamond particles are placed in a predetermined pattern within the matrix support material, and the diamond impregnated matrix support material is then impregnated with the diamond braze to promote chemical bonding of the diamond material. The predetermined pattern may be substantially planar, i.e. the diamond placement may be controlled by the use of a template, or may be substantially vertical, with channels being formed in the matrix support material to receive diamond particles, which are then infiltrated with the diamond braze.

In accordance with still yet another aspect of the present invention, the matrix support material may contain minor ingredients to enhance certain properties. For example, hard materials such as tungsten, tungsten carbide and silicon carbine may be added to increase wear resistance. Soft materials, such as molybdenum sulfide, copper, and silver, may also be added as solid lubricants.

The supportive material may be prepared by a conventional method. For example, the powder may be mixed with diamond grit thoroughly. An organic binder (e.g., PVA or PVB) may be added to hold the mixture. The mixture is then cold pressed to form the desirable shape (e.g., a saw blade). The precursor is then ready to be infiltrated by a suitable diamond braze.

As discussed, a fine matrix powder used for conventional tools may hinder the infiltration of the diamond braze. Moreover, it would react excessively with the braze so the melting temperature of the braze is raised. As a result, the infiltration may not be complete.

Alternatively, the mixture may be processed following the teaching of applicant's other, copending patent application (U.S. Patent Application, Serial No. 08/832,852 (identified as attorney docket no. T5100), filed April 4, 1997). For example, the powder blend of the supportive material may be cold rolled to form a sheet. The sheet can then be punched out with a desirable shape (e.g., a saw segment) (See Fig. 1). Several such punched segments may be assembled to form the precursor (see Fig. 2,3,4) for infiltration. As described in the pending patent application, by assembling substantially two-dimensional segments to form a three-dimensional body, the distribution of diamond grit in a tool can be positively controlled. Thus, diamond concentration in different parts of the same tool may be adjusted (see FIGS. 1A through 4).

Such a control of diamond distribution is highly desirable to improve the wear characteristics of the tool. For example, the sides of a diamond saw blade are often worn faster then the center, so it is advantageous to add more diamond grit on to the sides (see FIG. 1B).

Current applications require the matrix support material to serve dual functions: to provide the mechanical support of the tool, and to hold the diamond grit in the matrix. These two functions often demand contradictory properties. For example, as the mechanical support, the matrix support material must be strong and wear resistant (e.g., cobalt, or bronze mixed with tungsten carbide). However, the material with good mechanical support is often ineffective to adhere the inert diamond. On the other hand, a braze alloy (e.g., silver-copper-titanum alloys) may hold diamond firm, but are too soft to provide the mechanical support for the tool body. Thus it is desirable to separate these two functions of the matrix support material by using a composite material. In this case, the framework of the composite material is optimized for mechanical support, yet the filler material is designed to hold the diamond.

The composite material may be made by using coated diamond as discussed above. In this case, a diamond braze may be used to coat the diamond grit first and the coated grit is subsequently mixed in the matrix powder. However, the coating incurs an additional cost. Moreover, most diamond brazes are not in a powder form. Even if they were, it is very difficult to coat these brazes uniformly onto the diamond grit. As a result, coated diamond grit is seldom used today in making diamond tools.

The present invention makes the composite matrix support material by infiltrating a diamond braze into a supporting material that contains diamond grit. The

braze includes carbide formers such as chromium, manganese, silicon and aluminum, while avoiding volatile metals such as zinc, lead and tin.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings in which:

FIG. 1A shows a segment from a superabrasive tool formed by a plurality of linear, longitudinal layers disposed adjacent one another to form a three-dimensional superabrasive member;

FIG. 1B shows a cross-sectional view of one typical configuration of the tool segment shown in FIG. 1A, wherein a layer formed by a matrix support material and a relatively large superabrasive is sandwiched between two layers of matrix support materials which have smaller grit and higher concentration of the abrasive;

FIG. 2A shows a segment from a superabrasive tool formed by a plurality of arcuate, longitudinal layers which are attached to one another to form a three-dimensional superabrasive member;

FIG. 2B shows a cross-sectional view of a plurality of layers matrix support material as may be used with the segment shown in FIG. 2A;

FIG. 3 shows another possible layout of a segment of a cutting tool with transverse layers configured with a denser concentration of abrasive material disposed at a forward, cutting end of the three-dimensional superabrasive member;

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution

toward the upper surface of a tool with horizontal layers;

FIGs. 5A through 5D show one possible method for forming layers with controlled superabrasive distribution within the layer;

FIGs. 6A through 6C show an alternate method for forming one or more layers with controlled superabrasive distribution;

FIG. 7A shows a side view of a matrix support material formed in accordance with one aspect of the present invention, wherein a plurality of slots are formed in the matrix support material;

FIG. 7B shows a side view of the matrix support material of FIG. 7A, wherein a plurality of diamond particles are disposed in the slots and brazed to bond with the matrix support material and thereby form a plurality of abrasive fins in the matrix support material; and

FIG. 8 shows a perspective view of the matrix support material similar to that shown in FIGs. 7A and 7b, but with a plurality of abrasive needle structures.

DETAILED DESCRIPTION

Reference will now be made to the drawings in which the various elements of the present invention will be given numeral designations and in which the invention will be discussed so as to enable one skilled in the art to make and use the invention. It is to be understood that the following description is only exemplary of the principles of the present invention, and should not be viewed as narrowing the pending claims.

Referring to FIG. 1A, there is shown a perspective view of a segment, generally indicated at 10, formed by a plurality of layers, 14, 16 and 18. Each of the layers 14, 16 and 18 is formed by matrix

support material 24 impregnated with diamond particles, indicated by the circles 20, and has been infiltrated with a braze 28 selected to bond to the diamond particles and the matrix support material. Preferably, the diamond particles 20 constitute less than 50 percent by volume of the matrix support material - diamond mixture, and more preferably less than 40 percent by volume. Keeping the amount of diamond particles to the minimum helps to minimize cost while optimizing the useful life of the product.

Preferably, the diamond braze contains at least 3% by weight of a member selected from the group consisting of chromium, manganese, silicon and aluminum, and alloys and mixtures thereof. Additionally, the diamond braze should have a liquidus temperature of less than 1,100° C to avoid damage to the diamond during the brazing process.

As discussed in U.S. Patent No. _____ (U.S. Patent Application, Serial No. 08/832,852 (Attorney Docket No. T5100)), which is expressly incorporated herein, forming the segment 10 in a plurality of thin layers provides remarkably improved control over the distribution of the diamond particles 20. By controlling the distribution of the diamond particles 20 within each layer and then combining layers, a three-dimensional segment can be formed in which distribution of the diamond particles is controlled in each dimension. This, in turn, enables the formation of segments which are particularly adapted to the likely use of the segment, be it for polishing, cutting, grinding, etc. By tailoring the distribution and concentration of the superabrasive particles within the segment 10, more precise control is given over performance of the tool under actual working conditions.

The present invention further improves the above technique by infiltrating the matrix support material

24 with a braze 28 which is selected to chemically bond to the diamond particles and to the matrix support material. Thus, while the placement of the diamond particles shown in FIG. 1A is a marked improvement over the prior art, an additional increase in the segment's 10 useful life is obtained by utilizing a braze to form a chemical bond, rather than merely relying on mechanical retention of the diamond particles.

Likewise, the selective placement of differing sizes of diamond particles can used to form a cutting segment formed to resist premature wear to the sides of the segment, thereby extending the cutting segment's useful life. Referring specifically to FIG. 1B, there is shown a cross-sectional view of the cutting segment 10 of FIG. 1A. Unlike the cutting segments of the prior art, the cutting segment 10 is formed of three layers, 14, 16 and 18 respectively. The middle layer 16 has a plurality of superabrasive particles 20a which are of a first size (e.g. 40/50 mesh) and a first concentration. The outer layers 14 and 18, in contrast, have a plurality of superabrasive particles 20b, which are of a second size (e.g. 50/60 mesh) smaller than the first size, and in a second concentration greater than that present in the middle layer 16. The smaller, more densely distributed superabrasive particles 20b provide the outer layers 14 and 18 with a greater resistance to wear as they cut through concrete, rock, asphalt, etc. Because the outer layers 14 and 18 are more resistant to wear, the cutting segment 10 resists formation of a convex outer surface, as has traditionally occurred with cutting elements. By maintaining a more planar cutting surface, the cutting segment is able to maintain a straight cutting path so it can cut more efficiently with a longer useful life.

Furthermore, an additional increase in useful life is obtained by infiltrating the matrix support material 24 with a braze 28 formed from chromium, manganese, silicon, and/or aluminum, or an alloy or mixture thereof. While a wide variety of quantities of these materials may be used, it has been found that it is preferable if the chromium, manganese, silicon or aluminum or alloy or mixture in the diamond braze constitutes at least 3 percent of the braze by weight (and more preferably 5 percent). The braze 28 fills the pores in the matrix support material 24, which is typically powder selected from the group including iron, cobalt, nickel or alloys or mixtures thereof.

Another advantage to the use of multiple layers of matrix with diamond or some other superabrasive particle disposed therein is that the layers are easily formed into other desirable shapes for the cutting, drilling, grinding, etc., segment. For example, FIG. 2A shows a perspective view of a segment, generally indicate at 30, of a superabrasive tool formed by a plurality of arcuate, longitudinal layers which are attached to one another to form a three-dimensional superabrasive member which has been infiltrated with the braze 28 to thereby hold the diamond within the member. The segment 30 is formed from first, second and third layers, 34, 36 and 38, which are each arcuate. When the three are joined together, an arcuate segment 30 is created. Such a segment, of course, may be used on cutting tools which are non linear, e.g. a circular saw blade, and on other types of tools for which a nonlinear superabrasive segment is desired. Because the layers 34, 36 and 38 are initially formed independent of one another, they are much easier to conform to a desired shape, and are able to do so while the brazed diamond particles 20 disposed therein are held in their predetermined positions.

Referring now to FIG. 2B, there is shown a cross-sectional view of a plurality of the layers 34, 36 and 38 of the segment 30. Of course, the configuration of the diamond particles may be used with the segment shown in FIG. 1A or that shown in FIG. 2A. Unlike the embodiment of FIG. 1B, the layers are each provided with the same size and concentration of the diamond particles 20. However, because the spacing is substantially uniform, there is no underspacing or overspacing between the superabrasive particles, and the segment 30 wears more evenly than the segments of the prior art with randomly spaced particles. The more even wear prevents premature failure of the segment 30, and thus extends the life of the tool while keeping the amount of superabrasive used to a minimum. Furthermore, the braze 28 which bonds to the diamond particles and the matrix 24 further strengthens each layer and prevents loss of the diamond particles 20.

FIG. 3 shows another possible embodiment of a segment 50 made in accordance with the teachings of the present invention. The layered structure in a diamond segment may also be assembled transversely or horizontally, and the braze 28 may be applied to every layer, or to select layers as shown in FIG. 3. Thus, the segment 50 in FIG. 3 is formed from a plurality of transverse layers. A first plurality of the layers (i.e. the first four layers), indicated at 56, are provided with a first concentration of diamond particles 20 which are brazed to bond to the matrix support material 24. A second plurality of layers (i.e. the remaining 9 layers), indicated at 58, are provided with a second concentration, less than the first concentration and are also brazed to bond to the matrix support material 24.

Many cutting tools are configured such that the cutting segment 50 is provided with a lead edge which

performs a majority of the cutting and which receives most of the impact force when contacting the surface to be cut. For example, a circular saw blade will usually have a plurality of teeth or segments, each tooth having a leading edge which takes the force of the cutting. Because the leading edge preforms a significant portion of the cutting, it is much more susceptible to wear than are rearward portions of the tooth. When formed in accordance with the prior art, the teeth, however, often had relatively consistent concentrations of abrasive disposed thereon. Over time the leading edge wears significantly, but the other portions coated with diamond particles are subjected to minimal wear. Eventually, the abrasive is worn off the leading edge, while significant amounts remain on the other portions of each tooth. Thus, a considerable amount of superabrasive is wasted when the blade is discarded. The embodiment of FIG. 3 is specifically configured to overcome such concerns. The layers 56 and 58 are configured to provide substantially even wear across the cutting segment 50 by placing a larger percentage of the diamond particles 20 near the leading edge, than on the rear portions. Additionally, brazing the diamond particles 20 in layers 56 and 58 further extends tool life.

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution toward the upper surface of a tool with horizontal layers. As with the embodiment of FIG. 3, the controlled distribution of the diamond particles 20 forms an improved abrasive segment 70, while at the same time decreasing the cost of abrasive tools by decreasing the unnecessary consumption of diamond particles. Additionally, brazing may be used on some of the layers, while being omitted from other layers, to thereby customize the abrasive segment 70.

With routine experimentation and the teachings of the method of the present invention, those skilled in the art will be able to customize cutting, drilling, grinding, polishing and other types of abrasive segments which are specifically formed to maximize their abrasive ability (i.e. cutting, drilling, grinding, etc.) over an extended useful life, while simultaneously decreasing the amount of superabrasive which is used to form the tool.

Referring now to FIGs. 5A through 5D, there is shown one method for forming layers in accordance with the principles of the present invention. The first step of the method is to form a sheet 100 of matrix support material 104 which will be bonded to the superabrasive particles 20. The sheet 100 of matrix support material 104 can be formed from conventional powders such as cobalt, nickel, iron, copper or bronze. Additionally, for reasons which are discussed in detail below, it is highly advantageous to use coarse powders, such as those above 34 microns in diameter. While the use of course powders is inconsistent with the prior art teachings that it is desirable to use the finest powder available, considerable benefits may be achieved by combining course powder and braze to secure diamond particles in place.

There are many ways that a matrix powder can be made into the sheets 100. For example, the powder can first be mixed with a suitable binder (typically organic) and a solvent that can dissolve the binder. This mixture is then blended to form a slurry with a proper viscosity. In order to prevent the powder from agglomeration during the processing, a suitable wetting agent (e.g., menhaden oil, phosphate ester) may also be added. The slurry can then be poured onto a plastic tape and pulled underneath a blade or leveling device. By adjusting the gap between the

blade and the tape, the slurry can be cast into a plate with the right thickness. The tape casting method is a well known method for making thin sheets out of powdered materials and it works well with the method of the present invention.

Alternatively, the powder can be mixed with a suitable binder and its solvent to form a deformable cake. The cake can then be extruded through a die with a slit opening. The gap in the opening determines the thickness of the extruded plate. Alternatively, the material can also be drawn between two rollers with adjustable gap to form sheets with the right thickness.

It is desirable to make the sheets pliable for subsequent treatments (e.g., bending over the tool substrate). Therefore, a suitable organic plasticizer can also be added to provide the desired characteristics.

The use of organic agents for powder (metal, plastics, or ceramics) processing is documented in many text books and it is well known by those skilled in the art. Typical binders include polyvinyl alcohol (PVA), polyvinyl butyral (PVB), polyethylene glycol (PEG), pariffin, phenolic resin, wax emulsions, and acrylic resins. Typical binder solvents include methanol, ethanol, acetone, trichlorethylene, toluene, etc. Typical plasticizers are polyethylene glycol, diethyl oxalate, triethylene glycol dihydroabietate, glycerin, octyl phthalate. The organic agents so introduced are to facilitate the fabrication of metal layers. They must be removed before the consolidation of metal powders. The binder removal process (e.g., by heating in a furnace with atmospheric control) is also well known to those skilled in the art.

Once the sheet 100 of matrix support material 104 is formed, a template 110 is laid on the top of the sheet. The template 110 contains apertures 114 that

are larger than one abrasive particle 20, but smaller than two abrasive particles, thereby allowing a single particle of the abrasive to be disposed at each specific location.

The thickness of the template is preferably between 1/3 to 2/3 of the height of the average abrasive particle 20. However, other thicknesses may be used if appropriate accommodations are made for seating the abrasive particles in the desired locations.

After the template 110 is properly positioned, a layer of abrasive particles 20 is then spread over the template so that each aperture 114 receives an abrasive particle. Those particles not falling into the apertures 114 in the template 110 are removed by tilting the substrate, sweeping the template with a broom, or some other methods.

As shown in FIG. 5B, a generally flat surface 120, such as a steel plate, is then laid over the particles 20 which rest in the apertures 114 in the template 110. The flat surface 120 presses the abrasive particles 20 at least partially into the pliable sheet 100 of matrix support material 104 to seat the particles.

After removing the template 110, the flat surface 120 is used again to press the abrasive particles 120 firmly into the sheet 100 of matrix support material 104 as shown in FIG. 5C. While the flat surface 120 is preferable, those skilled in the art will appreciate that there may be occasions when it is desirable to have some of the abrasive particles 20 extend outwardly from the sheet 100 of matrix support material more that other abrasive particles. In such situations, a contoured or otherwise shaped surface could be used to seat some of the abrasive particles 20 deeper into the sheet 100 of matrix support material 104, than other particles.

If desired, the process shown in FIGs. 5A through 5C can be repeated on the other side of the sheet 100 of matrix support material 104 (as shown in FIG. 5D), to form an impregnated layer having diamond particles 20 distributed throughout the layer in some predetermined, desired pattern. The process is typically repeated several times to obtain multiple thin layers or sheets 100 which are impregnated with the diamond particles 20. Of course, each sheet 100 need not have the same distribution pattern for the diamond particles 20, nor need the concentration of the abrasive particles be the same in each sheet.

The abrasive impregnated sheets 100 are then infiltrated with a braze which is formed with chromium, manganese, silicon, aluminum or alloys or mixtures thereof. While prior art brazes typically includes metals which were designed to facilitate flow of the braze material, such as zinc, lead and tin, it has been found in accordance with the present invention that such materials actually impair the brazing process. The materials are generally more volatile, and have a tendency to contaminate the vacuum or inert atmosphere used in infiltration. While very small amounts of the volatile metals will not significantly interfere with brazing, amounts over about 1 or 2 percent can be undesirable. As used herein, substantially free of volatile metals, or substantially free of zinc, etc. is used to characterize such a situation in which the volatile metal is present in sufficiently small amounts as to not provide any impediment to the process of vacuum infiltration.

It is important that the infiltration temperature be kept lower than the melting point of the matrix powder so the tool body can maintain the shape during the infiltration of the diamond braze. Moreover, the brazing temperature must also be low enough to not

cause diamond to degrade. In addition to control the brazing temperature, the brazing time should also be kept short so the braze will not react excessively with diamond and the matrix powder. In the former case, diamond may also be degraded. In the later case, the alloying with the matrix powder may raise the melting point of the diamond braze. As a result, the diamond braze may solidify gradually and eventually stop to flow.

The environment for infiltration also may be controlled to provide superior performance. For example, if the braze material contains a strong getter of oxygen or nitrogen, such as titanium, a high degree of vacuum (e.g., 10^{-6} torr maximum) must be maintained during the infiltration of the braze. On the other hand, if the braze material contains a less sensitive getter, such as chromium and manganese, a lower degree of vacuum (e.g., 10^{-5} torr minimum) or a hydrogen atmosphere may be adequate for the infiltration.

After the infiltration, the produced part (e.g., a saw segment) may be trimmed (e.g., by grinding) to the finished dimension. It can then be mounted (e.g., by brazing) onto a tool body (e.g., a round steel blade) to make a finished product.

As discussed above, this invention uses a diamond braze as the infiltrant that penetrates the matrix powder of a diamond tool. Most diamond brazes can wet easily common matrix powders with major constituents of cobalt, nickel, iron, copper or bronze, so the infiltration may proceed smoothly.

In contrast to a sintering process that eliminates pores in the matrix powder by consolidation, the infiltration allows the diamond braze to fill up these pores. Sintering is achieved by diffusion of atoms mainly along surfaces. In order to facilitate the sintering process the matrix powder

must have large surface areas. Hence, in sintering, it is preferable to use fine powders. The fine powder can allow the sintering to proceed at a lower temperature.

The most widely used matrix powder for making diamond tools (e.g., saw segments) is cobalt powder. The standard sizes of cobalt powder for making conventional diamond tools are less than 2 micrometers. In the last decade, the diamond tool manufacturers have demanded finer and finer matrix powders. The commercial suppliers (e.g., Eurotungsten Co.) are therefore, moving toward making ultrafine (one micrometer), and even ultra-ultrafine (submicron) powders. With such a trend, the sintering temperature is continuously decreasing. A lower sintering temperature can not only reduce the degradation of diamond, it also reduces the cost of manufacturing. For example, the electrical power consumption for heating is lower. Moreover, the oxidation loss of graphite mold is also minimized.

The present invention, however, uses a diamond braze to fill up the pores of the matrix powder. Hence, contrary to a conventional sintering process, coarse-sized powders, i.e. greater than 400 U.S. mesh or 34 microns, are preferred. Moreover, while conventional methods require the packing density be as high as possible so sintering can proceed rapidly, the present invention prefers to use a precursor with a lower packing density to allow the easy flow of the diamond braze. In fact, sometimes, the porosity of the precursor body may be intentionally increased by using irregularly shaped matrix particles. This preference, again, is contrary to the conventional wisdom that requires the particles be as spherical as possible so the packing density can be increased.

As discussed, a fine matrix powder used for conventional tools may hinder the infiltration of the

diamond braze. Moreover, it would react excessively with the braze so the melting temperature of the braze is raised. As a result, the infiltration may not be complete.

The use of a coarse matrix powder has other benefits. For example, a coarse powder can mix better with different compositions. Hence, the diamond grit may distribute more uniformly in the matrix. Moreover, a coarse powder has a smaller surface area, and hence, a lower frictional force for infiltration. Therefore, it can flow easier in the mold. Of course, a coarse matrix powder is also much less expensive, so the production cost may be reduced.

It is important to note that this invention utilizes the matrix merely as the network for holding the diamond grit in place. Hence, the matrix may not have to be made of powder. For example, the matrix body may be made of a piece of steel with openings that contain diamond grits of PCD bodies, such as that which is discussed below with respect to FIGs. 7A and 7B.

The most critical part of this invention is in the selection of a diamond braze. Although there are numerous kinds of diamond brazes, only those that meet the following requirements are applicable. Firstly, the infiltration temperature of the braze must not be so high as to cause significant diamond degradation. The temperature limit is, in general, about 1100° C. The infiltration temperature can be 50° C above the liquidus of the braze. A course matrix powder and a shorter infiltration path requires a lower excess temperature beyond the melting point of the braze.

The diamond braze must wet the diamond and chemically bond with the diamond. As discussed above, a carbide former dissolved in a suitable solvent alloy can meet this requirement. However, the reactivity of the carbide former must be balanced between diamond

and oxygen or other gases such as nitrogen or hydrogen. It is a dilemma that a strong carbide former, such as titanium or zirconium that bonds diamond well are also gas scavengers. They would react quickly with harmful gases in the ambient atmosphere before forming the carbide with diamond.

Most diamond tools are manufactured in a graphite mold often in air or in an inert gas. The minute amount of oxygen or moisture in the atmosphere may oxidize the carbide former so the latter may not bond to diamond. This is true even if the brazing is performed in a vacuum or in a hydrogen atmosphere, unless the vacuum is kept lower than 10^{-6} torr, or the dew point of the gas is kept below - 60° C. Such a stringent requirement of vacuum or dew point often adds unnecessary cost to manufacturing.

On the other hand, if the reactivity is low, such as that of cobalt or nickel, the metal can be processed in graphite mold without being oxidized. However, it cannot bond to diamond either. Hence, there is a compromise for the carbide former between its ability to bond with diamond and its tendency to be oxidized.

In accordance with the present invention, it has been found that the preferred carbide former for the diamond braze is either chromium, manganese, silicon, aluminum or their alloys. The preferred total content of such carbide former is at least 3 percent, and more preferably at least 5 percent by weight. Examples of these brazes are NICROBRAZ LM (Ni-CR-B-Si-Fe), manufactured by Wall Colmonoy Company (U.S.A.), with a melting range of 970-1000° C, and 21/80 (Cu-Mn-Ni), manufactured by Degussa (Germany), with a melting range of 970-990° C. Other possible brazes include: Cu-Mn alloy near the eutectic composition (about 25 wt% Mn) with a melting point of about 880° C; Ni-Si alloy near the eutectic composition (about 50 wt% Si)

with a melting point of about 970° C; Cu-Si alloy near the eutectic composition (about 30 wt% Si) with a melting point of about 810° C; Al-Si alloy near the eutectic composition (about 15 wt% Si) with a melting point of about 600° C.

The above examples of infiltratable diamond brazes cover a wide range of mechanical properties and infiltration temperatures (e.g. about 50° C above the liquidus). The alloys of them may also be used for further adjustments of infiltration temperature and mechanical properties. The selection of diamond braze depends on the intended application. In general, more severe applications, such as sawing granite, concrete, or asphalt) would require a stronger diamond grit that may tolerate a higher temperature of brazing. Brazes which melt at higher temperatures are, in general, more wear resistant. On the other hand, less demanding applications, such as sawing limestone or marble, require lower strength diamond grit. Such a diamond is degraded easily at high temperature so it must be brazed at a lower temperature. Brazes of this type are typically less wear resistant.

The sheets 100 may be first assembled to form the precursor of the tool segment and then infiltrated with diamond braze, or they can be infiltrated by the braze and later assembled to form the tool segment or the entire tool body where appropriate. While the method described in FIGs. 5A through 5D is preferred for many applications, there are instances where it is desirable to have the abrasive particles 20 extend outwardly from the sheet 100 of matrix support material. For example, some tools may only have one layer of abrasive. This can be accomplished simply by leaving the template 110 in place when performing the steps shown in FIG. 5A and 5B, and not further

pressing the particles 20 into the matrix support material once the template has been removed.

In the alternative, FIGs. 6A through 6C show a side view of an alternate to the method discussed in FIGs. 5A through 5D. The sheet 130 of matrix support material in FIGs. 6A through 6C is formed to be of a lesser thickness than the cross-sectional thickness or diameter or the superabrasive particles 20. When the particles or pressed into the sheet 130, the thickness of the sheet forces the particles 20 to protrude from the matrix support material 134. The sheet 130 is then infiltrated with diamond braze in the manner discussed above.

While the use of the diamond braze 28 has been discussed with respect to the patterned distribution of diamond particles, it is equally applicable to the random distribution of diamond particles in a matrix support material. Once the diamonds have been placed in the matrix support material, a diamond braze comprising chromium, manganese, aluminum or silicon, and being substantially free of volatile metals, is melted and poured onto the matrix support material. The liquidous braze infiltrates the matrix support material and bonds the diamond particles to the matrix support material.

In addition to its use with conventional matrix support materials, such as metal powders, the diamond braze also facilitates the use of novel support materials, such as that shown in FIGs. 7A and 7B. Referring specifically to FIG. 7A, there is shown the matrix support material 200 of a saw segment, generally indicated at 210. The matrix support material 200 includes a plurality of slots 214 which are cut in specific intervals.

To form a finished cutting segment, the matrix support material 200 is placed in a mold (e.g. graphite or metal) made of refractory material (e.g.,

graphite). Diamond particles 20 (FIG. 7B) is poured into the slots 214 to fill the open slots. Diamond braze is added on top of these slots. After infiltration, the braze will fill in these slots and bond with the diamond particles 20, and with the matrix support material 200 to form a completed saw segment 210. In this geometry, the diamond particles form blades in the saw segment (FIG. 7B) instead of distributing throughout the matrix body as in the case of a conventional tool. Those skilled in the art will appreciate that such a configuration would be nearly impossible in accordance with the teachings of the prior art, because the matrix support material 200 was required to hold the diamond particles in place mechanically. In contrast, the use of the diamond braze enables the positioning of columns of diamond particles in a slot, hole, etc., because the braze bonds to the diamond and to the support material, the diamonds are secured in place. While the embodiment shown in FIGs. 7A and 7B forms diamond "fins", needle like columns of diamond also can be formed (FIG. 8). Furthermore, the slots, hole, etc, can be formed to provide such columns which are linear, or which curve in any desired direction. Thus, with routine experimentation, those skilled in the art can customize cutting, drilling, polishing, etc., segments which are customized to particular uses. The diamond particles used may be either diamond grit or thermally stable polycrystalline diamond (PCD). The infiltration will not only consolidate the matrix powder, but also bond the diamond firmly, so an integrated diamond tool is formed.

Example 1

40/50 mesh diamond grit (SDA-85+ made by De Beers Company) was mixed with iron powders coarser than 200 U.S. mesh, and an organic binder to form a mixture with diamond concentration of 20 (5% of total volume).

The mixture was cold pressed in a steel mold to form the shape of a saw segment. The precursor was placed in a graphite mold and overlaid with a powder of Nicrobraz LM. The mold was heated under vacuum to about 1,050° C for 20 minutes. The infiltrated braze had bonded diamond and matrix powder together to form a segment. Twenty-four of such segments were manufactured and they were trimmed to desirable tolerances. These segments were brazed onto a 14 inch round steel circular saw blade. The blade was used to cut granite at a faster cutting rate than was possible with conventional diamond saw blades. Additionally, the brazed saw blades had a longer useful life than a conventional diamond saw blade.

A distinct advantage cutting tools of the present invention have over the prior art cutting tools lies in the manner in which the tool may be used. Diamond saws are typically made in the form of a circular blade that cuts the workpiece by rotation in the same direction with each rotation. This one directional movement causes a "tail" to be formed, wherein the matrix material rotationally forward of the diamond particle is worn away, but the matrix material behind the diamond particle is protected by the diamond particle itself. Thus, the matrix material behind the diamond continues to hold the diamond particle in place. If the saw rotation were to be reversed, the diamond particle could easily be knocked free of the matrix.

Round saws, however, can only cut the work piece to a depth of less than one-half the diameter of the saw. In order to cut thicker work pieces, a frame or gang saw is typically used. Because these saws move reciprocally, the diamond particles must be securely held on each side. As a result, tails of diamond matrix cannot be maintained to hold the diamond particles in place. It is for this reason that

reciprocating diamond saws have not been used to saw hard rock such as granite. Rather, they are used to cut only soft materials such as marble.

This invention allows diamond to be held chemically by a braze. Hence, matrix tails are not needed to support the diamond. As a result, tools made according to the present invention can be used on reciprocating saws to cut hard materials. This breakthrough can expand diamond applications to markets which were previously unavailable due to limitations of the prior art.

Thus, there is disclosed an improved method for making diamond saw blades. The above description and examples are intended only to illustrate certain potential uses of this invention. It will be readily understood by those person skilled in the art that the present invention is susceptible of a broad utility and applications. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements will be apparent from or reasonably suggested by the present invention and the forgoing description thereof without departing from the substance for scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to its preferred embodiment, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for purpose of providing a full and enabling disclosure of the invention. The forgoing disclosure is not intended or to e construed to limit the present invention or otherwise to exclude any such other embodiment, adaptations, variations, modifications and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

CLAIMS

What is claimed is:

1. An abrasive tool comprising:

a matrix support material configured for holding diamond particles to be used as abrasives;

a plurality of diamond particles disposed in the matrix support material; and

an alloy infiltrated through the matrix support material and the diamond particles, the alloy being bonded to the diamond particles and the matrix support materials, the alloy comprising a metal alloy that contains 2 to 50 percent of an element selected from the group consisting of chromium, manganese, silicon and aluminum, and being substantially free of zinc.

2. The abrasive tool according to claim 1, wherein the matrix support material contains more than 50 percent by weight of material selected from the group consisting of cobalt, nickel, iron, copper and bronze and mixtures and alloys thereof.

3. The abrasive tool according to claim 1, wherein the matrix support material occupies more volume than the diamond particles.

4. The abrasive tool according to claim 1, wherein the diamond particles are less than 40 percent of the volume of the matrix support material and diamond particles combined.

5. The abrasive tool according to claim 1, wherein the matrix support material is formed of coarse-sized powders greater than 400 U.S. mesh.

6. The abrasive tool according to claim 1, wherein the diamond particles are disposed in the matrix support material in a predetermined pattern.

7. The abrasive tool according to claim 1, wherein the matrix support material is formed by a plurality of diamond impregnated sheets.

8. The abrasive tool according to claim 7, wherein the diamond impregnated sheets are made by rolling, extruding, or tape casting a mixture of metal powder and diamond grits.

9. The abrasive tool according to claim 7, wherein the diamond impregnated sheets are made by mechanically planing diamond grits into the metal sheet.

10. The abrasive tool according to claim 9, wherein the metal sheet is formed by the group consisting of rolling from an ingot and prepared from a metal powder.

11. The abrasive tool according to claim 7, wherein at least one of the diamond impregnated sheets has been infiltrated with the alloy.

12. The abrasive tool according to claim 1, wherein the alloy is substantially free of interfering metals selected from the group consisting of zinc, lead and tin.

13. The abrasive tool of claim 1, wherein the alloy comprises at least 3 percent by weight of a material selected from the group consisting essentially of chromium, manganese, silicon, and aluminum and mixtures and alloys thereof.

14. The abrasive tool according to claim 1 and characterized further in that the alloy is selected from the group consisting essentially of NICROBRAZ LM,

copper-manganese alloy, copper-silicon alloy, and aluminum-silicon alloy.

15. The abrasive tool of claim 1, wherein the alloy has a liquidus temperature of less than 1,100° C.

16. The abrasive tool of claim 1, wherein the matrix support materials has a plurality of slots formed therein, and wherein the diamond particles are disposed within the slots.

17. The abrasive tool of claim 16, wherein the slots are filled with an alloy to bond the diamonds disposed within the slots to the matrix support material defining the slots.

18. The abrasive tool of claim 1, wherein the diamond particles are disposed in columns extending into the matrix support material, and wherein the diamonds are held in place by the alloy.

19. The abrasive tool of claim 18, wherein the column is substantially linear.

20. The abrasive tool of claim 18, wherein the column is curved.

21. The abrasive tool of claim 1, wherein the tool is a circular saw blade.

22. The abrasive tool of claim 1, wherein the tool is a linear saw blade.

23. A method for forming a diamond impregnated tool comprising:

(a) forming a matrix support material configured for holding diamond particles to be used as abrasives;

(b) distributing diamond particles in the matrix supportive material; and

(c) infiltrating the matrix support material with an alloy that contains between 2 and 50 percent of an element selected from the group consisting essentially of chromium, manganese, silicon and aluminum, and being substantially free of zinc.

24. The method according to claim 23, wherein step (a) comprises, more specifically, forming the matrix support material from powder larger than 400 mesh.

25. The method according to claim 23, wherein step (a) comprises, more specifically, forming the matrix support material from irregularly shaped particles.

26. The method according to claim 23, wherein the method comprises, more specifically, distributing the diamond particles in the matrix support material in a predetermined pattern.

27. The method according to claim 23, wherein the method comprises, more specifically, infiltrating the matrix support material with an alloy substantially free of interfering metals selected from the group consisting of zinc, lead and tin.

28. The method according to claim 23, wherein the method comprises, more specifically, forming a plurality of slots in the matrix support material, and distributing diamond particles into the slots.

29. The method according to claim 23, wherein the method further comprises infiltrating the slots with alloy braze to bond the diamond to the matrix support material.

30. The method according to claim 23, wherein the method further comprises subjecting the matrix support material and diamond particles to a vacuum of at least 10^{-3} torr during infiltration.

31. The method according to claim 23, wherein the method comprises, more specifically, infiltrating the matrix support material and diamond particles with an alloy having at least 5 percent by weight of a carbide former selected from the group consisting essentially of chromium, manganese, aluminum and silicon and mixtures and alloys thereof.

32. The method according to claim 23, wherein the alloy is selected from the group consisting of Nicrobraz LM; an alloy including copper and manganese; an alloy including copper and silicon; an alloy including aluminum and silicon and an alloy including nickel and silicon.

33. The abrasive tool according to claim 1, wherein the tool is a wire saw.

34. The abrasive tool according to claim 33, wherein the tool is a diamond wire saw.

35. the abrasive tool according to claim 34, wherein the tool is a diamond wire saw that contains beads fitted over a steel cable.

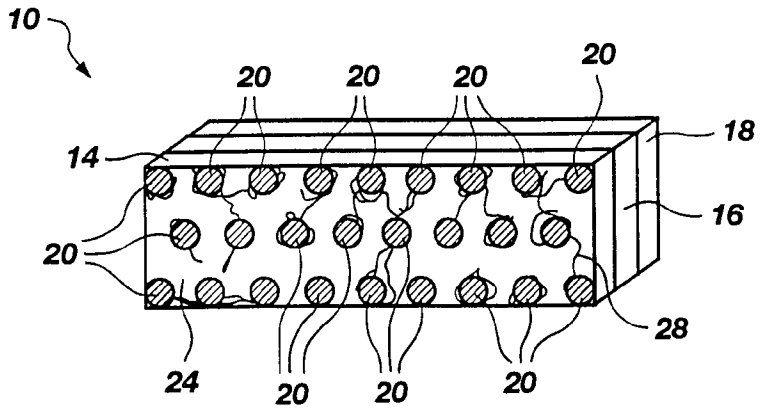


Fig. 1A

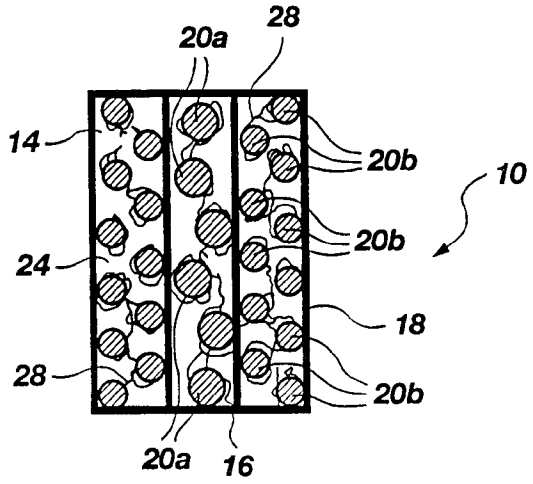


Fig. 1B

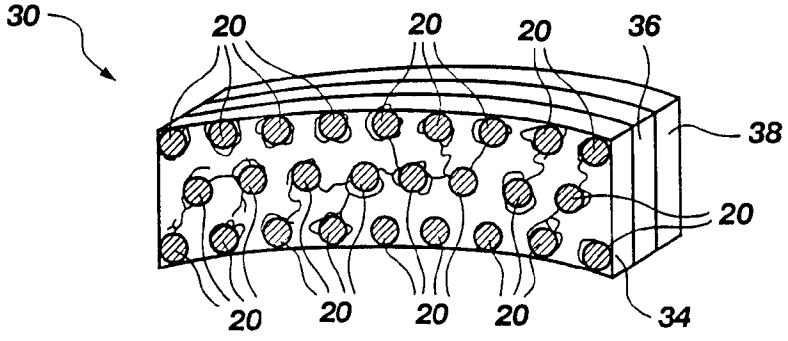


Fig. 2A

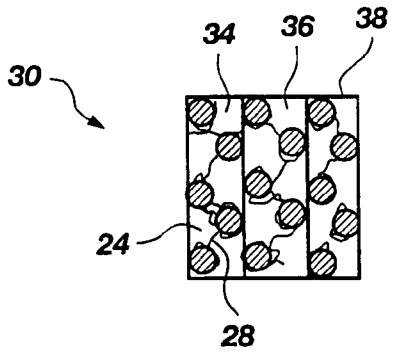


Fig. 2B

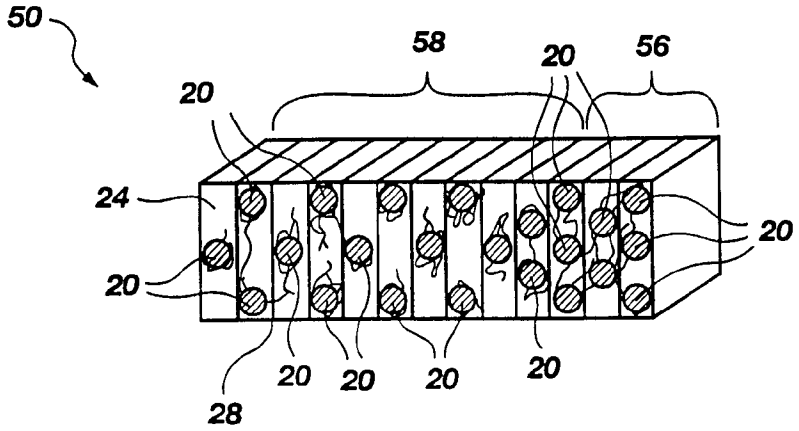


Fig. 3

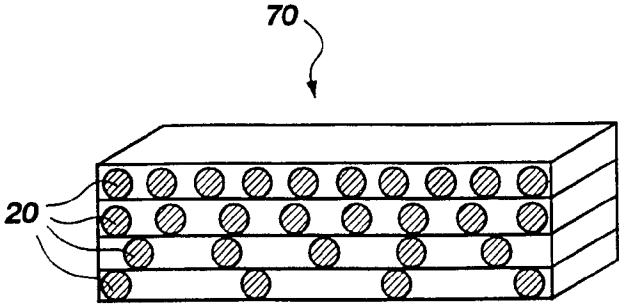


Fig. 4

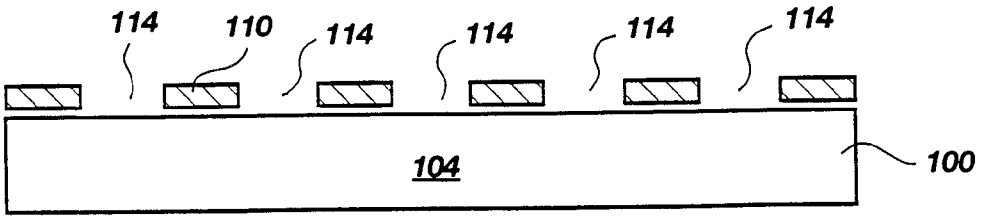


Fig. 5A

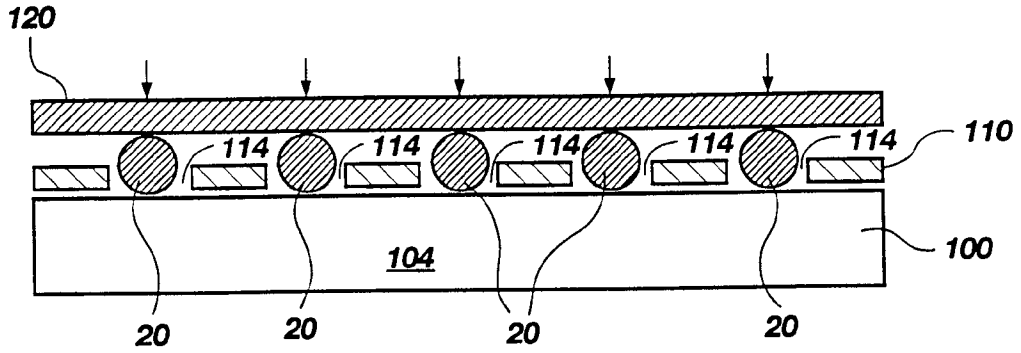


Fig. 5B

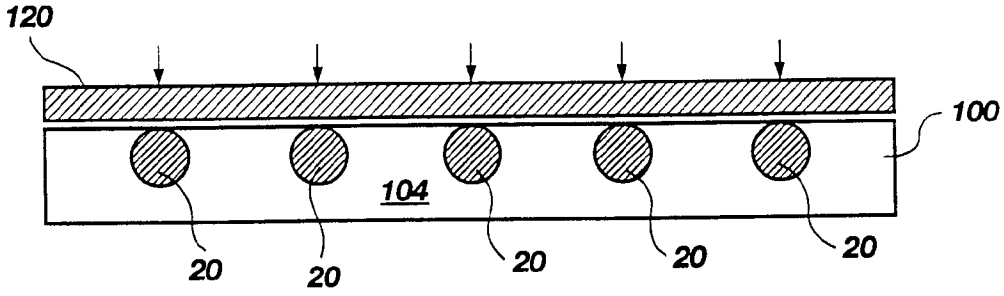


Fig. 5C

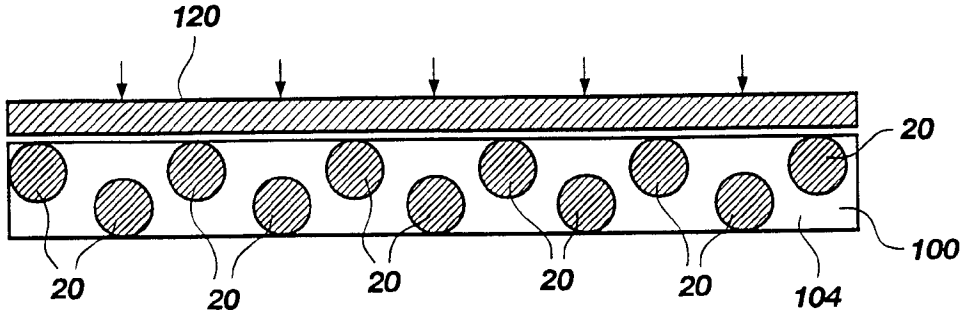


Fig. 5D

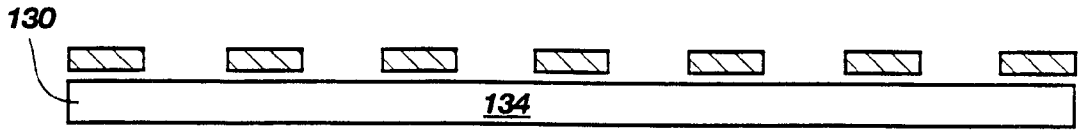


Fig. 6A

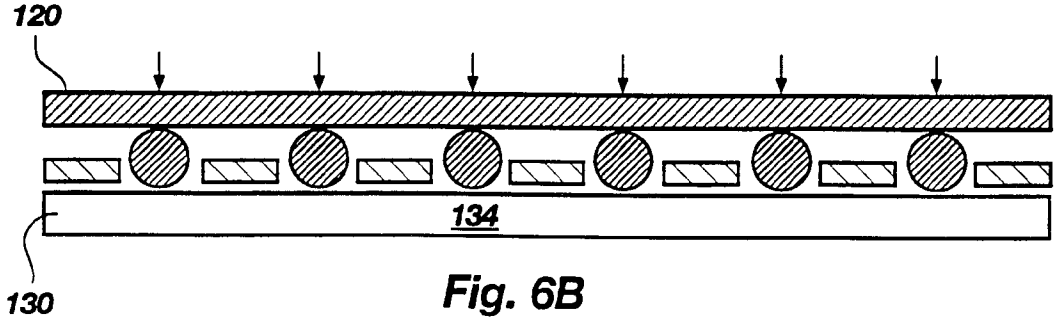


Fig. 6B

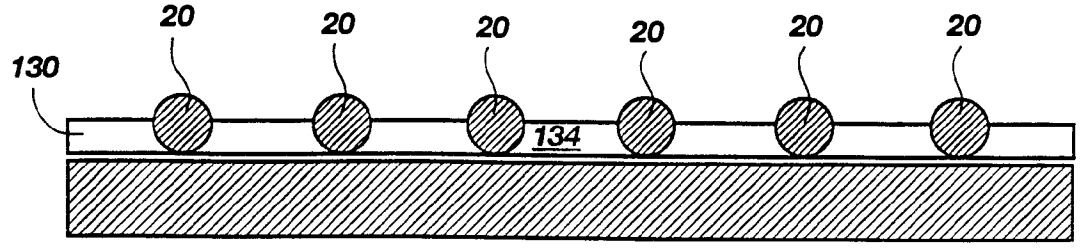


Fig. 6C

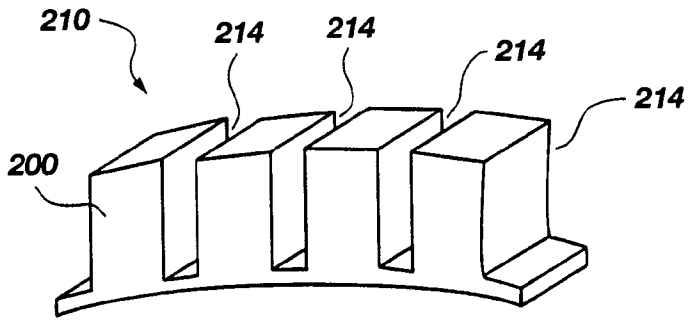


Fig. 7A

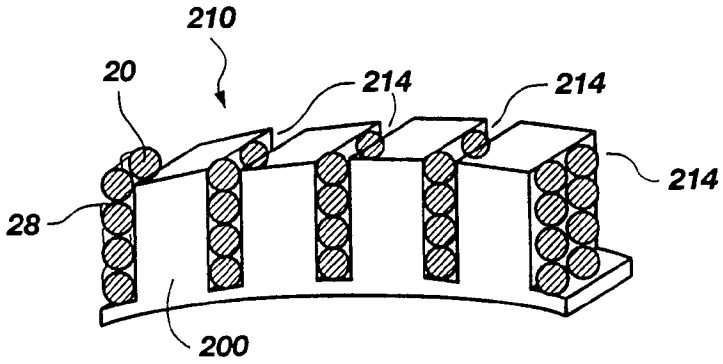


Fig. 7B

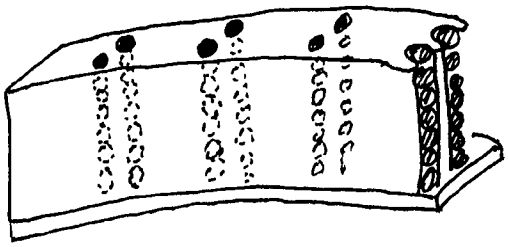


Fig. 8

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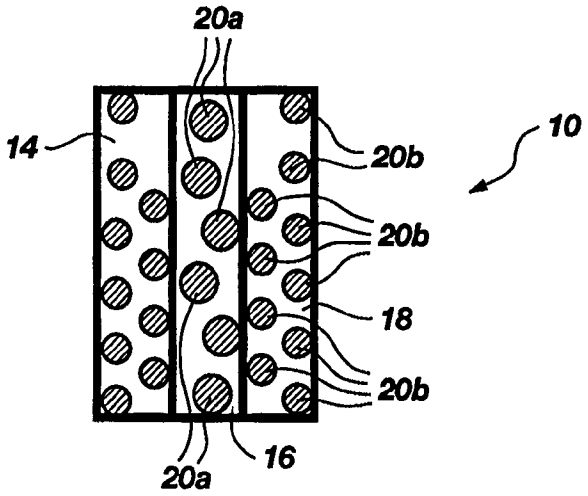
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(57) Abstract

An abrasive tool (10) that contains abrasive particles (20) distributed in a predetermined pattern. Such a pattern is produced by fabricating two-dimensional slices (14, 16, 18) and assembling them. Abrasive particles (20) may be incorporated during the process of making these slices, or they may be planted afterwards into these slices which contain matrix powder. The planting may be guided by a template with apertures laid in a specific pattern.



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ABRASIVE TOOLS WITH PATTERNED GRIT DISTRIBUTION AND METHOD OF MANUFACTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improved abrasive tools used for cutting, grinding and the like. More particularly, the present invention relates to improved abrasive tools wherein abrasive particles are distributed in a predetermined pattern in a matrix powder in order to decrease cost and/or increase the useful life of the tool.

2. State of the Art

Abrasive tools have long been used in numerous applications, including cutting, drilling, sawing, grinding, lapping and polishing materials. Because diamond is the hardest abrasive material and cubic boron nitride is the second hardest, the two materials have been widely used as superabrasives on saws, drills, and other tools which utilize the abrasive to cut, form or polish other hard materials. It is estimated that the total value of superabrasive tools now consumed world wide is over is over 5 billion U.S. dollars per year. More than half of the superabrasive tools are believed to be consumed in sawing and

drilling application such as cutting stones, concretes, asphalts, etc.

Superabrasive tools are particularly indispensable for applications where other tools lack the strength and durability to be practical substitutes. For example, in the stone industry where rocks are cut, drilled, or sawed, diamond tools are the type which are sufficiently hard and durable to make the cutting, etc., economical. If superabrasives were not used, many such industries would be economically infeasible. Likewise, in the precision grinding industry, superabrasive tools, due to their superior wear resistance, are uniquely capable of developing the tight tolerances required, while simultaneously withstanding wear sufficiently to be practical.

Despite the tremendous improvements which diamond and cubic boron nitride have provided for cutting, drilling and grinding tools, there are still several disadvantages which, if overcome, would greatly improve performance of the tools, and/or reduce their cost. For example, the abrasive diamond or cubic boron nitride particles are not distributed uniformly in the matrix that holds them in place. As a result, the abrasive particles are not positioned to maximize efficiency for cutting, drilling, etc., and for production costs of the tools. In some instances, the abrasive particles are disposed too close together.

In other instances, the abrasive particles are disposed to far apart from one another.

In all applications, the separation between abrasive particles determines the work load each particle will perform. Improper spacing of the abrasive particles typically leads to premature failure of the abrasive surface or structure. Thus, if the abrasive particles are too close to one another, some of the particles are redundant. The particles are present, but provide little or no assistance in the cutting, grinding, etc., application. Of course, excess particles add to the expense of the abrasive, due the high cost of diamond and boron nitride. Moreover, these non-performing particles can block the passage of debris, thereby reducing the cutting efficiency. Thus, having abrasive particles disposed too close to one another adds to the cost, while decreasing the cutting efficiency of the tool.

On the other hand, if abrasive particles are separated too far, the work load (e.g., the impact force exerted by the work piece) for each particle becomes excessive. The sparsely distributed particles may be crushed, or even dislodged from the matrix into which they are disposed. The damaged or missing abrasive particles are unable to fully assist in the work load. Thus, the work load is transferred to the surviving abrasive particles. The failure of each

abrasive particle causes a chain reaction which soon renders the tool ineffective to cut, drill, grind, etc.

A typical superabrasive tool, such as a diamond saw blade, is manufactured by mixing diamond particles (e.g., 40/50 U.S. mesh saw grit) with a suitable matrix (bond) powder (e.g., cobalt powder of 1.5 micrometer in size). The mixture is then compressed in a mold to form the right shape (e.g., a saw segment). The "green" form is then consolidated by sintering at a temperature between 700-1200 °C to form a single body with a plurality of abrasive particles disposed therein. Finally, the consolidated body is attached (e.g., by brazing) to a tool body, such a round blade of a saw, to form the final product.

Different applications, however, require different combinations of diamond (or cubic boron nitride) and matrix powder. For example, for drilling and sawing applications, a large sized (anywhere from 20 to 60 U.S. mesh) diamond grit is mixed with a metal powder. The metal powder is typically selected from cobalt, nickel, iron, copper, bronze, alloys thereof, and/or mixtures thereof. For grinding applications, a small sized (anywhere from 60 to 400 U.S. mesh) diamond grit (or cubic boron nitride) is mixed with either metal (typically bronze), ceramic/glass (typically a mixture of oxides of sodium, potassium, silicon, and aluminum) or resin (typically phenolic).

Because diamond or cubic boron nitride is much larger than the matrix powder (300 times in the above example for making saw segments), and it is much lighter than the latter (about 1/3 in density for making saw segments), it is very difficult to mix the two to achieve uniformity. Moreover, even when the mixing is thorough, diamond can still segregate from metal in the subsequent treatments such as pouring the mixture into a mold, or when the mixture is subjected to vibrations. This diamond distribution problem is particularly troublesome for metal matrix tools. Metal matrix tools may account for more than 60% of the total value of all diamond tools. Within metal matrix tools, diamond saws (circular saws, straight blades, wire saws, etc.) comprise about 80% of the value. Thus, finding a method for increasing life of the abrasive material, and/or decreasing the amount of abrasive which is needed is highly desirable. Such has been accomplished by the invention set forth herein. The invention is applicable to all superabrasive tools, and is particularly effective for diamond saws, the largest value category of all diamond tools.

Over the decades, there have been numerous attempts to solve the diamond distribution problem. Unfortunately, none of the attempted methods have proven effective and, as of today, the distribution of diamond particles in diamond tools is still random and

irregular, except for some special cases such as drillers or dressers, where large diamond particles are individually set by hand in the surface to provide a single layer.

One method used in an attempt to make the diamond distribution uniform is to wrap diamond particles with a thick coating of matrix powder. The concentration of diamond particles in each diamond tool is tailored for a particular application. The concentration determines the average distance between diamond particles. For example, the concentration of a typical saw segment is 25 (100 means 25% by volume) or 6.25% by volume. Such a concentration makes the average diamond to diamond distance about 2.5 times of the particle size. Thus, if one coats the diamond to 0.75 times of its diameter and mix the coated particle together, the distribution of diamond would be controlled by the thickness of coating and may become relatively uniform. Additional metal powder may be added as interstitial filler between these coated particles to increase the packing efficiency so the consolidation of the matrix powder in subsequent sintering would be easier.

Although the above described coating method has certain merit, in practice, the uniformity of coating is very difficult to achieve. There are many chemical methods to coat diamond grit and its aggregates (polycrystalline diamond). For example, Chen and Sung

(U.S. Patent Nos. 5,024,680 or 5,062,865) described a CVD method for coating diamond grit using a fluidized bed. Sung et al (U.S. Patent Nos. 4,943,488 or 5,116,568) described another CVD method for coating polycrystalline diamond by fluidized bed. However, most of these methods can only produce thin coatings (e.g. a few micrometers) that do not affect the diamond distribution. Moreover, chemical coating methods typically require treatment at high temperatures (e.g. greater than 900 °C) that may cause damage to diamond. It is well known that synthetic diamond grit tends to form microcracks above this temperature. These microcracks are formed by the back-conversion of diamond to graphite at high temperature. The back-conversion is induced by the catalytic action of metal inclusions that diamond incorporated during its synthesis. CVD treatments cannot readily make thick coatings, and those which are formulated are often cost prohibitive. Thus, CVD treatments are not practical methods to make diamond distribution uniform in the tool.

There are, however, less expensive mechanical methods (e.g., by tumbling diamond particles with metal powder) that can build up a thick coating on diamond grit, typically at a low temperature that would not cause the degradation of diamond. However, it is very difficult to achieve a thick coating with uniform thickness using such methods.

For example, in attempts to practice the invention described in U.S. Patent No. 4,770,907 C.M. Sung performed "Metal Coating of Saw Diamond Grit by Fluidized Bed" (see p 267-273 of Fabrication and Characterization of Advanced Materials, edited by S. W. Kim and S. J. Park of The Materials Research Society of Korea 1995). It was found that the thickness of coated diamond particles varied considerably. Moreover, only extremely fine (i.e. less than 5 micrometers) metal powders can be coated on diamond effectively. Furthermore, the reproducibility of this method is poor. Hence, although such coating may improve the diamond distribution in the tool, its effect is limited.

Furthermore, in mechanical coating, metal powder is held loosely by an organic binder (e.g., PVA, PEG). The coating may be easily rubbed off during the subsequent mixing process, and thereby losing its intended benefit. Although heat treatment may increase the mechanical strength of the coating, nonetheless, it is an additional step with cost.

There is yet another limitation associated with the current methods of coating diamond particles. Many times a diamond tool requires different sizes of diamond grit and/or different diamond concentrations to be disposed at different parts of the same diamond tool. For example, saw segments tend to wear faster on the edge or front than the middle. Therefore,

higher concentrations and smaller diamond grit are preferred in these locations to prevent uneven wear, and thus premature failure of the saw segment. These segments with different concentration/size combinations (known as "sandwich" segments) are difficult to fabricate by mixing coated diamond with metal powder to achieve a controlled distribution of the abrasive particles in the segment. Thus, despite the known advantages of having varied diamond grit sizes and concentration levels, such configurations are seldom used because of the lack of a practical method.

In summary, current arts are incapable of efficiently controlling the uniformity of diamond distribution in the tool. Likewise, the current methods are inadequate to provide effective control of size variations and/or concentration variations on different parts of the same tool. Moreover, even when the distribution is made relatively uniform, current arts cannot tailor the pattern of the distribution to overcome or compensate for typical wear patterns for the abrasive material, when used for a particular purpose. By resolving these problems, the performance of a diamond and other superabrasive tools can be effectively optimized.

It is estimated that less than 10% of abrasives are actually consumed at work. Most of remainder is wasted due to the low efficiency of using these tools.

Among the various causes of this low efficiency, the inability to place every abrasive at the desired location is a major factor. This invention is aimed to make a revolutionary improvement to overcome the deficiency by eliminating random distribution of abrasive particles. The result would be an abrasive tool with every abrasive particle positively planted at desired positions to achieve the maximum utility. Hence, the performance of the abrasive tool can be optimized.

By making the distribution of abrasive particles uniform or tailored to the particular applications of the tool, then the work load can be evenly distributed to each particle. As a result, the abrasive tool will cut faster and its working life be extended a considerable amount of time. Moreover, by eliminating the redundancy, less abrasive may be needed, thereby reducing the cost of the tool manufacture. Additionally, if the distribution can be controlled, abrasive tools utilizing diamond or cubic boron nitride can be configured to provide the most efficient wear profile possible.

The present invention resolves these problems and provides the advantages set forth above by providing a method for forming such tools wherein the abrasive particle distribution can be controlled to provide either uniform grit placement, or to provide grit placement which is tailored to the particular wear

characteristics of the tool. Because the distribution of the diamond particles is controlled, the particles can be disposed in patterns which provide for relatively even wear of the abrasive surface, rather than having portions of the surface wear prematurely. As each particle is more fully utilized, there is no need for redundant particles as a back up. Therefore, the cost of making the abrasive tools can be reduced by decreasing the overall amount of superabrasive which is used. For example, the cost of superabrasives (diamond or cubic boron nitride) is so high that it often accounts for about half of the total manufacturing cost of the tool. By maintaining the performance of a superabrasive tool with a substantially lower concentration used in a controlled distribution, significant cost saving may be realized due to the decreased use of the expensive abrasive.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for forming superabrasive tools, wherein the distribution of the superabrasive grit is controlled to provide improved cutting, grinding, etc., characteristics without requiring an increase in the amount of superabrasive grit used to form the tool.

It is another object of the invention to provide such a method wherein the distribution of the

superabrasive grit is controlled to promote more even wear of the abrasive surface, and thereby lengthen the useful life of the tool.

It is yet another object of the present invention to provide tools with minimal amount of superabrasive required to perform the task for which the tool is designed, thereby reducing the cost of making the tool.

The above and other objects of the invention are achieved by the use of a novel method of forming the superabrasive surface. While the distribution of the diamond or cubic boron nitride particles has always been viewed as a complex, three dimensional problem, the present invention reduces the distribution of the superabrasive to a substantially two-dimensional process that is easy to manipulate and control, and which can be repeated with a high degree of accuracy. More specifically, the desired distribution of abrasive particles in a matrix body is achieved by assembling layers of matrix material that contain a controlled, preset pattern of abrasive particles. Each layer is formed by distributing the superabrasive grit into a layer of bonding matrix in a predetermined pattern. Each layer which is assembled to form a superabrasive impregnated segment can be of the same distribution pattern and concentration, or the distribution pattern and/or concentration may vary from layer to layer.

In accordance with one aspect of the present invention, each layer is assembled by disposing a layer of matrix material so that it may be used as a precursor. The superabrasive grit is then disposed in the matrix material in a desire pattern. After the diamond particles are planted into the matrix material layer in a predetermined pattern, the process is repeated until a desired number of layers have been formed. These layers are then assembled to form the desired three-dimensional body. Subsequently, the diamond tool is consolidated (e.g., by sintering or infiltration as described above) to form the final product.

By reducing the three-dimensional problem to a two-dimensional solution through the use of the layers, the present invention can not only achieve the desirable diamond distribution pattern in the tool body, but can also provide the flexibility for possible manipulation of diamond concentration at different parts of the same tool body. Thus, for example, diamond particles can be disposed in denser concentrations in some layers than others, and the layers with the greater diamond concentrations can be disposed within the three-dimensional structure created in such a manner to prevent the uneven wear patterns that are typical in many prior art abrasive tools.

In accordance with another aspect of the present invention, each superabrasive layer is created by first forming a thin layer of bonding matrix. A template is then disposed on the bonding matrix. The template has a plurality of apertures formed therein which are sized to receive superabrasive grit of a particular size, with one particle being disposed in each aperture. As the superabrasive grit fills the apertures, it may subjected to pressure or otherwise moved into the bonding matrix. Because of the template, the superabrasive grit which enters the bonding matrix is disposed in a predetermined pattern. A plurality of such superabrasive layers can then be bonded together and attached to the tool by brazing, or some other process, to provide a three-dimensional superabrasive cutting or grinding member on the tool.

In accordance with another aspect of the present invention, the pattern in which the superabrasive grit is disposed may be uniform, or may be calculated to provide superabrasive members with particular cutting abilities. For example, the superabrasive particles may be disposed in varied concentrations to compensate for uneven wear patterns. Thus, the diamond distribution for the cutting edge of a saw may have a greater distribution of diamond particles on the lead edge and sides than on the middle portion which is generally subjected to less wear. Likewise, the sizes of the superabrasive particles can be

controlled to provide a cutting, grinding, etc., surface which is tailored to the particular purpose, such as to prevent chipping of the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings in which:

FIG. 1A shows a segment from a superabrasive tool formed by a plurality of linear, longitudinal layers disposed adjacent one another to form a three-dimensional superabrasive member;

FIG. 1B shows a cross-sectional view of one likely configuration of the tool segment shown in FIG. 1A, wherein a layer formed by a matrix material and a relatively large superabrasive is sandwiched between two layers of matrix materials which have smaller grit and higher concentration of the abrasive;

FIG. 2A shows a segment from a superabrasive tool formed by a plurality of arcuate, longitudinal layers which are attached to one another to form a three-dimensional superabrasive member;

FIG. 2B shows a cross-sectional view of a plurality of layers matrix material as may be used with the segment shown in FIG. 2A;

FIG. 3 shows another possible layout of a segment of a cutting tool with transverse layers configured with a denser concentration of abrasive material disposed, e.g., at a forward, cutting end of the three-dimensional superabrasive member;

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution toward, e.g., the upper surface of a tool with horizontal layers;

FIGs. 5A through 5D show one possible method for forming layers with controlled superabrasive distribution within the layer;

FIGs. 6A through 6C show an alternate method for forming one or more layers with controlled superabrasive distribution.

DETAILED DESCRIPTION

Reference will now be made to the drawings in which the various elements of the present invention will be given numeral designations and in which the invention will be discussed so as to enable one skilled in the art to make and use the invention. It is to be understood that the following description is only exemplary of the principles of the present invention, and should not be viewed as narrowing the pending claims.

Referring to FIG. 1A, there is shown a perspective view of a segment, generally indicated at 10, from a superabrasive tool (the remainder of which is not shown). The segment 10 is formed by a plurality of layers, 14, 16 and 18, which are impregnated with superabrasive particles, indicated by the circles 20. The plurality of layers 14, 16 and 18 are disposed adjacent to one another in a linear, longitudinal array so that the layers form the three-dimensional superabrasive segment 10.

As will be discussed in additional detail below, forming the segment 10 in a plurality of thin layers provides remarkably improved control over the distribution of the superabrasive particles. By controlling the distribution of the superabrasive particles within each layer and then combining layers, a three-dimensional segment can be formed in which distribution of the superabrasive particles is controlled in each dimension. This, in turn, enables the formation of segments which are particularly adapted to the likely use of the segment, be it for cutting, sawing, grinding, etc. By tailoring the distribution and concentration of the superabrasive particles within the segment 10, more precise control is given over performance of the tool under actual working conditions.

For example, when using a diamond saw blade to cut a rock (e.g., granite), the two sides of diamond

saw segments are cutting more materials than the center. As a result of the uneven wear, the cross section of the saw segment becomes convex in shape with the center bulging above both sides. This configuration typically slows the cutting rate of the saw blade. Moreover, the protruding profile may also cause the saw blade to deflect sideways in the cut slot. In order to maintain a straight cutting path, it is sometimes desirable to make a "sandwiched diamond segment" to reinforce both sides of the segment with layers impregnated with more superabrasive particles. Such a "sandwich segment" is difficult to manufacture by mixing diamond grit with metal powder by conventional means, but it can be easily accomplished by first planting diamond particles with desirable patterns in layered metal matrix and then assembling these layers together to form the sandwich segment.

In accordance with the present invention, a cutting segment can be formed to resist premature wear to the sides of the segment, thereby extending the cutting segment's useful life. Referring specifically to FIG. 1B, there is shown a cross-sectional view of the cutting segment 10 of FIG. 1A. Unlike the cutting segments of the prior art, the cutting segment 10 is formed of, for example, three layers, 14, 16 and 18 respectively. The middle layer 16 has a plurality of superabrasive particles 20a

which are of a first size (typically 40/50 U.S. mesh) and a first concentration (e.g. 20). The outer layers 14 and 18, in contrast, have a plurality of superabrasive particles 20b, which are of a second size (typically 50/60 mesh), smaller than the first size, and in a second concentration greater than that present in the middle layer 16 (e.g. 23). The smaller, more densely distributed superabrasive particles 20b provide the outer layers 14 and 18 with a greater resistance to wear as they cut through concrete, rock, asphalt, etc. Because the outer layers 14 and 18 are more resistant to wear, the cutting segment 10 resists formation of a convex outer surface, as has traditionally occurred with conventional tools. By maintaining a more planar cutting surface or even a concave profile, the cutting segment can maintain a straighter cutting path with a longer useful life. Moreover, by using a smaller grit on the flank of the saw, the finish of cut surface is more smooth. Furthermore, the chipping of the workpiece can be avoided.

Another advantage to the use of multiple layers of matrix with diamond or cubic boron nitride disposed therein is that the layers are easily formed into other desirable shapes for cutting, drilling, grinding, etc. For example, FIG. 2A shows a perspective view of a saw segment, generally indicate at 30, of a superabrasive tool formed by a plurality

(e.g., 3) of arcuate, longitudinal layers which are attached to one another to form a three-dimensional tool member. In this example, the segment 30 is formed from first, second and third layers, 34, 36 and 38, which are each arcuate. When the three are joined together, an arcuate segment 30 is created. Such a segment, of course, may be used on cutting tools which are non linear (e.g, circular saw blades), and on other types of tools for which a nonlinear superabrasive segment is desired. Because the layers 34, 36 and 38 are initially formed independent of one another, they are much easier to conform to a desired shape, and are able to do so while the superabrasive particles 20 disposed therein are held in their predetermined positions.

Each of the layers is impregnated with a plurality of superabrasive particles 20, typically diamond or cubic boron nitride. Because each layer is formed as a substantially two-dimensional unit (i.e., the matrix will usually be no more than two times the thickness of the diameter of the particles) superior control is provided over placement of the superabrasive particles. As discussed above, the random placement of the prior art often led to ineffective use of superabrasive particles. However, the controlled distribution of the present invention enables either even distribution designed to prevent under or over spacing, or controlled distribution so

that different portions of the segment have different sizes and concentrations which are matched to prevent traditional wear patterns.

Referring now to FIG. 2B, there is shown a cross-sectional view of a plurality of the layers 34, 36 and 38 of the segment 30. Of course, the superabrasive particle as may be used with the segment shown in FIG. 1A or that shown in FIG. 2A. Unlike the embodiment of FIG. 1B, the layers are each provided with the same size and concentration of the superabrasive particles 20. However, because the spacing is substantially uniform, there is no underspacing or overspacing between the superabrasive particles, and the segment 30 wears more evenly than the segments of the prior art with randomly spaced particles. The more even wear prevents premature failure of the segment 30, and thus extends the life of the tool while keeping the amount of superabrasive used to a minimum.

FIG. 3 shows another possible embodiment of a segment 50 made in accordance with the teachings of the present invention. The layered structure in a diamond segment may also be assembled transversely or horizontally. Thus, the segment 50 in FIG. 3 is formed from a plurality of transverse layers. A first plurality of layers, indicated at 56 are provided with a first concentration of superabrasive particles 20 (represented by four layers, that contain superabrasive particles 20 distributed within an

offset pattern). A second plurality of layers, indicated at 58, are provided with a second concentration, less than the first concentration (represented by nine layers with an offset pattern of superabrasive particles 20).

Many cutting tools are configured such that the cutting segment 50 is provided with a lead edge which performs a majority of the cutting and which receives most of the impact force when contacting the workpiece to be cut. For example, a circular saw blade will usually have a plurality of teeth (saw segments), each tooth having a leading edge which takes the force of the cutting. Because the leading edge preforms a significant portion of the cutting, it is much more susceptible to wear than are rotationally trailing portions of the tooth. When formed in accordance with the prior art, the teeth, however, often had similar concentrations of abrasive particles disposed therein. Over time the leading edge wears significantly, but the trailing layers 58 remain with minimal wear. Eventually, the abrasive of the saw tooth is worn off the leading edge, while significant amounts remain on the tail end. Thus, a considerable amount of superabrasive is wasted when the blade is discarded.

The embodiment of FIG. 3 is specifically configured to overcome such concerns. The layers 56 and 58 are configured to provide substantially even wear across the cutting segment 50 by placing a larger

percentage of the superabrasive particles 20 near the leading edge, than on rotationally distal portions. Thus, by the time the leading edge has reached the end of its useful life, the remaining portions of the cutting segment 50 have also been worn out. Such controlled distribution of the superabrasive particles 20 decreases the use of the expensive material and lowers the cost for making the cutting segment 50 without hurting performance. Additionally, by providing more even wear, the cutting segment 50 will often be able to maintain most of its cutting speed until shortly before ending its useful life.

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution toward the upper surface of a tool with horizontal layers. It is often found that the speed of cutting tends to decrease with the wear of the tool. Thus, with a reduced concentration of superabrasive particles, the tool can maintain its current cutting speed at a constant power of the machine. Thus, as with the embodiment of FIG. 3, the controlled distribution of the superabrasive particles 20 forms an improved abrasive segment 70, while at the same time decreasing the cost of abrasive tools by saving those superabrasive particles which are not needed.

With routine experimentation and the teachings of the method of the present invention, those skilled in

the art will be able to customize cutting, drilling, grinding, polishing and other types of abrasive segments which are specifically formed to maximize their performance (i.e. cutting, drilling, grinding, etc.) over an extended useful life, while simultaneously decreasing the amount of expensive superabrasive which is used to form the tool.

Referring now to FIGs. 5A through 5D, there is shown one method for forming layers in accordance with the principles of the present invention. The first step of the method is to form a sheet 100 of matrix material 104 which will be bonded to the superabrasive particles 20. The sheet 100 of matrix material 104 can be formed from conventional metal powders as discussed above, or other bonding agents which have yet to be discovered.

There are many ways that a matrix powder can be made into the sheets 100. For example, the powder can first be mixed with a suitable binder (typically organic) and a solvent that can dissolve the binder. This mixture is then blended to form a slurry with a proper viscosity. In order to prevent the powder from agglomeration during the processing, a suitable wetting agent (e.g., menhaden oil, phosphate ester) may also be added. The slurry can then be poured onto a plastic tape and pulled underneath a blade or leveling device. By adjusting the gap between the blade and the tape, the slurry can be cast into a

sheet with the right thickness. The tape casting method is a well known method for making thin sheets out of powdered materials and it works well with the method of the present invention.

Alternatively, the powder can be mixed with a suitable binder and its solvent to form a deformable cake. The cake can then be extruded through a die with a slit opening. The gap in the opening determines the thickness of the extruded plate. Alternatively, the material can also be drawn between two rollers with adjustable gap to form sheets with the right thickness.

It is desirable to make the sheets pliable for subsequent treatments (e.g., bending over a tool substrate which has a curvature). Therefore, a suitable organic plasticizer may also be added to provide the desired characteristics.

The use of organic agents for powder (metal, plastics, or ceramics) processing is documented in many text books and it is well known by those skilled in the art. Typical binders include polyvinyl alcohol (PVA), polyvinyl butyral (PVB), polyethylene glycol (PEG), paraffin, phenolic resin, wax emulsions, and acrylic resins. Typical binder solvents include methanol, ethanol, acetone, trichlorethylene, toluene, etc. Typical plasticizers are polyethylene glycol, diethyl oxalate, triethylene glycol dihydroabietate, glycerine, octyl phthalate. The organic agents so

introduced are to facilitate the fabrication of metal layers. They must be removed before the consolidation of metal powders. The binder removal process (e.g., by heating in a furnace with atmospheric control) is also well known to those skilled in the art.

Once the sheet 100 of matrix material 104 is formed, a template 110 is laid on the top of the sheet. The template 110 contains apertures 114 that are larger than one abrasive particle 20, but smaller than two abrasive particles, thereby allowing a single particle of the abrasive to be disposed at each specific location.

In this example, the thickness of the template is preferably between 1/3 to 2/3 of the height of the average abrasive particle 20. However, other thicknesses may be used if appropriate accommodations are made for seating the abrasive particles in the desired locations.

After the template 110 is properly positioned, a layer of abrasive particles 20 is then spread over the template so that each aperture 114 receives an abrasive particle. Those particles not falling into the apertures 114 in the template 110 are removed by tilting the substrate, sweeping the template with a broom, or some other similar method.

As shown in FIG. 5B, a generally flat surface 120, such as a steel plate) is then laid over the particles 20 which rest in the apertures 114 in the

template 110. The flat surface 120 presses the abrasive particles 20 at least partially into the pliable sheet 100 of matrix material 104 to seat the particles.

After removing the template 110, the flat surface 120 is used again to press the abrasive particles 120 firmly into the sheet 100 of matrix material 104 as shown in FIG. 5C. While the flat surface 120 is preferable, those skilled in the art will appreciate that there may be occasions when it is desirable to have abrasive particles protruding above the metal sheet 100 with equal height. Alternatively, some of the abrasive particles 20 may be wanted to extend outwardly from the sheet 100 of matrix material more than that of other abrasive particles. In such situations, a contoured or otherwise shaped surface could be used to seat some of the abrasive particles 20 deeper into the sheet 100 of matrix material 104, than other particles.

If desired, the process shown in FIGs. 5A through 5C can be repeated on the other side of the sheet 100 of matrix material 104 (as shown in FIG. 5D), to form an impregnated layer having abrasive particles 20 distributed throughout the layer in some predetermined, desired pattern. The process is typically repeated several times to obtain multiple thin layers or sheets 100 which are impregnated with the abrasive particles 20. Of course, each sheet 100

needs not have the same distribution pattern for the abrasive particles 20, nor does it need the concentration of the abrasive particles be the same.

The abrasive impregnated sheets 100 are next cut to any desired size and shape. The sheets 100 are then assembled to form the tool segment or the entire tool body where appropriate. Typically, the assembly of the sheets 100 is accomplished by a known method such as cold compaction with a press. The "green" body so formed can then be consolidated to form a final tool product by conventional method of sintering or infiltration as described by following the examples.

While the method described in FIGs. 5A through 5D is preferred for many applications, there are instances where it is desirable to have the abrasive particles 20 extend outwardly from the sheet 100 of matrix material. For example, some tools may only have one layer of abrasive. This can be accomplished simply by leaving the template 110 in place when performing the steps shown in FIG. 5A and 5B, and not further pressing the particles 20 into the matrix material once the template has been removed.

In the alternative, FIGs. 6A through 6C show a side view of an alternate to the method discussed in FIGs. 5A through 5D. The sheet 130 of matrix material in FIGs. 6A through 6C is thinner than the height of the superabrasive particles 20. Thus, in this

procedure, when the particles are pressed into the sheet 130, the particles 20 would protrude above the matrix material 134.

Although the present invention is intended for making three-dimensional abrasive tools, the teachings contained in the present application can readily be applied to two-dimensional tools as well. For example, U.S. Patent Nos. 3,894,673 and 4,108,576 describe certain brazed diamond tools that contain a single layer of diamond particles. These particles are brazed onto a tool shank by a chromium containing alloy. Such diamond tools are widely marketed (e.g., by Abrasives Technology of U.S.A.) for cutting and grinding non-ferrous materials (e.g., stones or glass).

However, the distribution of diamond particles on these tools are typically random and non-uniform. The methods illustrated in FIGs. 5A through 6C can readily be applied to such tools to improve the diamond distribution. In this case, the method offers several advantages over the conventional technology as described by these patents. For example, by making diamond particles distributed in a desirable pattern, the load of cutting can be evenly distributed to all diamond particles. As a result, the tool can cut faster with a longer life.

The performance may be further improved by having a braze layer of uniform thickness. This uniformity

can allow a better diamond retention and easier debris removal. Moreover, by fully utilizing each diamond particle for cutting, the concentration of diamond can be reduced. As discussed, diamond cost often accounts for about half of the total manufacturing cost of a diamond tool. Hence, by practicing this invention, manufacturing cost can be reduced substantially.

Also shown in FIG. 6A through 6C is the principle that the spacings of the apertures in the template 130 need not be uniform. Rather, variations in spacing can be provided to facilitate different concentrations on various portions of the sheet 130 of matrix material 134. Likewise, by controlling the size of the apertures 138 and the order in which the diamond particles are placed in the apertures, a single layer could be provided with particles of different sizes.

In addition to being able to improve the performance of the tool and to reduce the cost of the manufacturing, this invention also provides a easier method for making thin bladed tools. For example, the electronic industry requires using larger and larger silicon wafers (now 12 inches in diameter). Hence, thinner saw blades for slicing silicon crystals with lower kurf loss, and thinner dicing wheels for grooving silicon chips with tighter partitions have been in demand.

Prior to the present invention, it has been extremely difficult to make very thin tools that

contain evenly distributed diamond particles. The present invention provides an alternative method for making such tools. For example, it has been discovered that by mixing micron powders of diamond, a blend of metal powders (e.g., bronze and cobalt) and a suitable binder, the material can be rolled to a thickness thinner than 0.1 mm. By firing this thin sheet and mounting it on a tool holder, a thin dicing wheel can be made.

In the alternative to the above, it has been found in accordance with the present invention that some of the advantages of the controlled distribution, multilayered superabrasive configurations described above can be achieved without the use of a template. More specifically, the abrasive particles can also be mixed in with the matrix powder and made as an ingredient of the layered sheet. In this case, the distributions of abrasive particles are still somewhat random. Even so, their distribution is typically more uniform than that in a conventional abrasive body. The segregation of abrasive particles and matrix powders discussed in the background section is less extensive in a substantially two-dimensional sheet than in a three-dimensional body. This is particularly true for sheets made by a deforming process (e.g., by rolling). In this case, abrasive particles are further spread out in the matrix by the shearing action of the rollers.

This invention may also be applicable to other applications not related to making abrasive tools. For example, graphite or metal sheets planted with diamond particles may be used as seeds for diamond growth under high pressure and temperature. Industrial diamonds are typically produced by compressing alternative layers of graphite and metal catalyst (e.g., Fe, Co, or Ni alloy) to high pressure and heated above the melting point of the catalyst. Diamond will then nucleate randomly on the interface of these layers. The quality of the diamond crystal formed often suffers by the impingement of growing crystals that are distributed unevenly. Hence, the yield and cost of diamond synthesis can be substantially improved by making the nuclei distributed uniformly. This invention can provide layers of either graphite or metal catalyst with a pre-determined pattern of diamond seeds. If organic binders are introduced during the fabrication of these layers, they can be removed by heating in a furnace before loading into the press.

Example 1

40/50 mesh diamond grit (SDA-85^{+} made by De Beers Company) were mixed with metal powder to form a mixture with diamond concentration of 20 (5% of total volume). Five different proportion of cobalt (about 1.5 micrometer in size) and bronze (about 20

micrometers in size) were used for the matrix powder. An acrylic binder was added (8% by weight) to the mixture and the charge was blended to form a cake. The cake was then rolled between two stainless steel rollers to form sheets with a thickness of 1 mm. These sheets were cut in the shape of saw segments with a length of 40 mm and width of 15 mm. Three each of such segments were assembled and placed into a typical graphite mold for making conventional diamond saw segments. The assembled segments were pressed and heated by passing electric current through the graphite mold. After sintering for three minutes, the segments were consolidated to a height of 9 mm with less than 1% porosity. Twenty-four segments for each composition were fabricated. They were brazed onto a circular saw of 14 inches in diameter. These five blades were used for cutting granites and found to perform equal or better than those with higher diamond concentrations (e.g. 23) made by conventional methods. Microscopic examination of the worn segment indicated that although diamond particles were not planted into the layered matrix, they were distributed more evenly than segments prepared by the traditional method. The segregation of particles in layered matrix was considerably less than that in a thick body of conventional segments.

Example 2

The same procedures were followed as Example 1, but with 8 thinner layers (0.4 mm) for each segment. The diamond concentration was reduced to 15 and particles were planted according to the illustration as shown in FIGs. 5A through 5D. The diamond distribution was much improved. As a result, the performance of these blades were equal or better than those made by conventional methods with diamond concentration of 20.

Example 3

Iron powders of about 100 mesh were mixed with an S-binder made by Wall Colmonoy Company to form a cake. The cake was then rolled to form sheets of 0.4 mm in thickness. 40/50 mesh SDA-100^{+} diamond grit was planted into these sheets to attain a concentration of 15. These diamond containing sheets were cut in the shape of saw segments with a length of 40 mm and width of 9 mm. Eight of such segments were assembled as a group and placed in a graphite mold. Twenty-four groups were placed horizontally, and another twenty-four groups were placed vertically in the graphite mold. Nicrobraz LM powder (-140 mesh) (made by Wall Colmonoy Company) was added on the top of these segments. These samples were heated in a vacuum furnace (10^{-5} torr) to 1050 °C for 20 minutes for horizontally placed segments, and 30 minutes for

vertically placed segments. The melted LM alloy (Ni-Cr-B-Si with a liquidus point at 1000 °C) infiltrated into these segments and filled the porosity. The excess LM braze on these segments were ground by electrode discharge (EDG). Each of the 24 segments so fabricated were brazed onto a 14 inch (diameter) circular saw blade. These blades were used to cut granite and showed marked improvement over conventional saw blades.

Example 4

Nicrobraz LM powder was mixed with an acrylic binder and rolled to form layers of about 0.25 mm. 40/50 mesh MBS-960 diamond grit manufactured by General Electric Company was planted into these metal layers according to the method as illustrated in Figure 5. These diamond planted metal layers were cut in proper size and wrapped around 2,000 beads (pearls) of wire saw. The beads preferably have a taper angle between 3 and 5 degrees. These beads (10 mm in diameter by 10 mm long) were divided into two groups, one contains 280 crystals (about 0.2 carat) per bead; and the other, 400 crystals (about 0.3 carat). These beads were heated in a vacuum furnace to a temperature of 1,000 °C for 8 minutes. These beads were mounted on several wire saws and used to cut marble, serpentine and granite. The performance of these beads was found to be superior to conventional beads.

The latter beads were typically made by either hot pressing or electroplating. These conventional beads may contain a much higher amount of diamond (up to 1 carat) per bead.

Example 5

The same method as described by Example 4, but applied to other products, e.g., circular saws, thin-wall core bits, and curvature grounder. Each of these products shows superior performance over conventional electro-plated diamond tools having a similar or higher superabrasive concentrations.

The above description and examples are intended only to illustrate certain potential uses of this invention. It will be readily understood by those persons skilled in the art that the present invention is susceptible of a broad utility and applications. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements will be apparent from or reasonably suggested by the present invention and the forgoing description thereof without departing from the substance for scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to its preferred embodiment, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for the purpose

of providing a full and enabling disclosure of the invention. The forgoing disclosure is not intended to be construed to limit the present invention or otherwise to exclude any such other embodiment, adaptations, variations, modifications and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

CLAIMS

What is claimed is:

1. An abrasive tool having an abrasive impregnated segment comprising:

a matrix material configured for bonding abrasive particles; and

a plurality of abrasive particles distributed in the matrix material in a predetermined pattern.

2. The abrasive tool according to claim 1, wherein the plurality of abrasive particles are selected from the group consisting essentially of diamond, cubic boron nitride, alumina and silicon carbide.

3. The abrasive tool according to claim 1, wherein the abrasive impregnated segment is formed by a plurality of matrix material layers, each layer being impregnated with abrasive particles, and wherein the plurality of layers are disposed adjacent one another.

4. The abrasive tool according to claim 3, wherein the abrasive particles in one of the layers are larger than the abrasive particles in at least one of the other layers.

5. The abrasive tool according to claim 4, wherein the plurality of layers includes at least one outer layer and at least one inner layer, and wherein the abrasive particles of the at least one inner layer

are larger than the abrasive particles of the at least one outer layer.

6. The abrasive tool according to claim 5, wherein the abrasive segment is configured with two outer layers and at least one inner layer disposed between the outer layers, wherein each of the outer layers and the at least one inner layer has abrasive particles disposed therein, and wherein the abrasive particles disposed in the at least one inner layer are larger than those disposed in the outer layers.

7. The abrasive tool according to claim 3, wherein at least one of the layers has a greater concentration of abrasive particles than at least one of the other layers.

8. The abrasive tool according to claim 7, wherein the plurality of layers includes at least one outer layer and at least one inner layer, and wherein the at least one outer layer has a greater concentration of abrasive particles than the at least one inner layer.

9. The abrasive tool according to claim 8, wherein the abrasive segment is configured with two outer layers and at least one inner layer disposed between the outer layers, wherein each of the outer layers and the at least one inner layer has abrasive particles disposed therein, and wherein the abrasive particles disposed in the outer layers are disposed in

greater concentration than the abrasive particles in the at least one inner layer.

10. The abrasive tool according to claim 7, wherein the plurality of layers includes at least one first layer having a first concentration of abrasive particles, at least one second layer having a second concentration less than the first concentration, and at least one third layer having a third concentration less than the second concentration.

11. The abrasive tool according to claim 7, wherein the
abrasive impregnated segment has a leading edge configured to initially impact a surface to be cut, wherein the segment is formed by a plurality of layers and wherein the layers adjacent the leading edge having a higher concentration of abrasive particles than layers remote from the leading edge.

12. The abrasive tool according to claim 1, wherein the
abrasive particles are distributed in a uniform pattern throughout the impregnated segment.

13. The abrasive tool according to claim 12, wherein the abrasive particles are uniformly distributed throughout the tool.

14. The abrasive tool according to claim 1, wherein the tool has abrasive particles distributed therethrough, and wherein the tool has an outer

portion having a higher concentration of abrasive particles disposed therein.

15. The abrasive tool according to claim 1, wherein the segment has an impacting surface formed thereon and wherein the abrasive particles are distributed in higher concentration adjacent the impacting surface.

16. The abrasive tool according to claim 1, wherein the segment is formed by a plurality of two-dimensional layers assembled together to form a three-dimensional segment.

17. An abrasive tool comprising a plurality of layers formed from a matrix material for holding abrasive particles, and a plurality of abrasive particles distributed in the layers of matrix material, the layers being attached to one another to form a three-dimensional tool abrasive segment.

18. The abrasive tool of claim 17, wherein at least one of the layers is 1 millimeter thick or less.

19. The abrasive tool of claim 17, wherein the layers have been consolidated together by a method selected from the group consisting of brazing, sintering or infiltration.

20. The abrasive tool of claim 17, wherein the abrasive particles are distributed within the layers in predetermined patterns.

21. The abrasive tool of claim 20, wherein the distribution of the abrasive particles if uniform in at least one of the layers.

22. An abrasive tool comprising at least one layer of matrix material with abrasive particles formed therein, the layer being 1 millimeter or less in thickness and formed by rolling the matrix material and abrasive particles between rollers to improve uniformity in the distribution of the abrasive particles.

23. A method for forming an abrasive tool body, the method comprising:

(a) forming a sheet of matrix material configured for bonding to abrasive particles; and

(b) disposing a plurality of abrasive particles in the sheet of matrix material in a predetermined pattern.

24. The method according to claim 23, wherein the method comprises, more specifically, placing a template with a plurality of apertures formed therein on the sheet of matrix material prior to disposition of the plurality of abrasive particles so that placement of the abrasive particles is controlled by the position of the apertures, thereby selectively limiting placement of the abrasive particles in the sheet of matrix material to the positions of the apertures.

25. The method according to claim 24, wherein the method comprises, more specifically, using a template formed from a sieve.

26. The method according to claim 24, wherein the template is formed by a plate having a plurality of apertures formed therein, the apertures being configured in a predetermined pattern.

27. The method according to claim 26, wherein each aperture has a diameter which is greater than a diameter of the abrasive particles to be positioned thereby, but less than twice the diameter of the abrasive particles.

28. The method according to claim 23, wherein the method comprises, more specifically, forming the sheet of matrix material by tape casting.

29. The method according to claim 23, wherein the method comprises, more specifically, forming the sheet of matrix material by rolling.

30. The method according to claim 23, wherein the method comprises, more specifically, forming the sheet of matrix material by extrusion.

31. The method according to claim 23, wherein the method comprises, more specifically, forming a plurality of layers of matrix material having abrasive particles disposed therein, and attaching the layers together to form a three-dimensional abrasive segment.

32. A method for forming a layer of abrasive impregnated matrix material having improved abrasive distribution, the method comprising:

(a) forming a layer having a mixture of matrix material and abrasive particles; and

(b) rolling the layer of mixture to form a layer no greater than 1 millimeter thick.

33. A method of making layers catalyst for diamond synthesis, the method comprising:

(a) forming at least one layer of a catalyst; and

(b) planting a plurality of diamond particles in the catalyst in a predetermined pattern.

34. The method according to claim 33, therein the method further comprises disposing organic binders in the catalyst prior to planting the plurality of diamond particles, and removing the heating in a furnace before pressing the catalyst and diamond particles.

35. A method of making a source material for diamond synthesis, the method comprising:

(a) providing a layer of graphite; and

(b) planting a plurality of diamond particles in the layer of graphite in a predetermined pattern.

36. The abrasive tool according to claim 1, wherein the abrasive impregnated segment is formed by at least one layer of matrix material.

37. The abrasive tool according to claim 36, wherein the at least one layer of matrix material contains at least one layer of abrasive particles.

38. The abrasive tool according to claim 37, wherein the tool is a wire saw that it at least partially surrounded by the matrix material that contains the abrasive particles.

39. The abrasive tool according to claim 38, wherein the tool is a wire saw that contains diamond beads overcoated with diamond.

40. The abrasive tool according to claim 39, wherein the diamond bead has a taper angle of 3 to 5 degrees.

41. The abrasive tool according to claim 36, wherein the matrix material is consolidated by a method selected from the group consisting of brazing, sintering and infiltration.

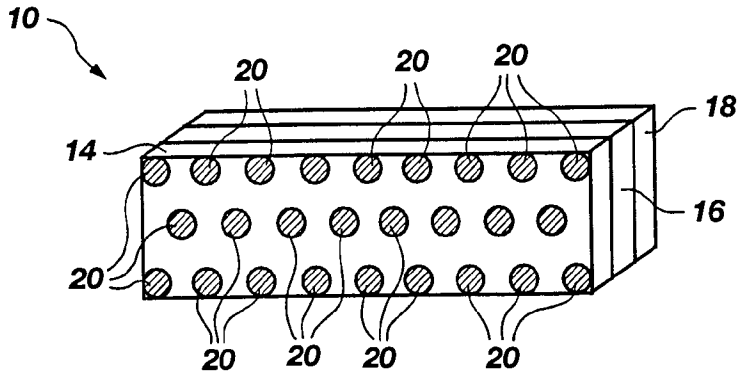


Fig. 1A

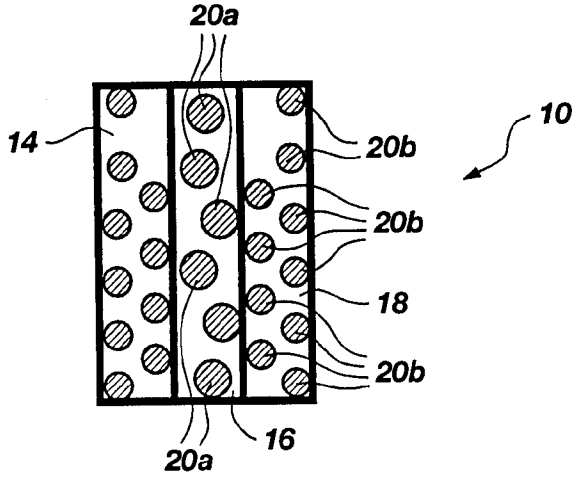


Fig. 1B

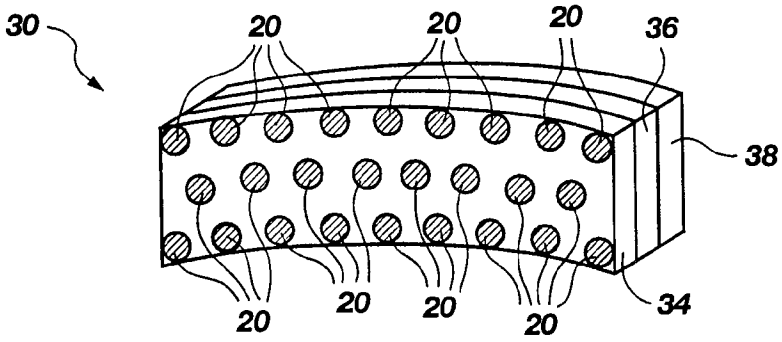


Fig. 2A

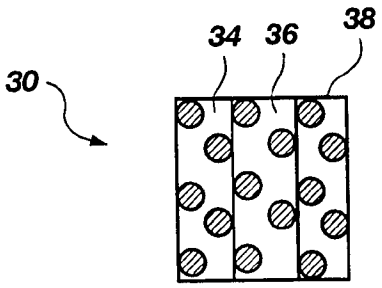


Fig. 2B

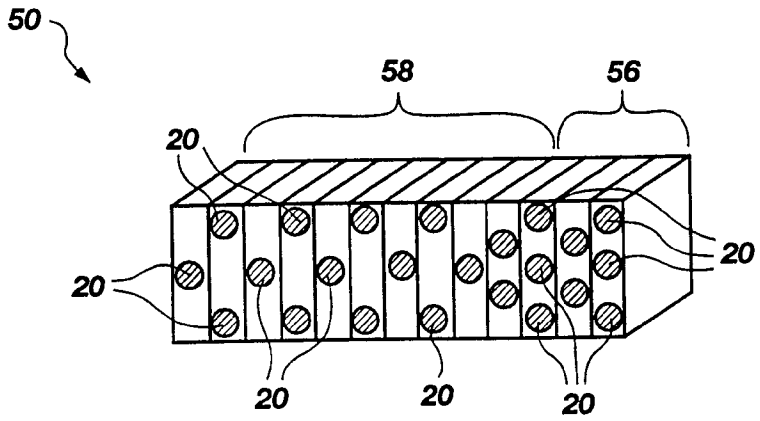


Fig. 3

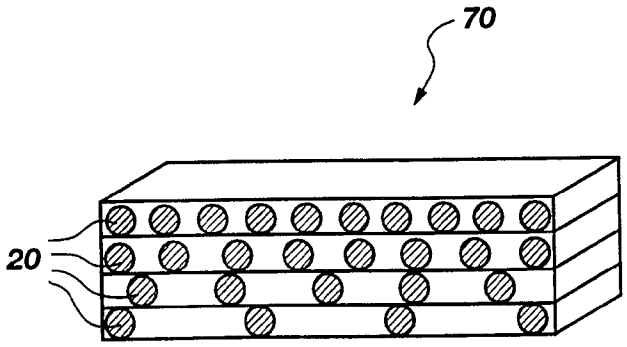


Fig. 4

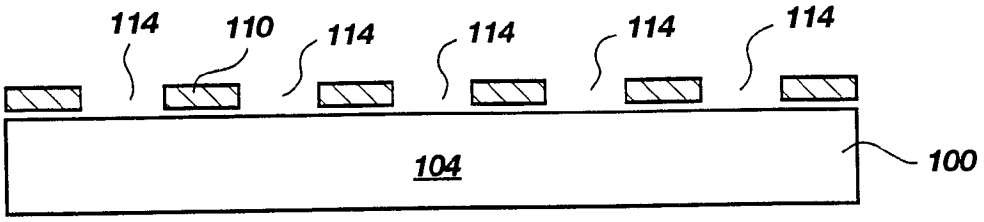


Fig. 5A

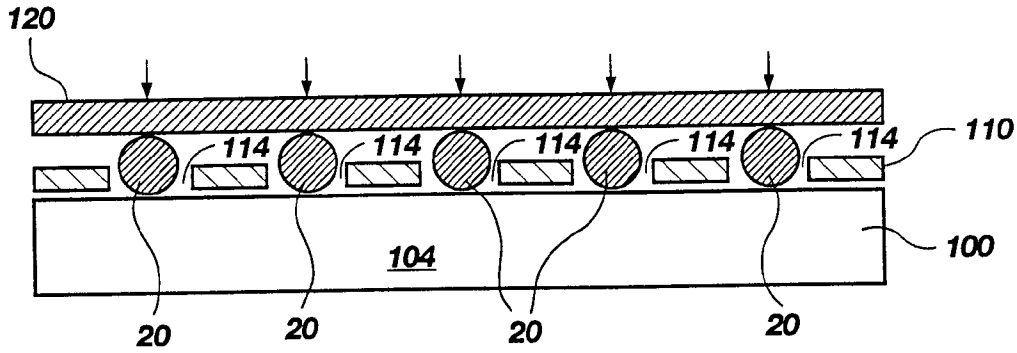


Fig. 5B

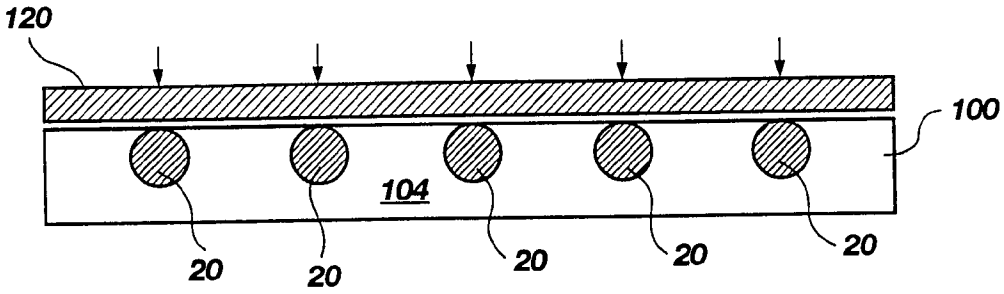


Fig. 5C

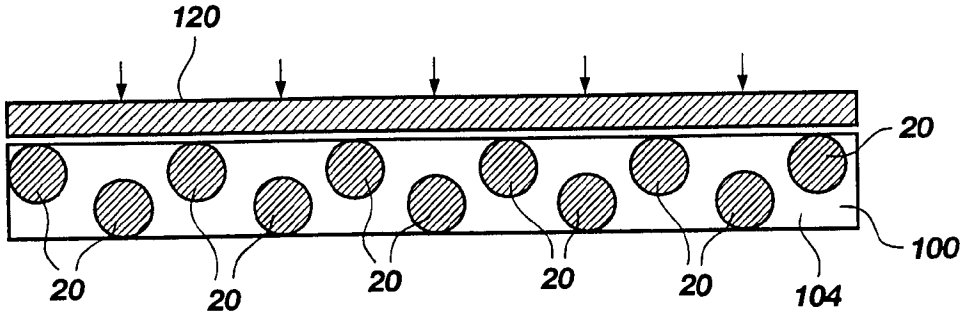


Fig. 5D

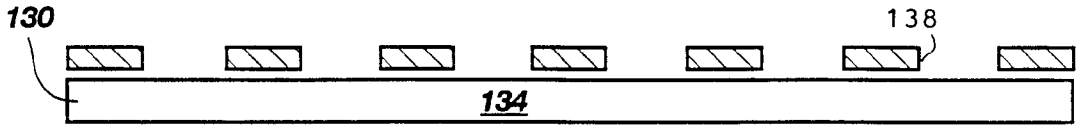


Fig. 6A

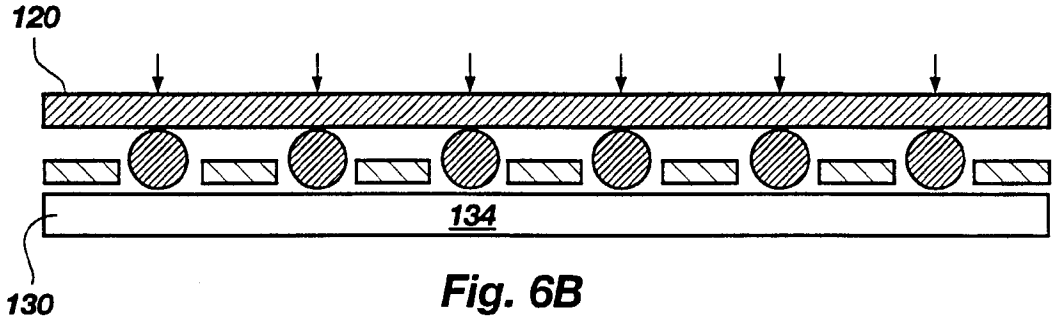


Fig. 6B

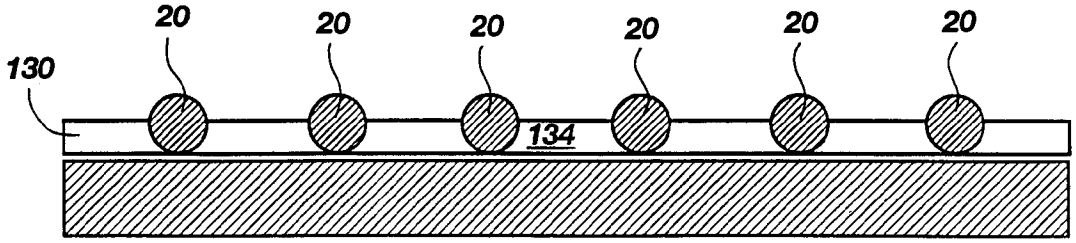


Fig. 6C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/05951

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B24D 11/00
US CL :451/540

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 451/527,529,533,540; 51/297; 125/16.02,21,22

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, 2,725,693 A (SMITH) 06 December 1955	1-41
Y	US, 2,952,951 A (SIMPSON) 20 September 1960, see entire document, specifically figure 2	1-41
Y	US, 3,146,560 A (HURST) 01 September 1964, see entire document.	1-41
Y	US 4,712,552 A (PANGBURN) 15 December 1987, see entire document, specifically figures 9 and 10.	1-41
A	US, 4,866,888 A (MURAI et al) 19 September 1989.	1-41
A	US 5,176,155 A (RUDOLPH, JR.) 05 January 1993.	1-41.

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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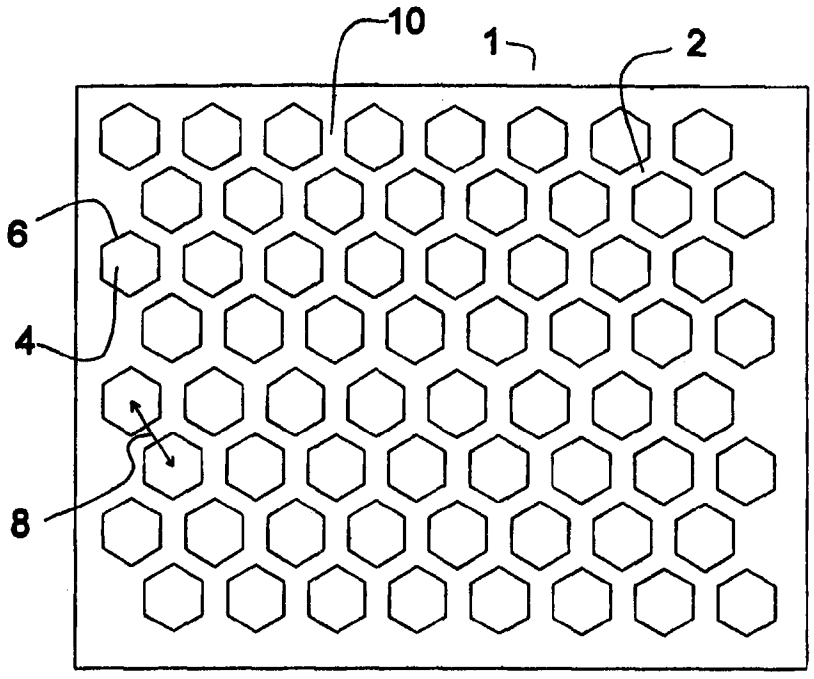
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(54) **Title:** PATTERNED ABRASIVE TOOLS

(57) **Abstract**

A method of making a metal bonded, abrasive tool uses a perforated stencil to place abrasive parcels in a pattern on the cutting surface of the tool. The stencil is placed against the tool preform so that the perforations define cavities. Metal brazing composition in the form of a paste is packed into the cavities and the stencil is removed to leave discrete parcels of brazing paste tacked to the cutting surface. Abrasive grains are deposited onto the paste particles and fixed in place by firing the preform at brazing conditions. The abrasive grains thus are precisely positioned and spaced apart on the cutting surface by abrasive free channels which are defined by the web of the stencil. The abrasive free channels provide paths to facilitate flow of coolant material and swarf particles at the cutting zone. The method can include initially placing the brazing paste parcels onto a resilient, transfer medium and subsequently transferring the parcels onto the preform cutting surface. This method is particularly useful for depositing an abrasive pattern on a non–planar or highly curved tool surface. In another contemplated variation of the invention, the abrasive grains are premixed with the brazing paste prior to filling the cavities.



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Patterned Abrasive Tools

This invention relates to the manufacture of abrasive tools. More specifically, it relates to making tools with abrasive grains disposed in discrete parcels separated from neighboring parcels on the cutting surface by open channels. The invention further relates to self-sharpening abrasive tools in which the abrasive parcels are formed from multiple, ultrafine abrasive grains embedded therein.

In certain abrasive tools for industrial applications abrasive grains are affixed to a metal preform. The grains are attached to the preform by brazing a metal bonding composition at temperatures above about 600°C.

Removing swarf from the cutting zone during grinding improves performance. Among other things, swarf removal reduces wear of the brazed bonding composition and premature dulling of the abrasive grains. Cooling the work piece is another way abrasive tool users obtain improved grinding performance. Often cooling is accomplished by bathing the work piece in a cool, liquid lubricant. By providing open spaces on the abrasive tool, manufacturers can enhance swarf removal and cooling efficiency. These open spaces provide paths for swarf to leave the cutting zone and conduct coolant to and from the work piece.

A typical method of creating swarf removal and coolant spaces involves cutting grooves or drilling holes through the preform. This technique is widely used in abrasive wheel manufacture. In segmented abrasive tool fabrication, channels can be created by placing gaps between abrasive segments. Normally, such segments are molded from mixtures of abrasive grains and bonding composition and then attached as units to the tool. These methods add to the complexity of the manufacturing operation, are time consuming, and add to product cost.

It is desirable to provide an efficient method of making an abrasive tool with swarf removal and cooling space. Some methods for placing abrasive grains in discrete locations separated by open space on an abrasive tool have been suggested.

U.S. 5,389,119 (Ferronato et al.) discloses a method of making a nonwoven fabric with discrete islands of abrasive bound to a porous fabric layer. The islands are created by

masking portions of a conductive fabric layer and electro-depositing or electroplating a metal structure which contains abrasive material in isolated, unmasked spots.

U.S. 4,826,508 (Schwartz et al.) teaches a method of forming a flexible abrasive member which includes applying a flexible mask of non-electrically conductive material having a multitude of discrete openings therein to one side of a flexible fabric, placing the fabric with the mask applied in a metal deposition bath, and depositing metal directly in the discrete openings in the presence of particulate abrasive material such that the metal adheres directly to the fabric and the abrasive material becomes embedded in the metal deposits.

U.S. 4,047,902 (Wiand) discloses a method of manufacturing a metal-plated abrasive product which entails providing a conductive or metallic backing member, masking off predetermined desired surface portions thereof to leave exposed, spaced-apart portions on the backing, and bonding abrasive grit particles to the exposed portions. The bonding is carried out by a metal plating process.

U.S. 4,863,573 (Moore et al.) teaches a method of making an abrasive article by screen printing a non-conductive mesh with non-electrically conductive ink. The mesh is passed through an electroplating bath while in contact with an electrically conductive cylinder or metal band. A first, nearly complete thickness of metal is electrodeposited onto the non-printed areas of the mesh. Then abrasive particles are deposited on the metal and a second, outer layer of metal is electrodeposited onto the first thickness of metal. The abrasive particles thus are captured by the outer layer of metal and lie at the surface of the metal.

U.S. 4,874,478 (Ishak et al.) provides a method of making an abrasive member comprising attaching a metal film to one surface of a flexible sheet, applying a mask of plating resistant material having a multitude of discrete openings to the exposed surface of the film and depositing metal directly through the openings into the metal film in the presence of particulate abrasive so that the metal adheres to the film and embeds the abrasive in the metal deposits.

Each of the foregoing references relates to manufacture of flexible abrasive fabric or film. Although these abrasive articles might be laminated to supporting substrates to form coated abrasive products, they generally cannot be used by themselves in many industrial grinding applications. Fabric or film-borne abrasive tools will not hold up in aggressive

grinding of construction materials, such as steel and concrete. Additionally, each referenced method employs electro-deposition or electroplating to attach the abrasive to the fabric. Such methods of attachment do not usually provide sufficient thickness of bond material to endure in demanding, industrial grinding applications.

Other approaches to incorporating open space in an abrasive matrix have been disclosed. U.S. 4,882,878 (Benner) describes a grinding wheel having a rigid, continuous abrasive-bearing matrix. The matrix has a plurality of spaced apertures extending into the wheel from the grinding surface. Preferably the matrix is of an organic binding material.

International Patent Application WO 96/26811 (Ferronato) discloses a flexible abrasive member having a backing layer on one side and deposits of abrasive particles and bonding material on the other side. The article further includes a permanent one way mold substantially encircling the deposits and extending along at least part of the height of the deposits. The deposits are placed in holes of the flexible abrasive member.

U.S. 5,152,917 (Pieper et al.) teaches the method of making a structured, coated abrasive article comprising a backing bearing a plurality of abrasive composites having precise shape and disposed in a non-random array. The method includes introducing a slurry of binder precursor and abrasive grains into cavities on the outer surface of a production tool. A backing is placed over the outer surface such that the slurry wets one major surface of the backing to form an intermediate article. The binder precursor is then cured before the intermediate article departs from the outer surface of the production tool. The binder precursor is a quick setting, curable or thermoplastic organic resin.

The prior art does not satisfy the need for a metal preform abrasive tool for aggressive grinding applications in which discretely spaced apart abrasive elements are strongly attached to the preform with a brazeable metal bonding composition. Accordingly, there is provided a process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a cutting surface on the abrasive tool with the stencil whereby the perforations define cavities adjacent the cutting surface;

(C) providing a brazing paste including a metal braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form parcels of brazing paste on the cutting surface, each parcel being separated from neighboring parcels by paste-free channels;

(F) depositing abrasive grains onto the parcels; and

(G) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

In another aspect, the present invention provides a process for making a metal preform abrasive tool in which selectively shaped and spaced apart parcels of brazing paste are first formed on a transfer medium. The brazing paste parcels are then transferred to the cutting surface of a metal preform where abrasive grains are added and brazing is accomplished. This method facilitates the manufacture of oddly-shaped and curved cutting surface abrasive tools. There is thus provided a process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a transfer medium with the stencil whereby the perforations define cavities adjacent the transfer medium;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form a patterned face of parcels of brazing paste on the transfer medium, each parcel being separated from neighboring parcels by paste-free channels;

(F) forcing the patterned face against a cutting surface of the abrasive tool;

(G) peeling the transfer medium away to leave the parcels on the cutting surface;

(H) depositing abrasive grains onto the parcels; and

(I) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of a mask for creating a stencil useful in the practice of the present invention.

DETAILED DESCRIPTION

The present invention is useful for fabricating abrasive tools in which abrasive grains are metal-bonded onto metal, primarily ferrous metal, preforms. The method can be used with a diverse variety of preform shapes. Representative preforms include flat disks, drill bit cores, abrasive wheel rims, saw blades and many specialty tool bodies, such as spherical, conical, and frustoconical-shaped preforms. The abrasive tools made according to this invention thus will be rugged and suitable for demanding industrial and construction material grinding and cutting applications.

The abrasive grains will be of a substance that is harder than the substance being cut. Very hard abrasive substances generally known as superabrasives, such as diamond, cubic boron nitride and mixtures of them can be used. Among these, diamond is preferred, primarily for cutting nonferrous materials. Many non-superabrasive substances also can be employed. Representative non-superabrasives which can be used in this invention include aluminum oxide, silicon carbide, tungsten carbide, and the like. Aluminum oxide encompasses standard alumina abrasive as well as seeded and unseeded sol-gel microcrystalline alumina, described in greater detail, below.

A preferred non-superabrasive is a microcrystalline alumina. Also preferred are the sol-gel alumina filamentary abrasive particles described in U.S. Pat. Nos. 5,194,072 and 5,201,916, incorporated herein by reference. "Microcrystalline alumina" means sintered sol-gel alumina in which the crystals of alpha alumina are of a basically uniform size which is generally smaller than about 10 μm, and more preferably less than about 5 μm, and most preferably less than about 1 μm in diameter. Crystals are areas of essentially uniform crystallographic orientation separated from contiguous crystals by high angle grain
boundaries.

Sol-gel alumina abrasives are conventionally produced by drying a sol or gel of an alpha alumina precursor which is usually but not essentially, boehmite; forming the dried gel into particles of the desired size and shape; then firing the pieces to a temperature sufficiently high to convert them to the alpha alumina form. Simple sol-gel processes for making grain suitable for use in accordance with the present invention are described, for example, in U.S. Patent Nos. 4,314,827; 4,518,397 and 5,132,789 ; and British Patent Application 2,099,012, the disclosures of which are incorporated herein by reference.

In one form of sol-gel process, the alpha alumina precursor is "seeded" with a material having the same crystal structure as, and lattice parameters as close as possible to, those of alpha alumina itself. The "seed" is added in as finely divided form as possible and is dispersed uniformly throughout the sol or gel. It can be added *ab initio* or it can be formed *in situ*. The function of the seed is to cause the transformation to the alpha form to occur uniformly throughout the precursor at a much lower temperature than is needed in the absence of the seed. This process produces a crystalline structure in which the individual crystals of alpha alumina are very uniform in size and are essentially all sub-micron in diameter. Suitable seeds include alpha alumina itself but also other compounds such as alpha ferric oxide, chromium suboxide, nickel titanate and a plurality of other compounds that have lattice parameters sufficiently similar to those of alpha alumina to be effective to cause the generation of alpha alumina from a precursor at a temperature below that at which the conversion normally occurs in the absence of such seed. Examples of such seeded sol-gel processes are described in U.S. Patent Nos. 4,623,364; 4,744,802; 4,788,167; 4,881,971; 4,954,462; 4,964,883; 5,192,339; 5,215,551; 5,219,806; and 5,453,104, the disclosures of which are incorporated herein by reference, and many others.

Preferably the abrasive grains are attached to the metal preform by a bond containing metal. The bond is formed from a metal braze composition which is thermally treated according to a conventional, high temperature brazing process. Metal braze compositions for uniting abrasive to a metal tool preform are well known. Illustrative metal braze compositions include silver, nickel, zinc, lead, copper, tin and mixtures of these metals alloyed with other metals, such as phosphorous, cadmium, vanadium and the like. Generally minor amounts of additional components can be included in the braze composition to modify the properties of the bond during and after brazing, such as to modify melting temperature, melt viscosity, abrasive surface wetting and bond strength. Copper/tin bronze-based alloys are preferred for bonding abrasives, especially superabrasives to metal. Certain so-called "active metals" or "reactive metals" including titanium, tantalum, chromium,
and zirconium, for example, can be added to the braze composition particularly for bonding diamond. These metals react with the carbon to form carbides and thereby improve the wetting of the braze composition on the superabrasive particle. Hybrid bond

material such as a metal filled resinoid braze composition containing a major fraction of metal can also be used with the present invention.

Brazing is performed at elevated temperatures selected with consideration to numerous system parameters such as solidus-liquidus temperature range of the metal brazing composition, geometry and material of construction of the preform and physical properties of the abrasive. For example, diamond can graphitize at temperatures above about 1000°C in air and above about 1200°C under vacuum or inert atmosphere. Hence, it is often desirable to braze at the lowest possible temperatures. The metal brazing composition should be selected to braze preferably at about 800-1025°C, and more preferably, at about 850-950°C.

The metal braze composition is usually employed in fine particulate form. The components of the metal braze composition can be present as prealloyed particles, as a mixture of separate component powders or a combination of both forms. The metal braze composition can be conveniently delivered to the braze site in paste form by mixing a liquid binder with the dry particulate components. The liquid binder facilitates blending of the dry particulate components to uniform composition and provides a vehicle for dispensing precise amounts of metal braze composition.

The liquid binder should be sufficiently volatile to evaporate or pyrolize below the melting temperature of the metal braze composition so as not to interfere with the formation of a secure bond between abrasive and preform. However, the volatility should not be so great that the paste dries too quickly. The paste should remain fluid for a reasonable time to permit assembly of the abrasive tool. Preferably, the paste should be fluid for at least several minutes and up to about an hour at ambient temperature and humidity conditions. Liquid binders are well known in the industry. Representative paste-forming binders suitable for use in the present invention include Braz™-Binder Gel from Vitta Company; "S" binder from Wall Colmonoy Corporation, Madison Heights, Michigan; and Cusil-ABA, Cusin-ABA, and Incusil-ABA pastes from Wesgo, Belmont, California. Active metal braze composition pastes including binder premixed with metal braze composition components can be obtained from Lucas-Millane Company, Cudahy, Wisconsin under the Lucanex ™ tradename, such as Lucanex 721.

The present invention uses a stencil to place abrasive parcels in a pattern on the abrasive tool. Generally, the stencil is a flat sheet structure. The sheet can be flexible

which permits it to conform to a curved cutting surface and to be rolled up for storage or for deployment in an endless belt configuration.

The stencil material should be capable of being perforated with a plurality of precisely positioned, selectively shaped holes. Perforating can be done by any well known technique, such as stamping with a die, photoetching, drilling and cutting. Stainless steel sheet can be reused repeatedly, is wear resistant, is generally not affected by a wide range of chemicals, and therefore, is a preferred stencil material. For one-time or limited reuse stencils, disposable material, such as plastic film and fiberboard sheeting, also is contemplated to fall within the scope of this invention.

The perforations will extend completely through the stencil. Shape and placement of the perforations determine the size and location of abrasive parcels on the tool. Any regular or non-regular geometric, area-enclosing shape can be employed. Uncut regions of the stencil correspond to open channels on the tool between abrasive parcels.

In use, one side of the stencil is brought in contact with the tool preform adjacent the cutting surface. The other side of the stencil remains exposed. The interior walls of the perforations and the cutting surface within the perimeters of the perforations define vacant cavities. On the exposed side of the stencils, the cavities are open.

The cavities are filled with brazing paste. Filling preferably is accomplished by forcing the paste into the cavities with a squeegee-like tool. That is, a thick bead of brazing paste is dispensed on the exposed side of the stencil, generally at one end of the cutting surface. The bead length extends slightly beyond the width of the cutting surface. A straight edged blade longer than the bead length is drawn with slight pressure from behind the bead across the exposed side of the stencil. The blade forces the paste into the cavities and removes the excess paste above the cavities flush with the exposed side of the stencil. The blade also wipes away excess paste from the exposed side of the stencil for reuse or disposal.

It is seen that the thickness of the stencil sheet will determine the height of the abrasive parcels on the tool. The thickness can vary widely to suit the needs of a particular grinding application. Generally, the thickness will be about equal to the maximum cross section dimension of the abrasive particles, although a different thickness can be used, especially if the binder concentration of the brazing paste varies outside the range of about 20-25 wt%. One can also appreciate that the size of the metal braze

composition particles should be small enough to form a smooth paste that will flow into the cavities. Particle size of 325 U.S. standard mesh or smaller, *i.e.,* at most 44 μm, is generally suitable.

The stencil is peeled away from the cutting surface. The parcels of brazing paste remain stuck to the cutting surface. Thus the brazing paste is disposed on the cutting surface in discrete islands separated from neighboring parcels by paste-free channels.

In one aspect, abrasive grains are deposited onto the still soft parcels of abrasive paste. Grains can be placed individually or dusted over the whole surface. In an embodiment, abrasive grains are at least about 100 μm and only one abrasive grain is deposited onto each of most parcels. A feeding apparatus can be used to facilitate individual placement of a single abrasive grain in each parcel of paste. Such feeding apparatus also advantageously may orient grain placement to optimize exposure of each grain's cutting facet relative to the workpiece. The fabricator thus can control the tool at the individual grain level to provide maximum cutting speed, minimum energy consumption, minimum grain fracture, or combinations of these parameters. The metal brazing composition will liquefy during brazing. Consequently, it may be necessary to provide means to preserve the orientation of individually placed grains until a permanent bond is formed at the conclusion of brazing. For example, this may be achieved by utilizing a stencil or feeding apparatus of a thermally stable composition, such as graphite or ceramic. The thermally stable stencil or feeding apparatus may be left in place during all or part of the brazing step.

In another embodiment the abrasive grains have a particle size of at most 10 μm. Preferably, the small grains are dusted onto the cutting surface to embed the grains in the parcels. Excess grains which dust into the paste-free channels are not embedded in the parcels. They can be removed by inverting the preform, by vacuum, by blowing with gas jets or like procedures. After removing excess grains, loosely embedded grains can be further buried in the parcels of paste. The grains can be deeply planted by placing a flexible release film over the parcel-populated cutting surface and applying pressure with a manual or automated roller, for example.

In yet another embodiment, the abrasive grains are premixed with the brazing paste prior to filling the cavities. The premixed grains should be smaller than the cross section

dimension of the perforations to permit the grains to enter the cavities. Preferably the premixed grains should be smaller than 75% of the stencil thickness.

Premixing of small grains with the paste can provide a uniform concentration throughout the paste. This technique will embed grains over the complete depth of the parcel. Moreover, the small grains can impart self-sharpening behavior to the premixed parcels. That is, each parcel on the tool will constitute a plurality of abrasive grains bonded within a matrix of metallic braze. Such parcels tend to wear by dislodging the most exposed abrasive grains. This will expose underlying fresh, sharp grains to continue grinding. Consequently, tools fabricated in this manner generally provide consistent, superior grinding performance as the parcels wear away over time in service.

Once the abrasive grains are embedded in the parcels of brazing paste, the preform can be fired by traditional methods. A brazing treatment causes the residual liquid binder to dissipate or burn off at intermediate temperature. At high temperature the metal braze composition components permanently unite the abrasive grains to the preform. Control of the thermal cycle variables permits the braze composition components to sinter without significantly changing the shape or placement of the parcels. One of ordinary skill in the art can select appropriate brazing time and temperature parameter to optimize parcel shape retention.

It is sometimes desirable to create a patterned abrasive on a tool exhibiting non-planar or extreme surface curvature. Deployment of a stencil directly against such a cutting surface may be problematic. In another aspect of this invention, this problem is solved by forming parcels of brazing paste on a transfer medium, and subsequently transferring the parcels to the cutting surface of a metal preform. The transfer medium can be a resilient, rubbery pad that is capable of conforming to the shape of the preform cutting surface. The operative face of the transfer medium preferably has a closed cell, smooth surface structure to facilitate transfer of paste parcels.

According to this variation of the invention, a stencil is provided with a plurality of perforations. Each perforation has a precise shape and is placed apart from neighboring perforations. One side of the stencil is brought in contact with a generally flat sheet of transfer medium while the other side of the stencil remains exposed. The interior walls of the perforations and the transfer medium within the perimeters of the perforations define vacant cavities. On the exposed side of the stencils, the cavities are open.

The cavities are filled with brazing paste. Filling preferably is accomplished by forcing the paste into the cavities, as explained above. The stencil is peeled away leaving the parcels of brazing paste stuck to the transfer medium. The parcel-bearing side of the transfer medium is pressed against the cutting surface of a tool preform. This can be accomplished to some advantage by first placing the parcel-free side of the transfer medium on a stable working surface, such as a table top or similar holding structure. The parcel-bearing side of the medium is held stationary and exposed. Then the cutting surface of the preform is forced against the stationary transfer medium. The parcels transfer to the cutting surface. Thereafter, abrasive particles can be added and the tool can be fired to permanently attach the abrasives.

EXAMPLES

EXAMPLE 1

The example can be better understood with reference to Fig. 1. Mask the surface of a 15 inch long by 15 inch wide by 0.010 inch thick stainless steel sheet with a U.V. impenetrable coating. The mask **1** is a continuous network **2** with exposed regular hexagonal areas **4** of 0.115 inches length on each side **6** and center-to-center distance **8** of 0.32 inches. The gap **10** between neighboring hexagons is 0.12 inches. Photoetch the sheet to open hexagonal perforations at the exposed areas and remove the mask.

Mount the perforated stainless steel stencil to a sturdy, rigid rectangular frame to maintain flatness. Place a 0.030 inch thick, 9.875 inch diameter, flat, circular steel preform for an abrasive disk on a table with the cutting surface facing up. Align the stencil centrally over the disk and clamp the frame to the preform so that the face of the disk contacts one side of the stencil. Maintain the exposed side of the stencil facing up in a horizontal plane.

Dispense an approximately 0.5 inch diameter, 12 inch long bead of Lucanex™ 721 braze paste just inside one edge of the rectangular frame. Use a 14 inch long, hard rubber squeegee, to draw the bead in a steady speed stroke across the exposed face of the stencil with slight downward pressure and to force the braze paste into the hexagonal cross-section cavities to a depth flush with the exposed surface of the stencil, *i.e.,* approximately 0.010 inch. Use only a single pass to prevent braze paste from bleeding under the stencil between perforations.

Unclamp the frame from the preform and lift the stencil vertically away from the disk face. Sprinkle 120/140 U.S. mesh type PDA 989 diamond abrasive grains from DAC Company, New York, New York to evenly dust grains over the disk face. Lift the preform from the table and invert to drop excess abrasive grains into a collection pan. Place the abrasive bearing preform cutting surface side up on a horizontal work surface. Align a 0.25 inch thick, 14 inch diameter circular rigid acrylic plastic sheet to overlay the preform and push down evenly to embed the abrasive grains into the braze paste parcels.

Remove the acrylic sheet and fire the preform in a vacuum furnace at about 15°C per minute to a maximum temperature of about 900°C, while maintaining pressure within the furnace below 10^{-4} Torr. Hold the preform at 900°C for 10 minutes and allow to cool to room temperature. This example demonstrates the manufacture of a flat, single diamond layer metal abrasive disk.

EXAMPLE 2

Drill 2.0 mm diameter circular holes on 5 mm centers in a 60° isometric pattern through a 0.2 inch thick by 12 inch wide by 12 inch long stainless steel sheet to form a stencil. Mount the stencil in a sturdy, rigid frame to maintain stencil flatness. Align the stencil over a 1 inch thick by 12 inch wide by 12 inch long pad of smooth-faced urethane rubber. Bring the stencil and rubber pad in laminating contact. Maintain the exposed side of the stencil facing up in a horizontal plane.

Dispense an approximately 0.5 inch diameter, 12 inch long bead of Incusil™ ABA braze paste along one edge of
the stencil. Use a 14 inch long, hard rubber squeegee, to draw the bead in a steady speed stroke across the exposed face of the stencil with slight downward pressure and to force the braze paste into the cylindrical cavities to a depth flush with the exposed surface of the stencil, *i.e.,* approximately 0.2 inch. Use only a single pass to prevent braze paste from bleeding under the stencil between perforations.

Lift the stencil vertically away from the face of the rubber pad. Sprinkle a 50/50 vol/vol mixture of 60/80 U.S. mesh diamond and cubic boron nitride abrasive grains from General Electric Company, Columbus, Ohio to evenly dust grains over the rubber pad. Lift the pad from the table and invert to drop excess abrasive grains into a collection pan. Replace the pad with abrasive/paste side up on a horizontal work surface.

Place a spherical steel preform firmly in a manual jig to expose the convex cutting surface of the preform. Press the preform vertically downward against the pad. Apply a slight rolling motion to the sphere to evenly transfer the parcels of abrasive laden brazing paste onto the cutting surface of the preform. Remove the manual jig and fire the preform as in Example 1. This example demonstrates the manufacture of an abrasive tool with a transfer medium according to the present invention. The abrasive tool is useful for grinding concave ball joints.

What is claimed is

1.A process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a cutting surface on the abrasive tool with the stencil whereby the perforations define cavities adjacent the cutting surface;

(C) providing a brazing paste including a metal braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form parcels of brazing paste on the cutting surface, each parcel being separated from neighboring parcels by paste-free channels;

(F) depositing abrasive grains onto the parcels; and

(G) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

2. The invention of claim 1 wherein the filling step includes forcing the brazing paste into the cavities with a straight-edged blade.

3. The invention of claim 2 wherein the abrasive grains are mixed with the brazing paste prior to filling the cavities.

4. The invention of claim 3 wherein the abrasive grains have a particle size of at most 10 μm.

5. The invention of claim 2 wherein the depositing step includes:

(i) dusting grains onto the cutting surface to embed grains into the parcels; and

(ii) removing non-embedded grains.

6. The invention of claim 5 wherein the depositing step further includes pressing the embedded grains into the parcels.

7. The invention of claim 1 wherein the abrasive grains have a particle size of at least about 100 μm and only one abrasive grain is deposited onto each of most parcels.

8. A process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a transfer medium with the stencil whereby the perforations define cavities adjacent the transfer medium;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form a patterned face of parcels of brazing paste on the transfer medium, each parcel being separated from neighboring parcels by paste-free channels;

(F) forcing the patterned face against a cutting surface of the abrasive tool;

(G) peeling the transfer medium away to leave the parcels on the cutting surface;

(H) depositing abrasive grains onto the parcels; and

(I) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

9. The invention of claim 8 wherein the filling step includes forcing the brazing paste into the cavities with a straight-edged blade.

10. The invention of claim 9 wherein the abrasive grains are mixed with the brazing paste prior to filling the cavities.

11. The invention of claim 10 wherein the abrasive grains have a particle size of at most 10 μm.

12. The invention of claim 9 wherein the depositing step includes:

(i) dusting grains onto the cutting surface to embed grains into the parcels; and

(ii) removing non-embedded grains.

13. The invention of claim 12 wherein the depositing step further includes pressing the embedded grains into the parcels.

14. The invention of claim 8 wherein the abrasive grains have a particle size of at least about 100 μm and only one abrasive grain is deposited onto each of most parcels.

15. The invention of claim 8 wherein the cutting surface is a three dimensional, curvilinear surface and the transfer medium is a flexible, resilient pad.

16. An abrasive tool fabricated by a process comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a cutting surface on the abrasive tool with the stencil whereby the perforations define cavities adjacent the cutting surface;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form parcels of brazing paste on the cutting surface, each parcel being separated from neighboring parcels by paste-free channels;

(F) depositing abrasive grains onto the parcels; and

(G) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

17. An abrasive tool fabricated by a process comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a transfer medium with the stencil whereby the perforations define cavities adjacent the transfer medium;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form a patterned face of parcels of brazing paste on the transfer medium, each parcel being separated from neighboring parcels by paste-free channels;

(F) forcing the patterned face against a cutting surface of the abrasive tool;

(G) peeling the transfer medium away to leave the parcels on the cutting surface;

(H) depositing abrasive grains onto the parcels; and

(I) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

18. The invention of claim 17 wherein the cutting surface includes a convex, spherical portion.

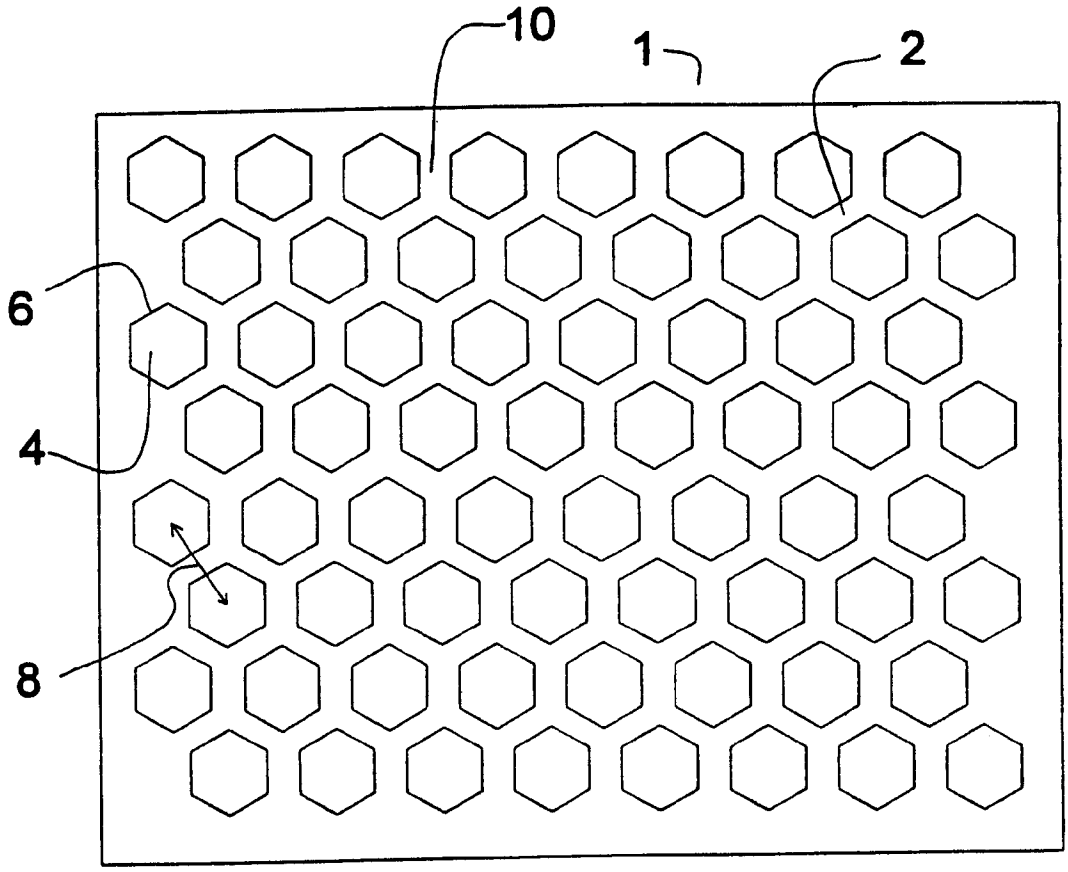


FIG. 1

INTERNATIONAL SEARCH REPORT

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A. CLASSIFICATION OF SUBJECT MATTER
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 380 390 A (TSELESIN NAUM N) 10 January 1995 see column 3, line 13 - column 5, line 6; figures 1-4	1,16 8,17
A	US 3 774 355 A (DAWSON C ET AL) 27 November 1973 see column 2, line 32 - line 58; figures 1-6,11	1,8,16, 17
A	US 4 010 583 A (HIGHBERG CARLE W) 8 March 1977 see column 8, line 38 - line 63; figures 4-6	1,16
A	US 5 219 462 A (BRUXVOORT WESLEY J ET AL) 15 June 1993 see column 3, line 62 - line 68; figure 2	2,3,9,10

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

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Date of the actual completion of the international search	Date of mailing of the international search report
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INTERNATIONAL SEARCH REPORT

Information on patent family members

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(54) Title: POLYCRYSTALLINE ABRASIVE GRIT

(57) Abstract: A method is provided for producing a plurality of polycrystalline ultra-hard abrasive grit. The method includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of crystalline abrasive grit. The ultra-hard abrasive is generally diamond or cubic boron nitride.

POLYCRYSTALLINE ABRASIVE GRIT

BACKGROUND OF THE INVENTION

This invention relates to polycrystalline abrasive grit.

Ultra-hard abrasive bodies in the form of either abrasive compacts or individual crystals are well known in the art. The abrasive compact will generally be a diamond compact, also known as polycrystalline diamond or PCD, or a cubic boron nitride compact, also known as polycrystalline cubic boron nitride or PCBN. These abrasive compacts have wide application in cutting, drilling, boring, milling and other abrasive applications.

Such ultra-hard abrasive bodies are produced under conditions of elevated temperature and pressure at which the ultra-hard abrasive is crystallographically stable. Polycrystalline diamond or polycrystalline boron nitride can be produced with or without a second phase or bonding matrix. The second phase, when provided, may be in the case of diamond a solvent/catalyst such as cobalt, or it may be a carbide-forming element such as silicon. Similar sintering mechanisms are utilised in PCBN synthesis with various carbides, nitrides and borides being common second phases.

Abrasive compacts are generally produced in the form of a disc, either free-standing or bonded to a support, which may be cut into smaller segments for use.

Single crystal ultra-hard abrasives in the form of either diamond or cubic boron nitride crystals, also referred to as "grit", are used in loose or bonded form for a variety of abrasive applications such as lapping, drilling, grinding and sawing.

Examples of abrasive tools which utilise single crystal ultra-hard abrasives are grinding wheels and saw segments. Bond types for such abrasives can be a metal, resin or a ceramic.

Diamond or CBN grits are typically produced through a high pressure/high temperature process where graphite or hexagonal boron nitride is converted in the presence of a suitable catalyst to, respectively, diamond or cubic boron nitride. In some cases natural diamond crystals are also employed.

The concepts of abrasive compacts and grits have been combined and have led to the development of polycrystalline grit. For instance United States Patent 4,776,861 describes a process for generating polycrystalline grit containing ultra-hard material. This is achieved by leaching non-diamond material from polycrystalline diamond or cubic boron nitride compacts obtained through a high pressure/high temperature process and subsequently crushing the leached product.

The process of high pressure/high temperature sintering followed by subsequent crushing is not ideal as a high amount of energy is consumed in crushing sintered PCD and control over the shape and size of the final product is limited. Hence yield and quality tend to be low.

SUMMARY OF THE INVENTION

According to the present invention, a method of producing a plurality of polycrystalline ultra-hard abrasive grit includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions at which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of polycrystalline abrasive grit.

The method of the invention involves, as a first step, the forming of the mass of ultra-hard abrasive particles or of combination of a precursor for such particles and solvent/catalyst into a plurality of green state granules. The term "green state granules" means a coherent mass of any suitable shape or size and which is produced, for example, by known granulation or pelletising techniques.

The green state granules will generally be produced in the presence of a second (or binder) phase. The second phase may be provided by a material which participates in or contributes to the formation of the polycrystalline ultra-hard abrasive grit, e.g. a solvent/catalyst for the ultra-hard abrasive. The second phase may also be a binder, organic or inorganic, which may be removed prior to subjecting the granules to the high temperature/high pressure sintering conditions. The second phase can also consist of a combination of these two second phases.

If a precursor for the ultra-hard abrasive is used, then a solvent/catalyst for that ultra-hard abrasive must also be present. Examples of suitable solvent/catalysts for such particles, particularly when the particles are diamond or cubic boron nitride, are well known in the art. The solvent/catalysts may be precursors which can be converted to the solvent/catalyst, e.g. metal oxides which on heating are converted to the metal. Such precursors are included in the term "solvent/catalyst".

Examples of combinations, generally in the form of mixtures, of ultra-hard abrasive particles or precursor particles and second phases which are useful in the practice of the invention are:

1. Diamond and a diamond solvent/catalyst which may be a transition metal such as cobalt, nickel, iron or manganese or non-metallic solvent/catalyst such as a carbonate or sulphate to produce a sintered, intergrown polycrystalline diamond grit material.

2. Graphite and a diamond solvent/catalyst which may be a transition metal such as cobalt, nickel, iron or manganese or a non-metallic solvent/catalyst such as a carbonate or sulphate to produce a sintered, intergrown polycrystalline diamond grit. In producing the grit, the graphite is converted to diamond.

3. A combination of 1 and 2.

4. Diamond and a carbide forming metal such as silicon or titanium to produce a grit which is a sintered polycrystalline diamond/ SiC or TiC composite.

5. A combination of 1 and 4 or 2 and 4.

6. Cubic boron nitride together with a boride or nitride forming metal such as aluminium, titanium, zirconium, hafnium, tantalum, molybdenum, niobium, chromium or tungsten or mixtures thereof introduced either in metallic form or as a substoichiometric or stoichiometric carbide, boride or nitride. The polycrystalline cubic boron nitride grit produced consists of cubic boron nitride and metal nitrides or borides.

7. A combination of 6 and cobalt, nickel, iron or manganese.

8. A combination of cubic boron nitride and alumina or a combination of diamond and alumina.

9. Hexagonal boron nitride and a suitable solvent/catalyst for cubic boron nitride such as magnesium, lithium or calcium in either metallic form, as a nitride or in the form of a boronitride to produce a sintered, intergrown polycrystalline cubic boron nitride grit. In producing the grit, the hexagonal boron nitride is converted to cubic boron nitride.

The green state granules are placed in the reaction zone of a standard high pressure/high temperature apparatus for the high pressure/high temperature sintering. Generally, the granules will be placed in a capsule which itself is placed in the reaction zone.

A separating medium separates individual granules in the reaction zone. The separating medium is preferably provided as a coating on individual granules. A particularly suitable method of coating individual granules is spray coating in a fluidised medium.

The separating medium, in one form of the invention, may be a metal or alloy which does not interfere with the high pressure/high temperature sintering of the green state granules. For example, molybdenum is a suitable coating

where the ultra-hard abrasive is diamond or a precursor for diamond, e.g. graphite.

The separating medium may also be an inert medium which adequately transmits pressure, e.g. a salt such as a chloride or a carbonate, graphite, hexagonal boron nitride or an oxide.

A chemical barrier layer may be applied to the green state granules , generally to coat the granules completely, prior to the separation medium being interposed between adjacent granules. Examples of suitable chemical barrier layers are niobium, molybdenum, tantalum, titanium or other transition metal. The chemical barrier layer may be left on the polycrystalline abrasive grit produced from the green state granules.

The separating medium and chemical barrier layers may be applied to the green state granules by spraying in the form of an aqueous or non-aqueous suspension. The granules will generally be in a fluidised state during spraying. Alternatively, the granules may be dipped into a suspension of the separation medium and/or chemical barrier layer, or these layers may be coated mechanically on to the granules.

In one particular form of the invention, the green state granules are placed in a container, the separating medium in powdered or liquid form poured into the container and the granules and the separating medium mixed. If necessary, good dispersion and mixing can be assisted by some mechanical agitation or vibration to ensure that there are no gaps and the green state granules are all embedded in or enclosed by the separating medium.

Before subjecting the green state granules to the elevated temperature and pressure sintering, any removable binder, e.g. an organic binder which is present is preferably removed, for example, by a pressureless heat treatment.

The heat treatment conditions will vary according to the nature of the granules and its content. Typical heat treatment or outgassing conditions are 500°C in an argon atmosphere or 400°C in air or 1100°C in a vacuum. A slow heating cycle is preferred.

The green state granules may optionally be densified. Densification can be achieved by uniaxial compaction or cold isostatic pressing. Some deformation of the granules will take place during this compaction. When the green state granules contain a binder which is removed, the densification may take place before or after the binder is removed.

The elevated temperature and pressure sintering conditions to which the green state granules are subjected are known in the art. Typical pressures are 3 to 9 GPa and typical temperatures are 1000 to 2500°C.

The sintered material is removed from the reaction zone of the high temperature/high pressure apparatus using known techniques. The material which is recovered is sintered and coherent and consists of a plurality of sintered granules separated by the separating medium and a chemical barrier layer, when provided. The individual sintered granules or polycrystalline ultra-hard abrasive grit can be released by removing the separating medium. For example, if the separating medium is a metal such as molybdenum, the material may be placed in a hot boiling acid such as 3 parts of boiling hydrofluoric acid and one part nitric acid. This will dissolve the molybdenum leaving a plurality of polycrystalline diamond grit. When the separating medium is hexagonal boron nitride, removal of the separating medium may be achieved by placing the sintered material in an ultrasonic bath filled with water. Hexagonal boron nitride is hydrolysed by the water and the sonification breaks up or disintegrates the hexagonal boron nitride.

The polycrystalline ultra-hard abrasive grit produced by the method of the invention will typically have a particle size less than 5 mm and typically less than 2 mm. This grit may be used in a variety of abrasive applications, depending on the content and composition of the grit. The polycrystalline nature of the grit provides for a better bond retention in the bonding matrix of an abrasive tool when compared with single crystal grit. Further, controlled fracture of the grit can occur resulting in sharp edges or points being continuously produced, in use. The invention provides a particularly effective and economic method of producing polycrystalline abrasive grit. Further, the method is versatile in that polycrystalline abrasive grit may be produced with or without a second (binder) phase and contain more than one type of ultra-abrasive. The method allows for the production of polycrystalline abrasive grit of controlled shape and size.

EXAMPLE 1

A solvent based suspension with a 80 weight percent diamond (average particle diameter approximately 10 microns) and 20 weight percent of submicron cobalt powder was prepared and approximately 1 volume percent of organic binder added. The suspension was processed using a combination of spray drying and fluidised bed technology to produce strong green state spherical granules of approximately 1mm diameter and a porosity of approximately 42%. A solvent based suspension was formulated using submicron molybdenum powder. The diamond/cobalt granules were fluidised and a thin layer of molybdenum of approximately 100 microns thickness was spray dried on to the granules, using the molybdenum suspension.

The coated green state granules were placed into a die set and uniaxially compacted to yield a green compact of approximately 60% density. Binder removal from the green state granules was achieved by heat treatment at 1100°C for 2 hours in vacuum. The outgassed green state granules were then

loaded into a metal canister. The canister was loaded into the reaction capsule of a standard high pressure/high temperature apparatus and the loaded capsule placed into the reaction centre of this apparatus. The contents of the canister were exposed to a temperature of approximately 1450°C and a pressure of 5 GPa. These conditions were maintained for 10 minutes. After completion of the treatment a densely sintered compact was recovered from the canister. A polished cross-section showed sintered polycrystalline diamond grit separated by a honeycomb structure of thin molybdenum veins. The compact was placed into a beaker with 3 parts of boiling hydrofluoric acid and 1 part nitric acid. After a few minutes of treatment the compact separated into a plurality of roundish particles of approximately 0,5 to 0,7 mm diameter. Closer examination showed these particles to consist of hard sintered polycrystalline diamond with the cobalt leached out of the surface region of the particles.

EXAMPLE 2

An organic suspension of hexagonal boron nitride containing a small amount of dissolved organic binder was prepared. The molybdenum clad green state granules described in Example 1 were fluidised and spray coated with a second approximately 100 micron thick coating of hexagonal boron nitride, using the hexagonal boron nitride suspension. Repeating the same compaction, outgassing and high temperature/high pressure treatment as described in Example 1 resulted in a coherent sintered compact recovered from the canister. The compact was placed into an ultrasonic bath filled with water. After a few minutes of sonification the compact separated into a plurality of roundish particles of approximately 0,6 to 0,8 mm diameter. Closer examination revealed the particles to consist of sintered polycrystalline diamond grit clad with a thin sintered molybdenum metal coating.

EXAMPLE 3

The procedure in Example 2 was repeated replacing the hexagonal boron nitride layer with a spray deposited sodium chloride layer. The binder removal temperature was lowered to 500°C in argon so as to prevent volatilisation of the chloride. Repeating the same compaction, outgassing and high temperature/high pressure treatment as described in Example 1 resulted in a coherent sintered compact recovered from the canister. The compact was placed into an ultrasonic bath filled with water. After a few minutes of sonification the compact separated into a plurality of roundish particles of approximately 0,6 to 0,8 mm diameter. Closer examination revealed the particles to consist of sintered polycrystalline diamond grit clad with a thin sintered molybdenum metal coating.

CLAIMS

1 A method of producing a plurality of polycrystalline ultra-hard abrasive grit includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions at which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of polycrystalline abrasive grit.

2 A method according to claim 1 wherein the green state granules are produced by granulation or pelletising.

3 A method according to claim 1 or claim 2 wherein the green state granules contain a second phase which is an organic or inorganic binder, such binder being removed prior to subjecting the granules to the high temperature/high pressure conditions.

4 A method according to claim 1 or claim 2 wherein the green state granules contain a second phase which participates in or contributes to the formation of the polycrystalline ultra-hard abrasive grit.

5 A method according to claim 4 wherein the second phase is a solvent/catalyst for the ultra-hard abrasive.

6 A method according to any one of the preceding claims wherein the green state granules contain diamond and a metal solvent/catalyst.

7 A method according to any one of claims 1 to 5 wherein the green state granules contain graphite and a diamond solvent/catalyst.

8 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond, graphite and a diamond solvent/catalyst.

9 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond and a carbide forming metal.

10 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond, a diamond solvent/catalyst and a carbide forming metal.

11 A method according to any one of claims 1 to 5 wherein the green state granules contain cubic boron nitride and a boride or nitride forming metal.

12 A method according to any one of claims 1 to 5 wherein the green state granules contain a combination of cubic boron nitride, a boride or nitride forming metal, and a metal selected from cobalt, nickel, iron and manganese.

13 A method according to any one of claims 1 to 5 wherein the green state granules contain cubic boron nitride and alumina.

14 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond and alumina.

15 A method according to any one of claims 1 to 5 wherein the green state granules contain hexagonal boron nitride and a solvent/catalyst for cubic boron nitride.

16 A method according to any one of the preceding claims wherein the separating medium is provided as a coating on individual granules.

17 A method according to any one of the preceding claims wherein the ultra-hard abrasive for the green state granules is diamond or a precursor for diamond, and the separating medium is molybdenum.

18 A method according to any one of the preceding claims wherein the separating medium is selected from a salt, graphite, hexagonal boron nitride and an oxide.

19 A method according to any one of the claims 1 to 16 wherein a chemical barrier layer is applied to the green state granules prior to the separation medium being interposed between adjacent granules.

20 A method according to claim 19 wherein the chemical barrier layer coats the granules completely.

21 A method according to 19 or claim 20 wherein the chemical barrier layer is selected from niobium, molybdenum, tantalum, titanium or other transition metal.

22 A method according to any one of claims 19 to 21 wherein the chemical barrier layer is left on the polycrystalline abrasive grit produced from the green state granules.

23 A method according to any one of the preceding claims wherein the elevated temperature conditions are a pressure in the range 3 to 9 GPa and a temperature in the range 1000 to 2500°C.

24 A method according to claim 1 substantially as herein described with reference to any one of the examples.

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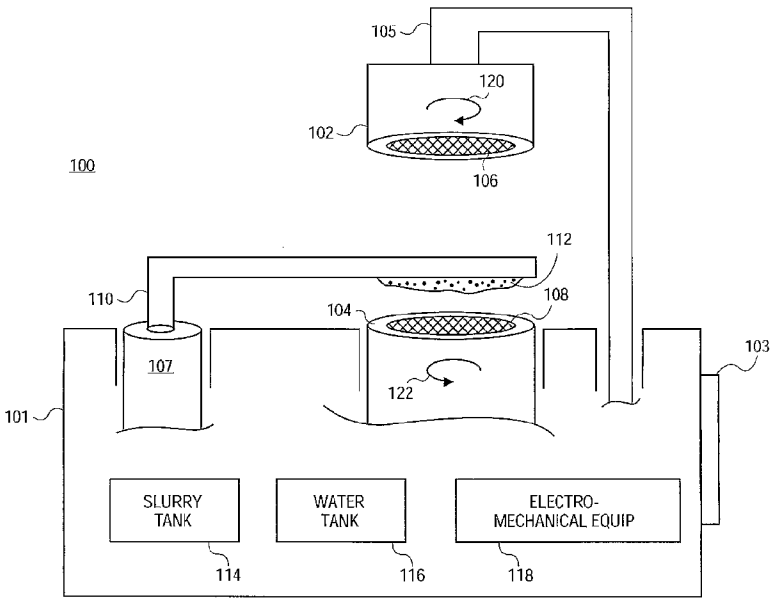
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(54) Title: DIAMOND CONDITIONING OF SOFT CHEMICAL MECHANICAL PLANARIZATION/POLISHING (CMP) POLISHING PADS



(57) Abstract: Conditioning of chemical mechanical planarization (CMP) using conventional diamond-embedded abrasive strips are well suited to condition conventional "hard" polishing but not soft polishing pads because the diamonds not only remove waste material, but they also damage the polishing surface of the pad. Embodiments of the present invention condition soft polishing pads using diamond strips without damaging the soft polishing pad (108).

WO 2004/094106 A1

DIAMOND CONDITIONING OF SOFT CHEMICAL MECHANICAL PLANARIZATION/POLISHING (CMP) POLISHING PADS

BACKGROUND

1. Field

[0001] Embodiments of the present invention relate to chemical mechanical planarization/polishing (CMP) and, in particular, to conditioning of CMP polishing pads.

2. Discussion of Related Art

[0002] Chemical mechanical planarization/polishing (CMP) is a process technology first developed in the mid-1980s to enable production of integrated circuits on substrates or wafers. CMP processes are used prepare wafers and to fabricate semiconductor devices or structures on the wafers. A CMP process may be used to planarize (*i.e.*, make flat) a semiconductor layer on a wafer, an insulating layer on the semiconductor layer, and a conductive layer on the insulating layer in predetermined patterns.

[0003] A typical CMP system includes a wafer carrier and a platen mounted in a housing. A polishing pad is secured to the platen and the wafer to be polished is secured in the wafer carrier. A typical CMP process operates as follows. The wafer carrier rotates the wafer and/or the platen rotates the polishing pad. Chemical slurry is applied to the surface of the polishing pad and the wafer is brought into contact with the polishing pad and is polished (or planarized). The combination of applying the chemical slurry and the mechanical rotation leads to the term "chemical-mechanical planarization."

[0004] As the wafer is polished, the chemical slurry and materials removed from the wafer tend to glaze the surface of the polishing pad, making the polishing pad slick and reducing the polishing rate and efficiency. It is thus important that the polishing pad surface be clean and free of surface irregularities. The process of cleaning the polishing pad is sometimes referred to a "conditioning" or "refreshing."

[0005] One method of conditioning polishing pads is to abrade them with a conventional diamond-embedded abrasive disk or strip. Although conventional diamond-embedded abrasive strips are well suited to condition "hard" polishing pads used for rough polishing,

they are not well suited to condition "soft" polishing pads used for fine polishing. When a soft polishing pad is conditioned with a diamond-embedded abrasive disk, the diamonds not only remove waste material, but they also damage the polishing surface of the pad.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally equivalent elements. The drawing in which an element first appears is indicated by the leftmost digit(s) in the reference number, in which:

[0007] Figure 1 is schematic diagram of a chemical mechanical planarization/polishing (CMP) polishing system according to an embodiment of the present invention;

[0008] Figure 2 is a flowchart illustrating a process performed by a CMP polishing system in according to embodiments of the present invention;

[0009] Figure 3 illustrates an example soft polishing pad according to an embodiment of the present invention;

[0010] Figure 4 illustrates operation of a conditioning arm according to an embodiment of the present invention; and

[0011] Figure 5 illustrates a diamond conditioner according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

[0012] Figure 1 is schematic diagram of a chemical mechanical planarization (CMP) polishing system 100 according to an embodiment of the present invention. The CMP polishing system 100 includes a housing 101, a polishing head 102, a control panel 103, a platen 104, a spindle 105, a wafer 106, a base 107, a soft polishing pad 108, a conditioning arm 110, a diamond (or artificial diamond) conditioner 112, a slurry tank 114, a spindle 115, a water tank 116, and electromechanical equipment 118. The slurry tank 114 and/or the water tank 116 may be located in or separate from the housing 101. The electromechanical equipment 118 may include vertical drivers, rotational drivers,

controllers, or other equipment generally used to operate arms, motors, and other devices in CMP polishing systems.

[0013] The platen 104 is mounted in the housing 101 and may be rotated by a motor (not shown) in the electromechanical equipment 118. The polishing head 102 is mounted on the spindle 105 and may be rotated by a motor (not shown) in the electromechanical equipment 118. The wafer 106 is mounted with the surface to be polished face down and away from the polishing head 102. The soft polishing pad 108 mounted to the platen using an adhesive. During polishing of the wafer 106, the polishing head 102 may be rotated in a direction opposite to the rotation of the polishing pad 108 may be, as shown by arrows 120 and 122. Alternatively, the polishing head 102 may rotate while the platen 104 remains stationary. Alternatively still, the polishing head 102 may be stationary while the platen 104 rotates. The slurry tank 114 delivers slurry to the surface of the soft polishing pad 108 during wafer 106 polishing.

[0014] The conditioning arm 110 pivots in its base 107 when conditioning the soft polishing pad 108. A motor (not shown) in the electromechanical equipment 118 may move the conditioning arm 110. The water tank 116 may dispense a rinsing solution, such as potable water or de-ionized (DI) water, to the surface of the soft polishing pad 108 during conditioning of the soft polishing pad 108.

[0015] Figure 2 is a flowchart illustrating a process 200 performed by the CMP polishing system 100 according to embodiments of the present invention. A machine-readable medium with machine-readable instructions thereon may be used to cause a processor to perform the process 200. Of course, the process 200 is only an example process and other processes may be used. The example process 200 may be used to remove metal, oxides, glass, silicon, etc. Although the example process 200 is described with reference to wafers, the example process 200 may be used for semiconductors, memory disks, or other suitable objects requiring smoothness, planarity, fine polishing, etc., such as lenses and mirrors.

[0016] In a block 202 the head 102 holds the wafer 106 and rotates the wafer 106 against the soft polishing pad 108 as slurry from the slurry tank 114 is applied to the surface of the

soft polishing pad 108 and the platen 104 applies a force to the wafer 106. In a block 204, the head 102 disengages the wafer 106 from contact with the soft polishing pad 108 and the slurry stops flowing to the surface of the soft polishing pad 108.

[0017] In a block 206, the soft polishing pad 108 is conditioned using the diamond conditioner 112. In one embodiment of the present invention, the platen 104 rotates the soft polishing pad 108, rising solution from the water tank 116 rinses the soft polishing pad 108, e.g., by supplying DI water to the surface of the soft polishing pad 108, and the conditioning arm 110 with the diamond conditioner 112 sweeps across (e.g., back and forth) the soft polishing pad 108. Although polishing of the soft polishing pad 108 may be described in some embodiments as being performed *ex situ* (between wafer 106 polishings), polishing of the soft pat 108 in other embodiments may be performed *in situ* (while wafers 106 are being polished), or some combination of both. Of course, the soft polishing pad 108 may be conditioned according to embodiments of the present invention prior to polishing any wafers 106.

[0018] One or a combination of the following process parameters may be modified to improve the process for soft pad 108 conditioning using the diamond conditioner 112 to ensure that the conditioning arm 110 with the diamond conditioner 112 do not destroy or significantly reduce the lifetime of the soft polishing pad 108. In fact, according to embodiments of the present invention, the lifetime of the soft polishing pad 108 is significantly increased. Increased soft polishing pad 108 lifetime results in reduced labor costs and costs of parts, as well as improved processes, (*e.g.*, soft polishing pads 108 do not have to be changed as often).

[0019] In one embodiment, the conditioning arm 110 applies approximately 0.25 psi to the soft polishing pad 108 through the diamond conditioner 112 as opposed to approximately three psi applied using conventional hard polishing pad techniques..

[0020] In known soft polishing pad conditioning methods, the platen and thus the soft polishing pad does not rotate. In embodiments of the present invention, the rotational speed of the platen 104 and thus the soft polishing pad 108 may be approximately one hundred revolutions per minute 100 (rpm)

[0021] In known soft polishing pad conditioning methods, there may be no DI water flowing to the soft conditioning pad. In one embodiment of the present invention, the volumetric flow rate of DI water from the DI water tank 116 may may be one gallon per minute (gpm). Alternatively, the volumetric flow rate may be anywhere from zero to approximately seven gallons per minute.

[0022] In known soft polishing pad conditioning methods, there is no diamond conditioner used, thus no down force applied to a soft polishing pad In one embodiment, the down force applied to the soft polishing pad by the diamond conditioner 112 may be 0.25 psi.

[0023] In known soft polishing pad conditioning methods, no diamond conditioner is used. n known hard polishing pad conditioning methods, the diamond conditioner makes at least ten sweeps. In one embodiment, the diamond conditioner 112 makes one sweep across the soft polishing pad.

[0024] Figure 3 illustrates the example soft polishing pad 108 according to an embodiment of the present invention. The example soft polishing pad 108 includes several pores 302 and may be made from napped poromerics-porous urethane layers on a mylar or compressible urethane substrate. In an alternative embodiment, the example soft polishing pad 108 may be a soft pad made with tangled polyester fibers coated with polyurethane. In another embodiment, the example soft polishing pad 108 may be a felt sheet of fibers impregnated with micro porous elastomer. Alternatively still, the example soft polishing pad 108 may be a porous thermoplastic resin matrix, typically polyurethane, reinforced with a fibrous network such as a felted mat of polyester fibers. An example of a suitable soft pad includes any of the Politex® Series polishing pads available from Rodel Holdings in Wilmington, Delaware.

[0025] The soft polishing pads 108 according to embodiments of the present invention are to be distinguished from known hard polishing pads, which include micro porous polyurethane polishing pads that are relatively hard and not as compressible when compared to other types of polishing pads and polyurethane impregnated felt polishing

pads. Examples of hard pads include the SUBA 1000 Series polishing pads and the SUBA® Pads available from Rodel in Phoenix, Arizona.

[0026] Figure 4 illustrates operation of the conditioning arm 110 according to an embodiment of the present invention. When the soft polishing pad 108 is moving and a wafer 106 is being polished, the conditioning arm 110 (and the diamond conditioner 112) remain in the position 402 situated adjacent to the perimeter of the soft polishing pad 108. After a predetermined number of wafers have been polished by the soft polishing pad 108, or when the polishing rate has been decreased due to build up of slurry and other debris, the conditioning arm 110 is pivoted at one end by the base 107, lowered onto the soft polishing pad 108, and swept along an arc indicated by the arrows 408 from the position 402 across the surface of the soft polishing pad 108 (as shown by phantom lines) to a second position 406 adjacent to the other side of the perimeter of the soft polishing pad 108 (also shown by phantom lines).

[0027] Figure 5 illustrates the diamond conditioner 112 according to an embodiment of the present invention. The diamond conditioner 112 includes a base 502 having diamonds 504. The base 502 may be any suitable rigid substrate. The diamonds 504 may be synthetic diamonds, natural diamonds, etc.

[0028] The diamonds 504 may be placed on the base 502 using chemical vapor deposition (CVD). Alternatively, the diamonds 404 may be embedded in the base 502. For example, the diamond conditioner 112 may be formed by embedding diamond particles in nickel coated on the surface of a rigid substrate according to well-known or proprietary techniques.

[0029] Embodiments of the invention can be implemented using hardware, software, firmware, or a combination of hardware and software. In implementations using software, the software may be stored on a computer program product (such as an optical disk, a magnetic disk, a floppy disk, etc.) or a program storage device (such as an optical disk drive, a magnetic disk drive, a floppy disk drive, etc.).

[0030] The above description of illustrated embodiments of the invention is not intended

to be exhaustive or to limit the invention to the precise forms disclosed. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. These modifications can be made to the invention in light of the above detailed description.

[0031] In the above description, numerous specific details, such as particular processes, materials, devices, and so forth, are presented to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the embodiments of the present invention can be practiced without one or more of the specific details, or with other methods, components, etc. In other instances, well-known structures or operations are not shown or described in detail to avoid obscuring the understanding of this description.

[0032] Various operations have been described as multiple discrete operations performed in turn in a manner that is most helpful in understanding embodiments of the invention. However, the order in which they are described should not be construed to imply that these operations are necessarily order dependent or that the operations be performed in the order in which the operations are presented.

[0033] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, process, block, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0034] The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Rather, the scope of embodiments of the invention is to be determined entirely by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.

CLAIMS

What is claimed is:

1. A method of conditioning a chemical mechanical planarization (CMP) polishing pad, comprising:

conditioning a soft polishing pad using diamond conditioner.

2. The method of claim 1, further comprising:

rotating a soft polishing pad on a platen;

rinsing the soft polishing pad; and

passing a diamond conditioner over the soft polishing pad.

3. The method of claim 2, further comprising:

applying zero pounds per square inch (psi) to the soft polishing pad from the platen.

4. The method of claim 1, wherein passing the conditioning arm having the diamond conditioner thereon over the soft polishing pad comprises passing the diamond conditioner over the soft polishing pad during wafer polishing.

5. The method of claim 1, wherein passing the conditioning arm having the diamond conditioner thereon over the soft polishing pad comprises passing the diamond conditioner over the soft polishing pad between wafer polishings.

6. The method of claim 1, further comprising rotating a wafer against the soft polishing pad.

7. The method of claim 6, further comprising applying a slurry to the surface of the soft polishing pad.

8. A chemical mechanical planarization (CMP) system, comprising:

a head mounted in a housing;

a wafer mounted to the head;

a platen mounted in the housing;

a soft polishing pad mounted to the platen;

a pad conditioning arm mounted in the housing; and

a diamond conditioner mounted to the pad conditioning arm.

9. The system of claim 8, further comprising a slurry tank mounted in the housing.

10. The system of claim 9, further comprising a water tank mounted in the housing.

11. The system of claim 8, further comprising electromechanical equipment mounted in the housing.

12. A chemical mechanical planarization (CMP) apparatus, comprising:

a soft polishing pad adhered to a platen in a housing; and

a pad conditioning arm mounted in the housing, the pad conditioning arm having a diamond conditioner attached thereto.

13. The CMP apparatus of claim 12, wherein the soft polishing pad comprises napped poromerics-porous urethane layers on a substantially compressible substrate.

14. The CMP apparatus of claim 13, wherein the soft polishing pad comprises napped poromerics-porous urethane layers on a mylar substrate.

15. The CMP apparatus of claim 12, wherein the soft polishing pad comprises napped poromerics-porous urethane layers on a substantially compressible urethane substrate.

16. The CMP apparatus of claim 12, wherein the diamond conditioner comprises a diamond strip.

17. The CMP apparatus of claim 12, wherein the diamond strip comprises synthetic diamonds embedded in a base.

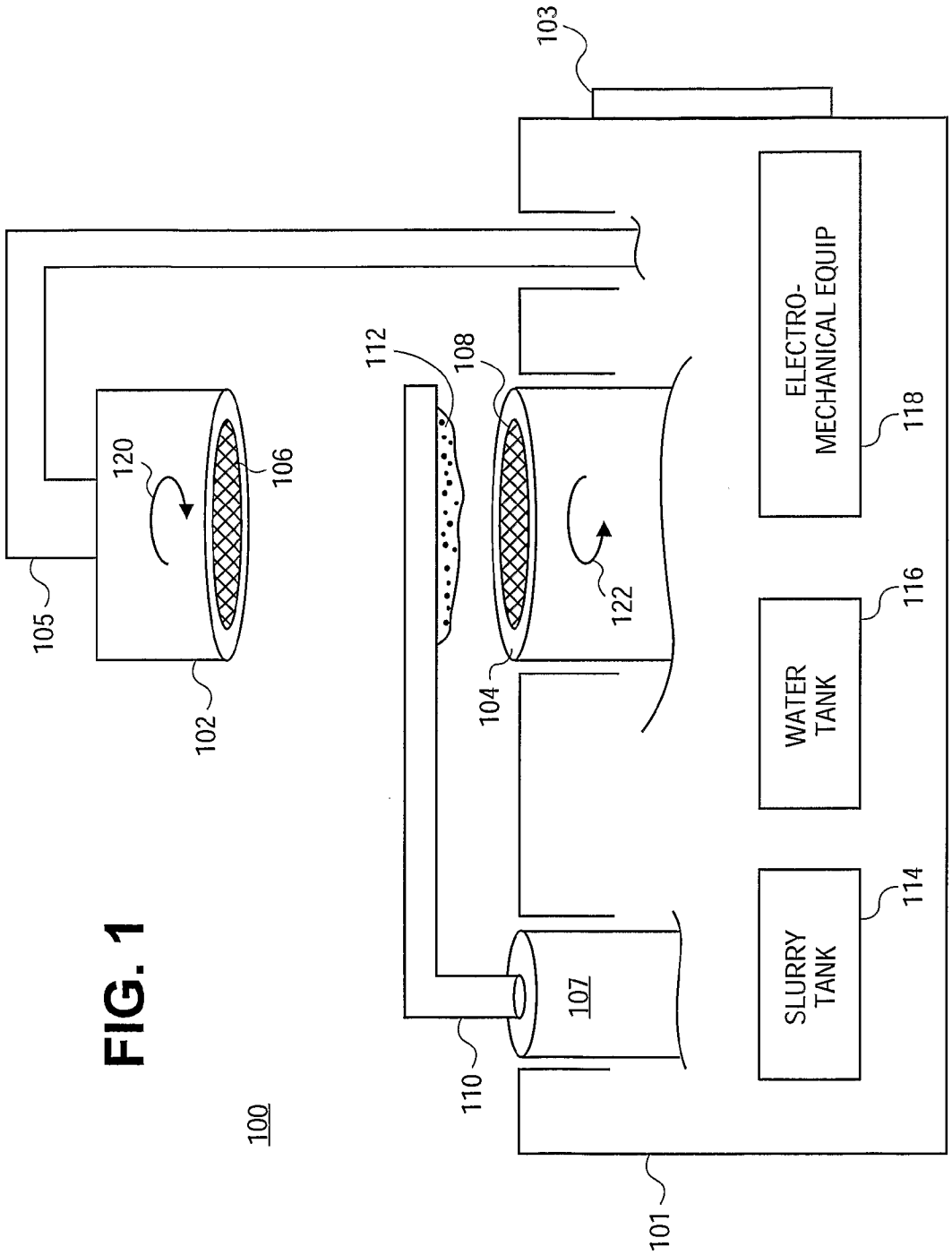

103
ELECTRO-
MECHANICAL EQUIP
118
112
108
120
106
105
102
104
122
WATER
TANK
116
SLURRY
TANK
114
107
110
101
100

FIG. 1

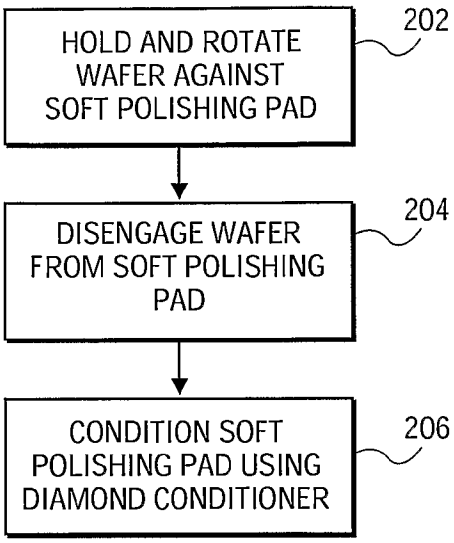

HOLD AND ROTATE WAFER AGAINST SOFT POLISHING PAD
202
DISENGAGE WAFER FROM SOFT POLISHING PAD
204
CONDITION SOFT POLISHING PAD USING DIAMOND CONDITIONER
206

FIG. 2

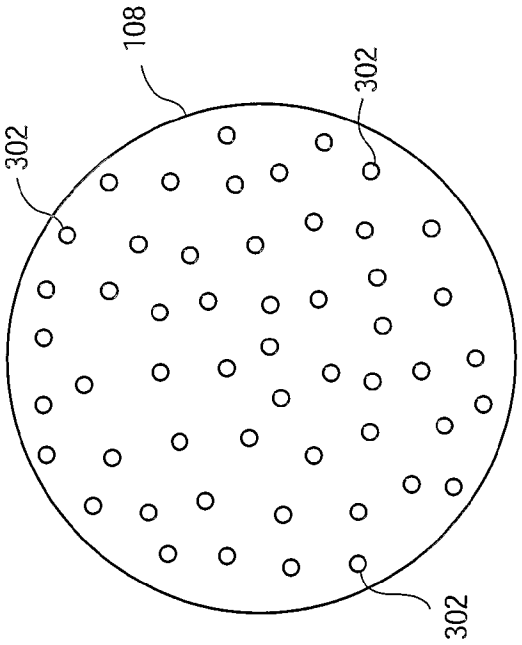


FIG. 3

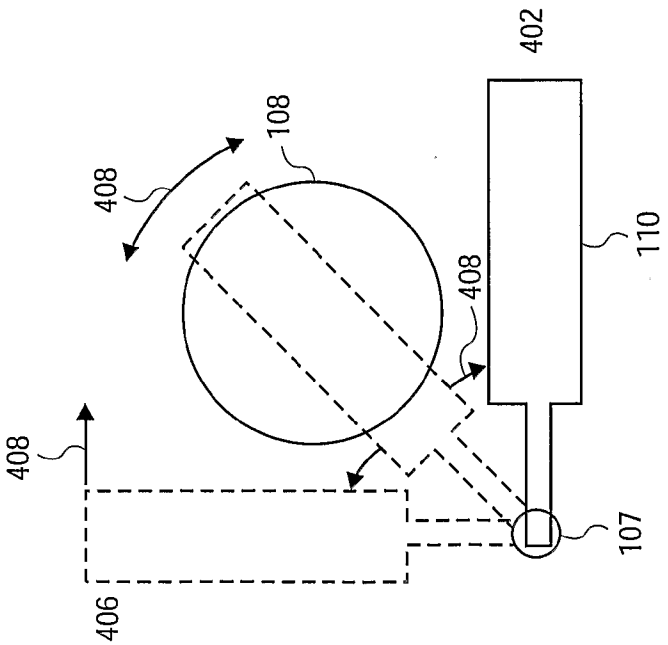


FIG. 4

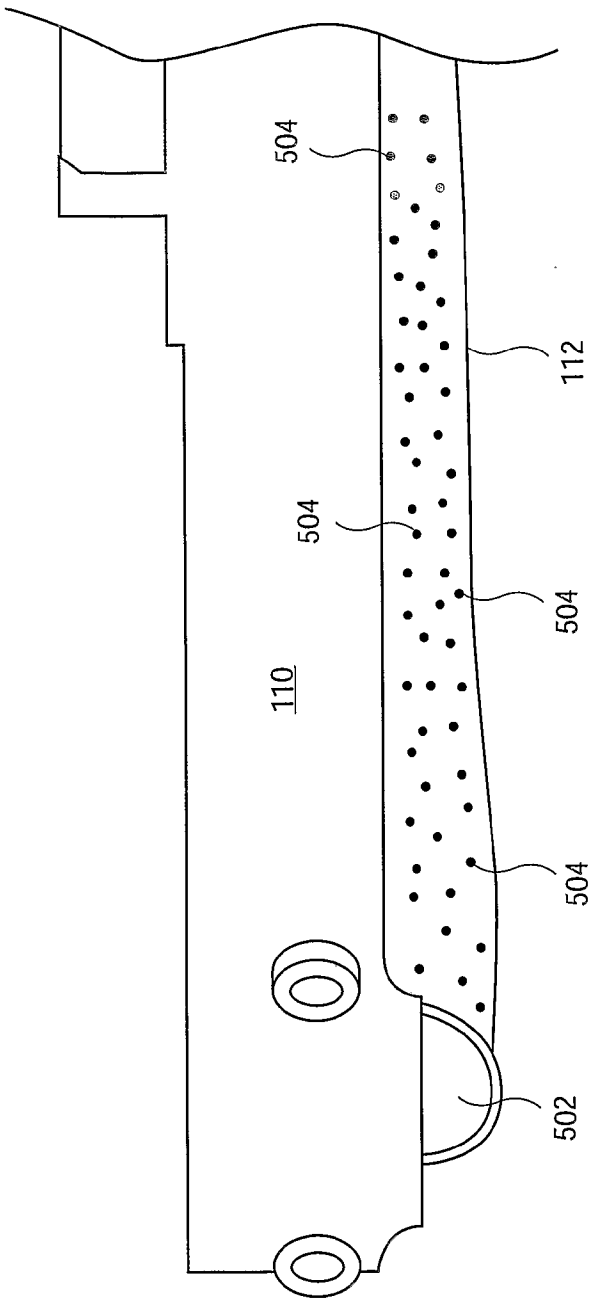


FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
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According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B24B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/029155 A1 (LI JUI-LUNG ET AL) 11 October 2001 (2001-10-11) paragraphs '0034!,'0035!,'0043!; claim 1; figure 3	1-17
A	US 2002/137436 A1 (GOTKIS YEHIEL ET AL) 26 September 2002 (2002-09-26) paragraph '0024!; figure 5C	16,17

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

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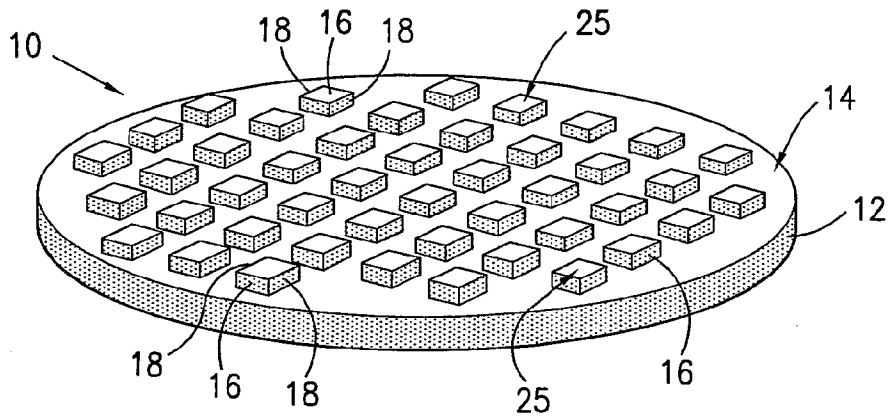
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(54) Title: SUPERHARD CUTTERS AND ASSOCIATED METHODS



(57) Abstract: A cutting device (10) comprises a base (12) having a working side (14) that is oriented to face a workpiece (19) from which material is to be removed. A plurality of individual cutting elements (16) are arranged on the working side of the base, with each cutting element having a peak that comprises at least one cutting edge (18) that is formed from a polycrystalline superhard material. The peaks of the cutting elements are aligned in a common plane (20).

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SUPERHARD CUTTERS AND ASSOCIATED METHODS

FIELD OF THE INVENTION

The present invention relates generally to cutting devices used to plane workpieces formed of various materials. Accordingly, the present invention involves the fields of chemistry, physics, and materials science.

BACKGROUND OF THE INVENTION

It is estimated that the semiconductor industry currently spends more than one billion U.S. Dollars each year manufacturing silicon wafers that exhibit very flat and smooth surfaces. Typically, chemical mechanical polishing ("CMP") is used in the manufacturing process of semiconductor devices to obtain smooth and even surfaced wafers. In a conventional process, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movement of the platen and the carrier.

While this well-known process has been used successfully for many years, it suffers from a number of problems. For example, this conventional process is relatively expensive and is not always effective, as the silicon wafers may not be uniform in thickness, nor may they be sufficiently smooth, after completion of the process. In addition to becoming overly "wavy" when etched by a solvent, the surface of the silicon wafers may become chipped by individual abrasive grits used in the process. Moreover, if the removal rate is to be accelerated to achieve a higher productivity, the grit size used on the polishing pad must be increased, resulting in a corresponding increase in the risk of scratching or gouging expensive wafers. Furthermore, because surface chipping can be discontinuous, the process throughput can be very low. Consequently, the wafer surface preparation of current state-of-the-art processes is generally expensive and slow.

In addition to these considerations, the line wide (e.g., nodes) of the circuitry on semiconductors is now approaching the virus domain (e.g., 10-100 nm). In addition, more layers of circuitry are now being laid down to meet the increasing demands of advanced logic designs. In order to deposit layers for making nanometer sized features, each layer must be extremely flat and smooth during the semiconductor fabrication. While diamond grid pad conditioners have been effectively used in dressing CMP pads for polishing

previous designs of integrated circuitry, they have not been found suitable for making cutting-edge devices with nodes smaller than 65 nm. This is because, with the decreasing size of the copper wires, non-uniform thickness due to rough- or over-polishing will change the electrical conductivity dramatically. Moreover, due to the use of coral-like dielectric layers, the fragile structure must be polished very gently to avoid disintegration. Hence, the pressure used in CMP processes must be reduced significantly.

In response, new CMP processes, such as those utilizing electrolysis (e.g. Applied Materials ECMP) of copper or those utilizing air film cushion support of wafer (e.g. Tokyo Semitsu), are being pursued to reduce the polishing pressure on the contact points between wafer and pad. However, as a consequence of gentler polishing action, the polishing rate of the wafer will decrease. To compensate for the loss of productivity, polishing must occur simultaneously over the entire surface of the wafer. In order to do so, the contact points between the wafer and the pad must be smaller in area, but more numerous in quantity. This is in contrast to current CMP practice in which the contacted areas are relatively large but relatively few in number.

Thus, in order to polish fragile wafers more and more gently, the CMP pad asperities must be reduced. However, to prevent the polishing rate from declining, more contact points must be created. Consequently, the pad asperities need to be finer in size but more in number. However, the more delicate the polishing process becomes, the higher the risk of scratching the surface of the wafer becomes. In order to avoid this risk, the highest tips of all asperities must be fully leveled. Otherwise, the protrusion of a few "killer asperities" can ruin the polished wafer.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a cutting device, including a base having a working side that can be oriented to face a workpiece from which material is to be removed. A plurality of individual cutting elements can be arranged on the working side of the base. Each cutting element can have a peak that comprises at least one cutting edge that is formed from a polycrystalline superhard material. The peaks of the cutting elements can be aligned in a common plane. The base and each of the cutting elements can be formed from an integral piece of polycrystalline superhard material.

In accordance with another aspect of the invention, a cutting device is provided, including a base having a working side that can be oriented to face a workpiece from

which material is to be removed. The base can be formed from an integral piece of a polycrystalline superhard material. A plurality of individual cutting elements can be integrally formed with the working side of the base. Each cutting element can have a peak that comprises at least a tip. The peaks of the cutting elements can be aligned in a common plane.

In accordance with another aspect of the invention, a method of forming the cutting device above is provided, including the steps of: providing a polycrystalline superhard material compact; and removing material from a working side of a base of the polycrystalline superhard material compact to form the plurality of individual cutting elements from the polycrystalline superhard material compact.

In accordance with another aspect of the invention, a product is provided that can be formed by the process comprising: engaging a surface of a workpiece with a plurality of individual cutting elements of a cutting device, the individual cutting elements being integrally formed from a working side of an integral piece of a polycrystalline superhard material and each cutting element having a peak that is aligned in a common plane; and moving the workpiece and the cutting device relative to one another to thereby remove material from the workpiece with the cutting elements.

There has thus been outlined, rather broadly, various features of the invention so that the detailed description thereof that follows may be better understood, and so that the present contribution to the art may be better appreciated. Other features of the present invention will become clearer from the following detailed description of the invention, taken with the accompanying exemplary claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, perspective view of a cutting device in accordance with an embodiment of the invention;

FIG. 2 is a side, plan view of the cutting device of FIG. 1;

FIG. 3 is a schematic, partial side view of a cutting element cutting a workpiece in accordance with an embodiment of the invention;

FIG. 4A is a perspective, more detailed view of a series of cutting elements in accordance with an embodiment of the invention;

FIG. 4B is a perspective view of a cutting device having arcuate cutting elements in accordance with an embodiment of the invention;

FIG. 5 is a sectional view of a pair of cutting elements of the cutting device of FIG. 1;

FIG. 6 is a sectional view of a cathode and an anode of an electrical discharge machining process;

FIG. 7A is a top view of a cutting device in accordance with an embodiment of the invention;

FIG. 7B is a sectional view of a series of cutting elements of the cutting device of FIG. 7A;

FIG. 8 is an image of a cutting device with a magnified image of a cutting element in accordance with an aspect of the invention; and

FIG. 9 is an image of a cutting device with a magnified image of a cutting element in accordance with an aspect of the invention.

It will be understood that the above figures are merely for illustrative purposes in furthering an understanding of the invention. Further, the figures may not be drawn to scale, thus dimensions, particle sizes, and other aspects may, and generally are, exaggerated to make illustrations thereof clearer. Therefore, departure can be made from the specific dimensions and aspects shown in the figures in order to produce the cutting devices of the present invention.

DETAILED DESCRIPTION

Before the present invention is disclosed and described, it is to be understood that this invention is not limited to the particular structures, process steps, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

It must be noted that, as used in this specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a cutting element" includes one or more of such elements and reference to "a brittle material" includes reference to one or more of such a material.

Definitions

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

As used herein, "particle" and "grit" may be used interchangeably, and when used in connection with a carbonaceous material, refer to a particulate form of such material. Such particles or grits may take a variety of shapes, including round, oblong, square, euhedral, etc., as well as a number of specific mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes. All mesh sizes referred to herein are U.S. mesh unless otherwise indicated. Further, mesh sizes are generally understood to indicate an average mesh size of a given collection of particles since each particle within a particular "mesh size" may actually vary over a small distribution of sizes.

As used herein, "substantial," or "substantially," refers to the functional achievement of a desired purpose, operation, or configuration, as though such purpose or configuration had actually been attained. Therefore, cutting edges that are substantially aligned in a common plane function as though, or nearly as though, they were precisely aligned in such a plane.

Furthermore, when used in an exclusionary context, such as a material "substantially lacking" or being "substantially devoid of, or free of" an element, the terms "substantial" and "substantially" refer to a functional deficiency of the element to which reference is being made. Therefore, it may be possible that reference is made to a material in which an element is "substantially lacking," when in fact the element may be present in the material, but only in an amount that is insufficient to significantly affect the material, or the purpose served by the material in the invention.

As used herein, "working side" refers to the side of a tool which contacts or is configured to contact material of a workpiece during a planing or dressing procedure. In some aspects, the working side may merely face a workpiece to be worked, but may not actually contact the workpiece.

As used herein, a "common plane" refers to a profile, including planar or contoured profiles, above a base surface with which the peaks of the cutting elements are to be aligned. Examples of such profiles may include, without limitation, wavy profiles, convex profiles, concave profiles, multi-tiered profiles, and the like.

As used herein, cutting "edge" refers to a portion of a cutting element that includes

some measurable width across a portion that contacts and removes material from a workpiece. As an exemplary illustration, a typical knife blade has a cutting edge that extends longitudinally along the knife blade, and the knife blade would have to be oriented transversely to a workpiece to scrape or plane material from the workpiece in order for the cutting "edge" of the knife blade to remove material from the workpiece.

As used herein, "superhard" may be used to refer to any crystalline, or polycrystalline material, or mixture of such materials which has a Mohr's hardness of about 8 or greater. In some aspects, the Mohr's hardness may be about 9.5 or greater. Such materials include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), polycrystalline cubic boron nitride (PcBN) as well as other superhard materials known to those skilled in the art. Superhard materials may be incorporated into the present invention in a variety of forms including particles, grits, films, layers, etc.

As used herein, "vapor deposition" refers to a process of depositing materials on a substrate through the vapor phase. Vapor deposition processes can include any process such as, but not limited to, chemical vapor deposition (CVD) and physical vapor deposition (PVD). A wide variety of variations of each vapor deposition method can be performed by those skilled in the art. Examples of vapor deposition methods include hot filament CVD, rf-CVD, laser CVD (LCVD), metal-organic CVD (MOCVD), sputtering, thermal evaporation PVD, ionized metal PVD (IMPVD), electron beam PVD (EBPVD), reactive PVD, and the like.

As used herein, "sintering" refers to the joining of two or more individual particles to form a continuous solid mass. The process of sintering involves the consolidation of particles to at least partially eliminate voids between particles. Sintering may occur in either metal or carbonaceous particles, such as diamond. Sintering of metal particles occurs at various temperatures depending on the composition of the material. Sintering of diamond particles generally requires ultrahigh pressures and the presence of a carbon solvent as a diamond sintering aid, and is discussed in more detail below. Sintering aids are often present to aid in the sintering process and a portion of such may remain in the final product.

As used herein, the term "cutting element" refers to a protrusion or an indentation formed in a cutting device that includes one or more cutting edges or tips that are configured to cut or plane material from a surface of a workpiece. While not so limited,

cutting elements described herein can include a frontal surface and an upper surface that meet at substantially a 90° angle to form the cutting edge. In some cases, cutting elements of the present invention have a three-dimensional configuration with relatively substantial width, depth and height. Each cutting element can include one or more cutting edges that have a cutting width coinciding with one of the width or depth of the cutting element.

As used herein, the term "peak" refers to a relative portion of a cutting element that extends the greatest distance from a base of a cutting element. Thus, when oriented to contact a workpiece, the peaks of cutting elements of a cutting device would contact the surface of the workpiece prior to any other portion of the cutting device contacting the workpiece.

As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

Concentrations, amounts, particle sizes, volumes, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited.

As an illustration, a numerical range of "about 1 micrometer to about 5 micrometers" should be interpreted to include not only the explicitly recited values of about 1 micrometer to about 5 micrometers, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc. This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides a cutting device and associated methods that can be utilized in cutting or otherwise affecting a workpiece to remove material from the

workpiece and provide a finished, smooth and/or flat surface to the workpiece. Cutting devices of the present invention can be advantageously utilized, for example, as planing devices that plane material from a workpiece, as dressing devices that dress various workpieces, and as polishing devices that polish various workpieces.

In the embodiment of the invention illustrated in FIG. 1, the cutting device 10 can include a base 12 that can have a working side 14 that faces a workpiece (19 in FIG. 3) to be cut or planed. A plurality of individual cutting elements 16 can be arranged on the working side of the base. Each of the cutting elements can include at least one cutting edge or tip 18, each of which can be aligned in a common plane 20, shown schematically in FIG. 2. As discussed in more detail below, the cutting edges can be engaged with the workpiece 19, and the workpiece and the cutting edges can be moved relative to one another, to cut, slice, plane or otherwise remove small pieces or chips from the workpiece to create a surface on the workpiece that is both very flat and very smooth.

In one aspect of the invention, each of the cutting elements 16 can include one or a plurality of cutting edges 18 aligned in the common plane 20. Thus, in the embodiment illustrated in FIG. 1, each of the cutting elements includes four cutting edges, which can each serve to cut or plane material from a workpiece. By including a plurality of cutting elements, each with a plurality of cutting edges, a total length of cutting edges per cutting element can be advantageously increased. In addition, since each cutting element is of substantially the same height, relative to the working surface of the base, all of the cutting edges from all of the cutting elements can be aligned in the same common plane. By aligning each of the cutting edges in a common plane, the cutting device is substantially self-aligned to shave higher regions of the workpiece first, then continue cutting until all "high" points on the workpiece have been reduced, leaving a smooth and flat workpiece surface.

The cutting edges 18 of the cutting elements 16 can be formed from a variety of materials including, in one embodiment, a polycrystalline superhard material. While not so limited, the polycrystalline superhard material can be a polycrystalline diamond compact ("PCD") or a polycrystalline cubic boron nitride compact ("PcBN"). The PCD or PcBN compact can be formed in a variety of manners, as discussed in more detail below. In the aspect of the invention shown in FIG. 1, the base 12 and each of the cutting elements 16 and cutting edges 18 are integrally formed from an integral piece of polycrystalline superhard material.

The cutting device of the present invention can be utilized in a number of applications, and in one embodiment is particularly well adapted for use in planing substantially brittle materials, such as silicon wafers, glass sheets, metals, used silicon wafers to be reclaimed by planarization, LCD glass, LED substrates, SiC wafers, quartz wafers, silicon nitride, zirconia, etc. In conventional silicon wafer processing techniques, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movements of the platen and the carrier. Thus, the silicon wafer is essentially ground or polished, by very fine abrasives, to a relatively smooth surface.

While grinding of silicon wafers has been used with some success, the process of grinding materials such as silicon wafers often results in pieces of the material being torn or gouged from the body of the material, resulting in a less than desirable finish. This is due, at least in part, to the fact that grinding or abrasive processes utilize very sharp points of abrasive materials (which are often not level relative to one another) to localize pressure to allow the abrasives to remove material from a workpiece.

In contrast to conventional polishing or grinding processes, the present invention can utilize one or more cutting edges of cutting elements to cut material from a workpiece to finish or plane a surface of the workpiece. In general, when a cut is made in a material, the region of the cut will either deform plastically or will crack in a brittle manner. If the plastic deformation is slower than the crack propagation, then the material is known as brittle. The reverse is true for ductile deformation. However, under a high pressure, the rate of crack propagation is suppressed. In this case, a brittle material (e.g. silicon) may exhibit more ductile characteristics, similar to soft metals. When a sharp cutting edge of the present invention is pressed against the surface of brittle silicon, the area of the first contact is extremely small (e.g. a few nanometers across). Consequently, the pressure can be very high (e.g. several GPa). Because the cracks are suppressed, the sharp diamond edge can penetrate silicon plastically. As a result, the external energy can be transferred to the very small volume of silicon continually to sustain the ductile cutting. In other words, the sharp cutting edges can shave or plane silicon in a manner not previously achieved.

The PCD or PcBN compacts of the present invention are generally superhard, resulting in little yielding by the cutting elements when pressed against a wafer. As hardness is generally a measure of energy concentration, e.g., energy per unit volume, the

PCD or PcBN compacts of the present invention are capable of concentrating energy to a very small volume without breaking. These materials can also be maintained with a very sharp cutting edge due to their ability to maintain an edge within a few atoms.

As the ductility of the silicon is maintained by applying pressure to a very small volume, the penetrating radius is generally kept relatively small. This is shown by example in FIG. 2, where the depth of the cutting elements 16 is shown generally by the letter "d" and is on the order of about 0.1 mm. In addition, the shape of the cutting edge must be kept relatively sharp; in some cases with a radius on the order of 2 nm. In order to accommodate these dual traits, the material of the cutting edge of the present invention is hard enough to withstand deformation during the cutting or planing process. In this manner, both sharpness and hardness of the cutter is realized to ensure the ductility of the workpiece. The ductile process of cutting and removing material from a workpiece is shown schematically in FIG. 3, where cutting edge 18 of cutting element 16 is shown shaving chip 24 from the workpiece 19.

Each of the cutting elements 16 can include a substantially planar face 25 that can define a workpiece contact area. A combined workpiece contact area of all of the cutting elements can comprise from between about 5% of a total area of the base to about 20% of a total area of the base. Thus, in one aspect of the invention, if a PCD cutter has a diameter of about 100 mm, and the combined contact areas of the cutting element will be about 10% of that total, then the total contact area of all cutting elements can be about 7850 mm^2. An edge-to-area ratio of each cutting element can be about 4/mm, resulting in a total edge length being about 31400 mm.

The life of the PCD or PcBN cutting devices can often be limited by the radius of the cutting edge. When the edge becomes worn such that the radius is increased to about 10 nm, the contact area may increase up to 100 times. This will reduce the contact pressure significantly. As a result, the edge will not "bite" into the silicon but will rather slide against its surface. In this case, heat will be generated, and the wafer surface might become thermally damaged. Thus, in it can be important that a sharp edge be maintained on the cutting edges, less than about 10 nm in radius for many applications.

The contact area of a cutting device in accordance with the present invention will generally determine the pressure applied to the workpiece. Generally, the larger the area ratio is between the cutting element contact area and the groove, the smaller the contact pressure between the cutting element and the workpiece will be. The contact pressure (P)

will determine the penetration depth (d) as the following expression:

$$d = Pt/B,$$

where t is the thickness of the wafer; and B is the bulk modulus of the workpiece.

In general, bulk modulus measures the incompressibility of a material. Its value generally correlates to the pressure to compress a material completely (zero thickness) at the initial rate of volume reduction. Bulk modulus of a PCD compact is about 4 Mb (megabars); the bulk modulus of silicon is about 1 Mb. Thus, silicon is about four times more compressible than a PCD compact. When a PCD cutting device or planer is pressed against a silicon wafer, the relative displacement of the wafer is due primarily to the sink of silicon wafer surface relative to the PCD surface. A typical silicon wafer is about 1 mm in thickness, so the shaving depth may be approximated by:

$d = 10^{-6}$ P mm, where P is expressed in bar or atmospheric pressure.

If P = 1 bar, then the shaving thickness is about 1 nm. This is about five atomic layers. At this penetration depth, if the cutting edge is sharp (e.g. radius < 1 nm), then the shaving or cutting is ductile, resulting in a finished, planed surface that is very smooth, in some cases smoother than a mirror finish. For this reason, it is important to shave, cut or plane a silicon wafer with very sharp edge of the PCD planer. If the edge becomes overly dull, the ductility of silicon can be lost and the resulting brittle fracturing may destroy the wafer surface.

The cutting devices of the present invention can be utilized in either a wet system or a dry system. In a dry application, the cutting elements can be used to cut or plane chips from a workpiece without the presence of a liquid slurry. In a typical application, the cutting device can be mounted to a holder cushion that can be coupled to a rotatable chuck. The workpiece, for example, a silicon wafer, can be coupled to a vacuum chuck that provides for rotation of the workpiece. Both the rotatable chuck and the vacuum chuck can be rotated in either a clockwise or a counterclockwise direction to remove material from the workpiece. By changing the rotation of one element relative to another, more or less material can be removed in a single rotation of the workpiece. For example, if the workpiece and planer are rotated in the same direction (but at different speeds), less material will be removed than if they are rotated counter to one another.

In this typical application, a slurry can be applied that can aid in planing the workpiece surface. The slurry can be either a water slurry or a chemical slurry. In the case where a chemical slurry is used, the chemical can be selected to provide cooling or to react with the surface of the workpiece to soften the workpiece to provide a more efficient cutting process. It has been found that the wear rate of a silicon wafer can be dramatically increased by softening its surface. For example, a chemical slurry that contains an oxidizing agent (e.g. H_2O_2) may be used to form a relatively highly viscous oxide that will tend to "cling" on the wafer surface. In this case, the PCD cutting devices of the present invention need not necessarily cut the wafer, but rather can scrape the oxide off the surface of the wafer. Consequently, the sharpness of the cutting edge becomes less critical. In addition, the service life of the cutting device can be greatly extended by utilizing a slurry. For example, a PCD scraper used with a slurry may last 1000 times longer than a PCD cutter.

Another way to expedite the removal of silicon wafer is by applying a DC current across the wafer surface. Although diamond is an insulator, PCD is often electrically conducting due to its inclusions of metallic cobalt. In this case, the silicon wafer can be connected to an anode (not shown) and the PCD can be connected to a cathode (not shown). An electrolytically conducting slurry may be used to bridge the two electrodes. In this case, the surface of the silicon may be oxidized by anodation. Furthermore, silicon or its surface circuitry can be dissolved by electrolysis that will further accelerate the material removal process.

Thus, if the cutting device is used to shave or plane in a dry system, it may last for a few passes on a 12 inch wafer. However, chemical slurry may increase the scraped surface area by a thousand times, and if electrical current is applied to assist the material removal, the cutting device may last an even longer time.

FIG. 4A illustrates a variety of cutting elements 16a, 16b, 16c in accordance with an embodiment of the invention. In this aspect of the invention, the cutting elements can be sized and shaped with rectangular cross sections, oval cross sections, circular cross sections, triangular, polygonal, pyramidal cross sections, etc. The various sized and shaped cutting elements can be formed by varying locations, and widths, of grooves cut on the surface of the PCD or PcBN compacts. While not shown in the figures, the cutting elements can also be formed below the surface of a PCD or a PcBN compact, such that the cutting elements comprise inset cavities that include, for example, circular or polygonal

shapes.

As shown in FIG. 4B, the cutting elements 16d can be formed in elongate, arcuate fashion, with grooves cut or formed between the cutting elements. The grooves or depressed regions of the PCD or PcBN compacts can serve as the reservoirs for slurry used to cut wafer, as well as for cut debris. The pattern of the network and the depth of the grooves or recessions can affect the flow for both slurry and debris. Each PCD cutting element design can be optimized for the individual process of planarization of a particular workpiece.

FIG. 5A illustrates two additional embodiments of the invention in which cutting element 16 of the cutting device 10 of FIG. 1 includes a series of secondary cutting elements 40a and 40b formed on an upper surface or face of the cutting element. In this aspect of the invention, the secondary cutting elements can be configured to maintain a sharpness of each of the cutting edges during use of the cutting device. As shown, the secondary cutting elements can vary in shape, and can include pyramidal-shaped cutting elements. The secondary cutting elements can also be formed in a truncated pyramidal shape (not shown). By utilizing secondary cutting elements on the primary cutting elements, the total cutting edge length of the cutting element can be extended by as much as 10,000 times.

FIGs. 7A and 7B illustrate another embodiment of the invention in which a plurality of cutting elements 16e and 16f are formed in a PCD base 12a. As can be appreciated from FIG. 7A, the present invention can provide for the integral formation from a superhard polycrystalline material of cutting elements having differing sizes and configurations. For example, in the embodiment shown, the larger cutting elements 16e can be used as cutting, planing or dressing elements while the smaller cutting elements 16f can be used primarily as "stopping" elements. In other words, the larger cutting elements can extend further from the base 12a of the PCD to cut further, or deeper, into the workpiece (not shown in this figure) on which the PCD is being used.

When the larger cutting elements 16e extend sufficiently far, or deep, into the workpiece, the smaller cutting elements can "bottom out" on the surface of the workpiece to limit further traveling of the larger elements 16e into the workpiece. To facilitate this concept, the larger cutting elements can be made sharper than the smaller cutting elements: for example, they can terminate in an apex point, while the smaller cutting elements can terminate in a flat, planar face. In this manner, the larger cutting elements can more easily

cut the workpiece than can the smaller cutting elements, causing the smaller elements to serve as depth "stopping" elements. In this manner, the present invention can provide very accurate control of the depth that the cutting elements cut into a workpiece (e.g., a PCD pad that is being dressed).

FIGs. 8 and 9 present images taken of cutting elements 16g and 16h, respectively, formed from an integral piece of PCD. As will be appreciated, the present invention provides a great deal of flexibility in the shape and size of the cutting elements that can be formed, with some cutting elements formed in an upright "mesa" configuration, and others formed in a pyramidal configuration.

In addition, as the cutting elements of the present invention can be formed from an integral piece of polycrystalline superhard material, there generally remains a useful excess portion of polycrystalline superhard material below the cutting elements on the base of the cutting device (or that forms the base of the cutting device). Thus, in one aspect of the invention, once the cutting elements have become dull or damaged during use, the cutting device can be sharpened by removing a thin layer of the superhard material across the entire face of the cutting device in the same pattern that was originally created on the face of the device. Cutting devices of the present invention can thus be relatively easily sharpened or repaired, so long as sufficient polycrystalline material remains beneath the cutting elements to allow for further sharpening of the cutting elements.

The PCD or PcBN compacts utilized in the present can be formed in a variety of manners. In one embodiment of the invention, the PCD compact can contain micron (e.g. 1 to 10 μm) diamond, and can be polished before use. In another aspect, the diamond grains can be large (e.g. 50 μm) and the surface can be ground without polishing. In one aspect of the invention, SiC grains can be mixed with diamond grains as the feed stock for a PCD compact. The PCD can include a diamond content of about 80% to about 98% by volume.

The cutting elements of the present invention can be formed on or in the polycrystalline superhard material in a variety of manners. In one aspect, the grooves between the individual cutting elements can be formed on a PCD surface with electro-chemical machining, by laser ablation, by plasma etching, by oxidation (to form carbon dioxide or monoxide gas), hydrogenation (to form methane gas), etc. Laser beams with relatively longer wavelengths (e.g. ND:YAG) have been shown to form grooves on PCD effectively. Laser beams with relatively short wavelengths (e.g. excimers) may be used to

carve out the secondary cutting elements on top of the primary cutting elements (as shown in FIG. 5). While the latter may be slower in cutting speed, it is generally more precise due to the shorter wavelength used. Moreover, the surface damage can be less with more concentrated energy in higher frequencies. This has been found suitable for shaving or planing a silicon wafer in accordance with the present invention.

In another aspect of the invention, material can be removed from a polycrystalline superhard material compact to integrally form the individual cutting elements from the polycrystalline superhard material compact. In other words, the cutting elements can be formed by removing the polycrystalline material from around and about the cutting elements, leaving the cutting elements as the only remaining material above the base of the cutting device.

In one aspect of the invention, the material is removed from the PCD or PcBN compact by electrical discharge machining ("EDM"). In this aspect, the EDM process can utilize one or more electrodes that include diamond. For example, the cathode used in the EDM process can be a boron doped diamond material and the anode used in the EDM process can be the PCD (in this case, the PCD would generally need to be at least partially electrically conductive). As current is applied through the boron doped diamond material, the material of the PCD can be carefully and controllably removed to form various patterns on the PCD.

As shown for example in FIG. 6, in one aspect of the invention, the anode 30 of the EDM process can comprise a portion of a boron doped diamond ("BDD") material through which current is applied. The BDD anode can include a series of "V"-shaped protrusions 31 that, during the EDM process, form a series of corresponding channels 32 in the PCD compact 34 (which, in turn, define a plurality of cutting elements in the PCD compact). While the protrusions are shown as being generally V-shaped, it is of course contemplated that they can be formed in a variety of shapes that can be selected to form channels having desired shapes in the PCD compact. As is known to those having ordinary skill in the art, the EDM process will generally utilize an insulating liquid such as oil or deionized water, the details of which are not illustrated in the drawings.

It has been found that, while the configuration illustrated in FIG. 6 (in which the PCD compact serves as the cathode of the EDM process and the BDD material serves as the anode) performs well, the reverse configuration can also be used. For example, in this aspect of the invention, the BDD material is used as the anode and the PCD is used as the

cathode, resulting in the PCD material removal rate being relatively fast (note that both the BDD material and the PCD material will be consumed, at varying rates, during the EDM process). However, by reversing the polarity (e.g., by using the BDD as the cathode and the PCD as the anode), the PCD material removal rate will be slower than in the first configuration but the surface finish of the PCD will better.

It is contemplated that the use of an electrically conducting diamond containing material as an electrode to remove material from another electrically conducting diamond containing material (as the other electrode) can be extended to a variety of applications in addition to those explicitly discussed herein. For example the diamond-diamond EDM process can be utilized to remove material from an electrically conductive diamond material that is used in: abrasive applications, load bearing applications, protective covering applications, heat spreading applications, material molding applications, acoustic applications, semiconductor applications, etc.

In accordance with another aspect, the present invention provides a product formed by a process comprising: engaging a surface of a workpiece with a plurality of individual cutting elements of a cutting device, the individual cutting elements being integrally formed from a working side of an integral piece of a polycrystalline superhard material and each cutting element having a peak that is aligned in a common plane; and moving the workpiece and the cutting device relative to one another to thereby remove material from the workpiece with the cutting elements.

Examples

The following examples present various methods for making the cutting tools of the present invention. Such examples are illustrative only, and no limitation on present invention is meant thereby.

Example 1:

A boron doped diamond film ("BDD") having a resistivity of about 0.001 ohm-cm and a thickness of about 500 μm has a "zigzag" pattern formed on one edge via a wire EDM process. The resulting blade is mounted on an EDM machine as a cathode. The anode is a flat PCD about 100 mm in diameter and about 2 mm in thickness. The diamond table used is about 500 μm in thickness. An electrically conducting fluid is used to carry the electricity between the two electrodes. During the EDM process, the PCD is gradually traversed across the stationary BDD blade. This process is repeated while the BDD is

gradually descending into the PCD compact. The portion of the PCD that is brought in close proximity to the edge of the BDD is selectively eroded away by electrical discharging, electrolysis, and dissolution.

In this manner, a corresponding "zigzag" pattern of ridges is gradually formed on the flat PCD top. When the grooves reach a predetermined height (e.g., 80 μm), the serrated ridges so formed are cleaned for measurements of geometry. Subsequently, the PCD is rotated 90 degrees and the process is repeated such that pyramid shapes are formed. The angle of the pyramids produced generally matches the angle of the zigzag pattern on the BDD. The tips of these pyramids also duplicate the pattern of recesses of the zigzag pattern on the BDD.

The PCD planer so formed has improved dimension tolerances compared to PCD planers formed by metallic electrodes used in an EDM process. In addition, the consumption rate of BDD blade is much lower. Also, the voltage (90 V) and current (30A) utilized are much lower than metallic electrode processes (e.g. 120 V and 80A). During the process of EDM, the pulsation period for EDD (20 micro seconds on by 20 micro seconds off) can be 10 times longer due to diamond's exceptional thermal stability, thermal conductivity, and chemical inertness. It was estimated that the maximum electrode temperature (about 400° C, compared to oxidation threshold temperature of 750° C) during the BDD EDM process was about 200° C lower than that of the metallic process. The wear rate of the BDD (0.3%) was also fractional compared to the wear rate of copper tungsten (30%). The EDM speed (20 microns per minutes) was twice as fast.

Example 2

The above example was repeated with the reverse polarity: e.g., the BDD was positively biased. In this case, the EDM process was still viable except that the wear rate of the BDD was more than doubled. However, the surface finish of the ADD improved due to a slower erosion rate on the surface.

Example 3

The process of Example 1 was repeated except that the cathode was replaced by a PCD blank of 1.6 mm in thickness (PCD table 0.5 mm thick, cemented tungsten carbide 1.5 mm thick). The PCD used had a 25 μm diamond grain size, it contained 10 wt% of cobalt and had an electrical resistivity of 0.001 ohm-cm.

Example 4

BDD grits of 100/120 mesh were used to make a bronzed bonded grinding wheel. The outside diameter was shaped by a BDD EDM process to form a zigzag pattern thereon. The BDD wheel was then used as a cathode for an EDM process performed on a PCD blank. During the traversing of the PCD surface, the BDD wheel was slowly turned to uniformly expose the contact edge from which electrical current was emitted. After the ridges were formed, the PCD was rotated to traverse in a perpendicular direction until a series of pyramidal cutting elements were formed on the PCD.

Example 5

A BDD was formed to an "A" point and used as an anode in an EDM process. A PCD compact was rotated about the "A" point to gradually form a V notch in the PCD compact. The V notch was formed at several radius positions in order to produce concentric ridges on the PCD surface. The resulting tool can be used as a PCD planer for truing workpieces.

Example 6

The process of Example 5 was repeated followed by traversing the "zigzag"-patterned BDD in three equally spaced directions. The resulting triangular pyramid formed concentric island chains. The resulting tool included excellent radial slurry/debris passages as well as very sharp cutting points.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use may be made without departing from the principles and concepts set forth herein.

CLAIMS

What is claimed is:

1. A cutting device, comprising:

a base having a working side that can be oriented to face a workpiece from which material is to be removed; and

a plurality of individual cutting elements arranged on the working side of the base, each cutting element having a peak that comprises at least one cutting edge that is formed from a polycrystalline superhard material, the peaks of the cutting elements being aligned in a common plane.

2. The device of claim 1, wherein the base and each of the cutting elements are formed from an integral piece of polycrystalline superhard material.

3. A cutting device, comprising:

a base having a working side that can be oriented to face a workpiece from which material is to be removed, the base being formed from an integral piece of a polycrystalline superhard material; and

a plurality of individual cutting elements integrally formed with the working side of the base, each cutting element having a peak that comprises at least a tip, the peaks of the cutting elements being aligned in a common plane.

4. The device of either of claim 2 or claim 3, wherein the polycrystalline superhard material comprises a polycrystalline diamond compact.

5. The device of claim 4, wherein the polycrystalline diamond compact has a diamond grain size of about 50 μm or smaller.

6. The device of claim 5, wherein the polycrystalline diamond compact has a diamond grain size of about 1 μm to about 10 μm.

7. The device of claim 4, wherein the polycrystalline diamond compact has a diamond content of about 80% to about 98% by volume.

8. The device of either of claim 2 or claim 3, wherein the polycrystalline superhard material comprises a polycrystalline cubic boron nitride compact.

9. The device of claim 1, wherein the cutting device comprises a planing device.

10. The device of claim 3, wherein the cutting device comprises a dressing device.

11. The device of claim 1, further comprising a series of secondary cutting elements formed on a face of each of the cutting elements, the secondary cutting elements being configured to maintain a sharpness of each of the cutting edges during use of the cutting device.

12. The device of either of claim 1 or claim 3, wherein the peaks of the cutting element are operable to cut a substantially brittle material.

13. The device of claim 12, wherein the brittle material is a member selected from the group consisting of: a metal, a silicon wafer, a used silicon wafer to be reclaimed by planarization, LCD glass, an LED substrate, a SiC wafer, a quartz wafer, silicon nitride, zirconia, sapphire, lithium niobate, lithium titantate, PZT, gallium arsenide, gallium nitride, indium nitride, boron phosphate, aluminum nitride and boron nitride.

14. The device of either of claim 1 or claim 3, wherein the peak of each of the cutting elements includes a plurality of cutting edges aligned in the common plane.

15. The device of either of claim 1 or claim 3, wherein the peak of each of the cutting elements includes a shape selected from the group consisting of: a square, a rectangle, a triangle, a hexagon, a circle and an oval.

16. The device of either of claim 1 or claim 3, further comprising a series of secondary cutting elements having at least a tip aligned in a second common plane, the second common plane being disposed closer to an opposing side of the base than is the common plane, the secondary cutting elements being configured to limit a depth to which the cutting elements can cut into the workpiece.

17. The device of claim 16, wherein the secondary cutting elements terminate in a planar face.

18. The device of either of claim 1 or claim 3, wherein the peaks of the cutting elements are leveled relative to the common plane within about 0.5 μm to about 50 μm.

19. The device of claim 18, wherein the peaks of the cutting elements are leveled relative to the common plane within about 25 μm.

20. The device of either of claim 1 or claim 3, wherein the common plane is pitched from about 200 μm to about 2000 μm across the working side of the cutting device.

21. A method of forming the cutting device as recited in either claim 2 or claim 3, comprising the step of:

providing a polycrystalline superhard material compact; and

removing material from a working side of a base of the polycrystalline superhard material compact to form the plurality of individual cutting elements from the polycrystalline superhard material compact.

22. The method of claim 21, wherein the polycrystalline superhard material compact comprises a polycrystalline diamond compact.

23. The method of claim 22, wherein the polycrystalline diamond compact has a diamond grain size of about 50 μm or smaller.

24. The method of claim 23, wherein the polycrystalline diamond compact has a diamond grain size of about 1 μm to about 10 μm.

25. The method of claim 22, wherein the polycrystalline diamond compact has a diamond content of about 80% to about 98% by volume.

26. The method of claim 21, wherein the polycrystalline superhard material compact comprises a polycrystalline cubic boron nitride compact.

27. The method of claim 21, further comprising forming a series of secondary cutting elements on an upper surface of each of the cutting elements, the secondary cutting elements being configured to maintain a sharpness of each of the cutting elements during use of the cutting device.

28. The method of claim 21, wherein cutting edges of the cutting elements are operable to cut a substantially brittle material.

29. The method of claim 28, wherein the brittle material is a member selected from the group consisting of: a metal, a silicon wafer, a used silicon wafer to be reclaimed by planarization, LCD glass, an LED substrate, a SiC wafer, a quartz wafer, silicon nitride, zirconia, sapphire, lithium niobate, lithium titantate, PZT, gallium arsenide, gallium nitride, indium nitride, boron phosphate, aluminum nitride and boron nitride.

30. The method of claim 21, wherein forming the cutting elements includes aligning a plurality of cutting edges of each cutting element in the common plane.

31. The method of claim 21, wherein the peak of each of the cutting elements includes a shape selected from the group consisting of: a square, a rectangle, a triangle, a circle and an oval.

32. The method of claim 21, wherein removing material from the working side of the base includes removing material by a process selected from the group consisting of: laser ablation, electro-chemical machining, plasma etching, oxidation and hydrogenation.

33. The method of claim 21, wherein removing material from the working side of the base includes removing material by electrical discharge machining.

34. The method of claim 33, wherein the electrical discharge machining process utilizes an electrode that includes diamond.

35. The method of claim 34, wherein the electrode is an anode that includes boron doped diamond.

36. The method of claim 35, wherein the boron doped diamond anode includes a series of shaped protrusions extending therefrom, the shaped protrusions being configured to remove material from the face of the compact in a grooved pattern.

37. The method of claim 34, wherein the electrode is a cathode that includes boron doped diamond.

38. The method of claim 35, wherein the boron doped diamond cathode includes a series of shaped protrusions extending therefrom, the shaped protrusions being configured to remove material from the face of the compact in a grooved pattern.

39. The method of claim 21, wherein removing material from the face of the compact further comprises forming a series of secondary cutting elements having at least a tip aligned in a second common plane, the second common plane being disposed closer to an opposing side of the compact than is the common plane, the secondary cutting elements being configured to limit a depth to which the cutting elements can cut into the workpiece.

40. The method of claim 39, wherein each of the secondary cutting elements terminates in a planar face.

41. The method of claim 21, wherein the peaks of the cutting elements are leveled relative to the common plane within about 0.5 μm to about 50 μm.

42. The method of claim 41, wherein the peaks of the cutting elements are leveled relative to the common plane within about 25 μm.

43. The method of claim 21, wherein the common plane is pitched from about 200 μm to about 2000 μm across the face of the cutting device.

44. A product formed by a process comprising:

engaging a surface of a workpiece with a plurality of individual cutting elements of a cutting device, the individual cutting elements being integrally formed from a working side of an integral piece of a polycrystalline superhard material and each cutting element having a peak that is aligned in a common plane; and

moving the workpiece and the cutting device relative to one another to thereby remove material from the workpiece with the cutting elements.

45. The product of claim 44, wherein the polycrystalline superhard material comprises a polycrystalline diamond compact.

46. The product of claim 45, wherein the polycrystalline diamond compact has a diamond grain size of about 50 μm or smaller.

47. The product of claim 46, wherein the polycrystalline diamond compact has a diamond grain size of about 1 μm to about 10 μm.

48. The product of claim 45, wherein the polycrystalline diamond compact has a diamond content of about 80% to about 98% by volume.

49. The product of claim 44, wherein the polycrystalline superhard material comprises a polycrystalline cubic boron nitride compact.

50. The product of claim 44, wherein each of the plurality of cutting elements includes a cutting edge aligned in the common plane.

51. The product of claim 44, wherein the process further comprises engaging the surface of the workpiece with a series of secondary cutting elements having at least a tip aligned in a second common plane, the second common plane being disposed closer to an opposing side of the polycrystalline superhard material than is the common plane, to thereby limit a depth to which the cutting elements cut into the workpiece.

52. The product of claim 51, wherein the secondary cutting elements terminate in a planar face.

53. The product of claim 44, wherein the peaks of the cutting elements are leveled relative to the common plane within about 0.5 μm to about 50 μm.

54. The product of claim 44, wherein the peaks of the cutting elements are leveled within about 15 μm.

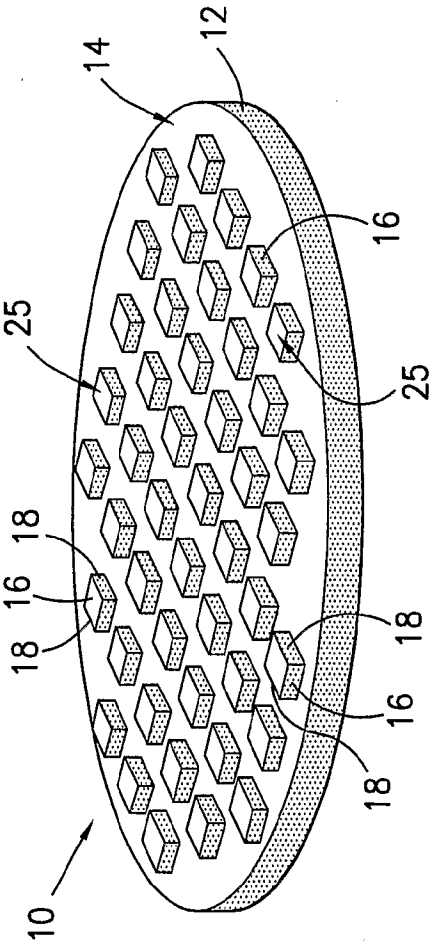


FIG. 1

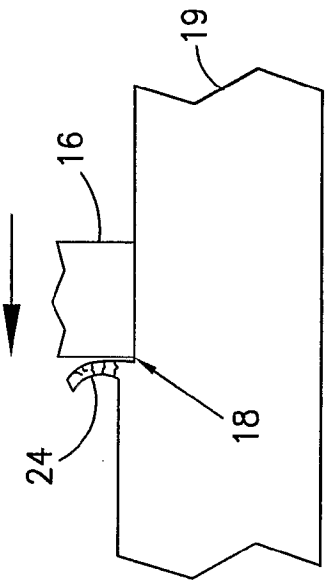


FIG. 3

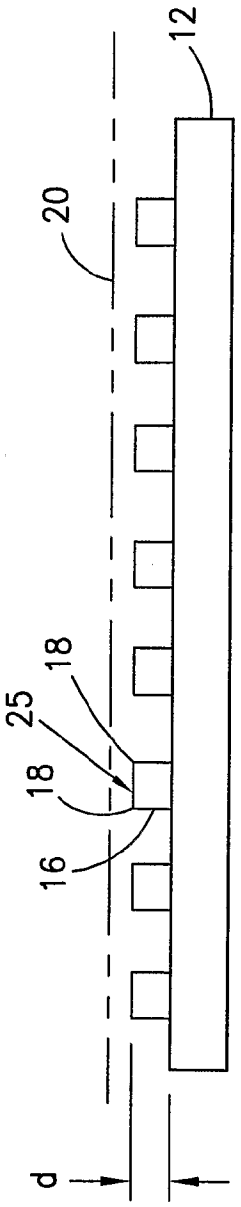


FIG. 2

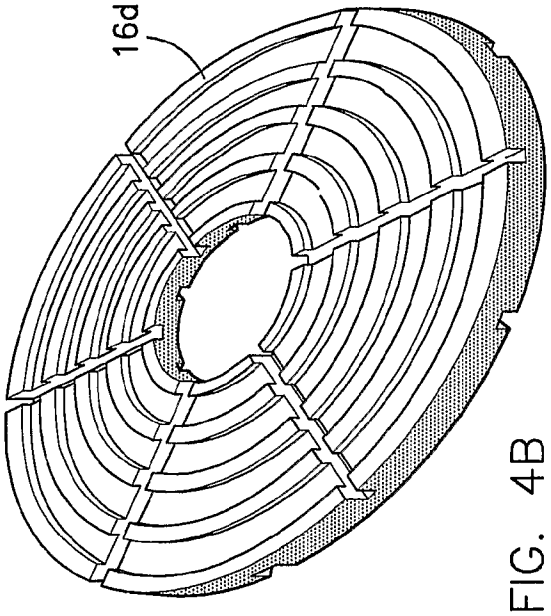


FIG. 4B

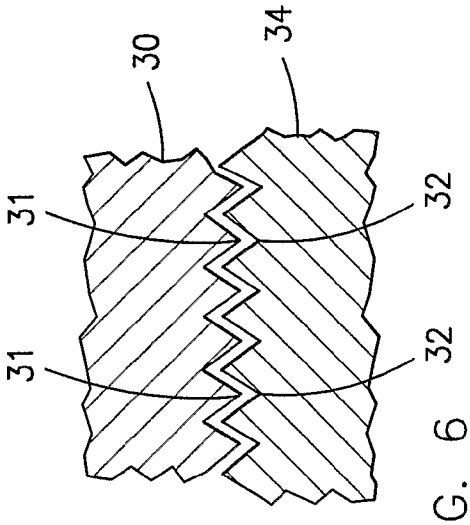


FIG. 6

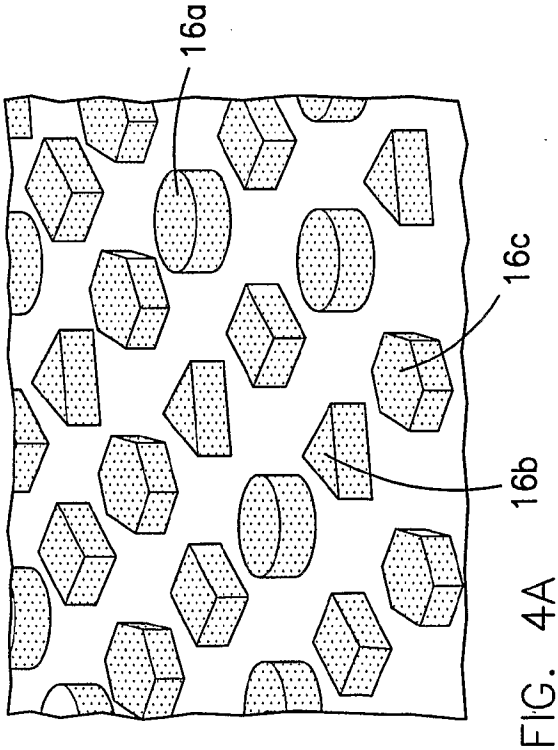


FIG. 4A

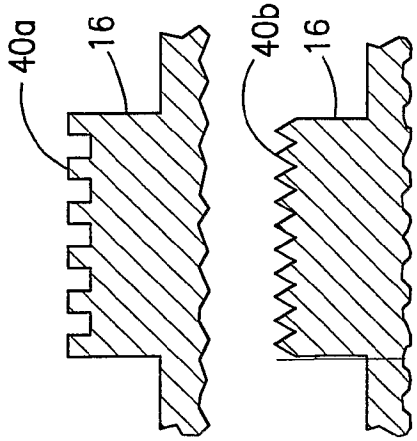


FIG. 5

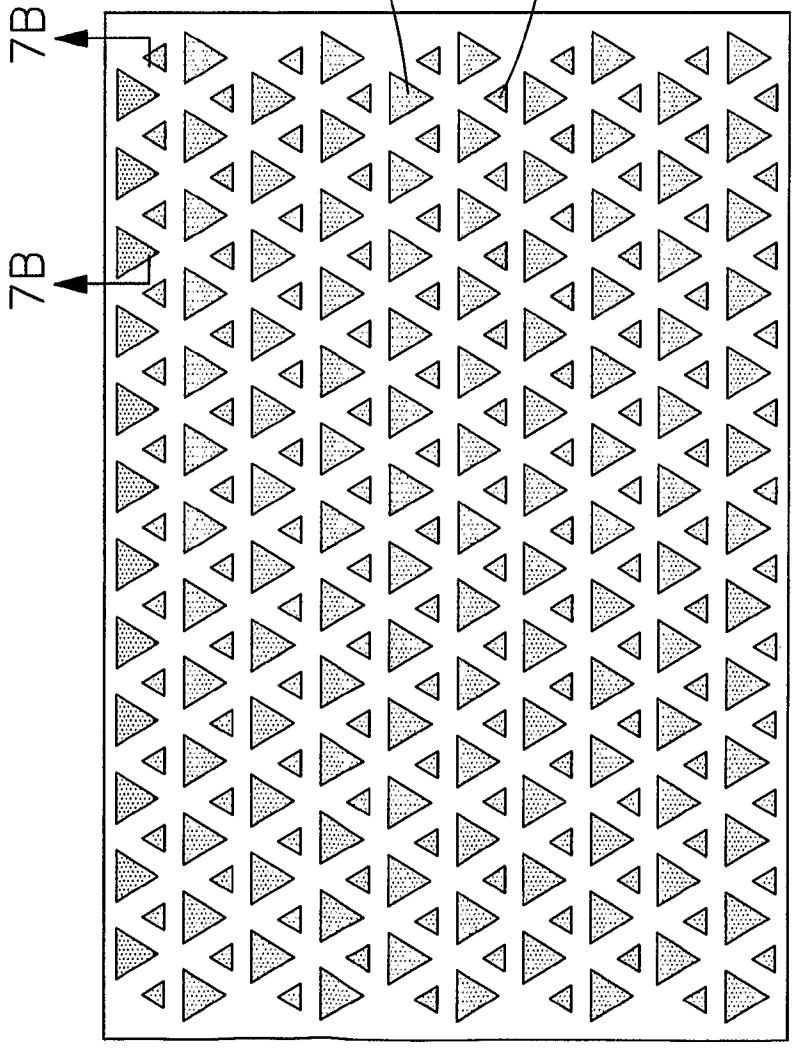


FIG. 7A

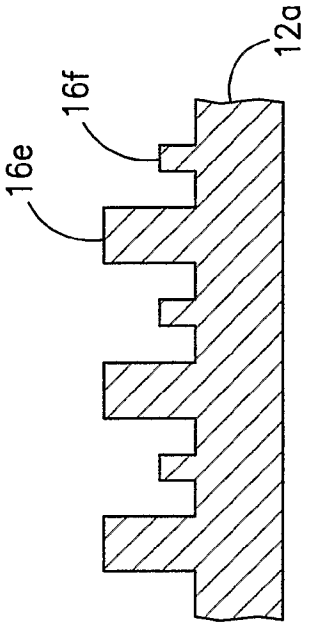


FIG. 7B

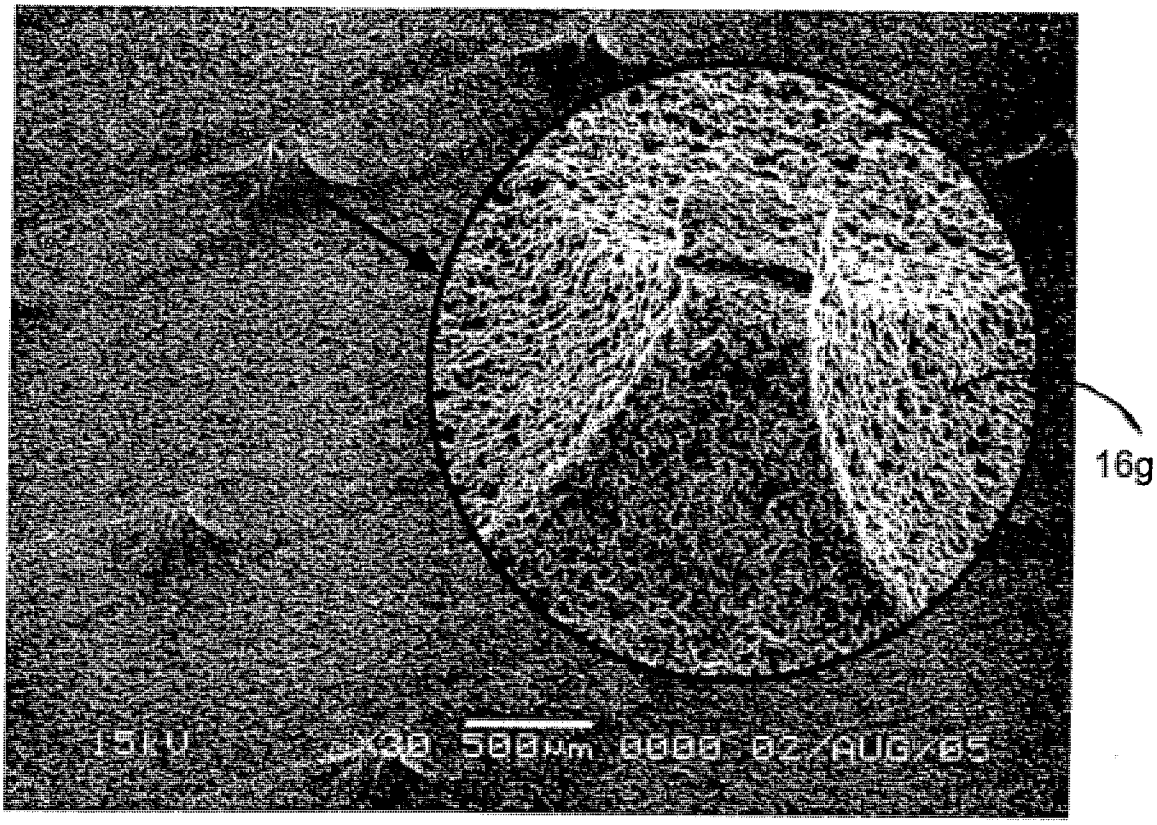


FIG. 8

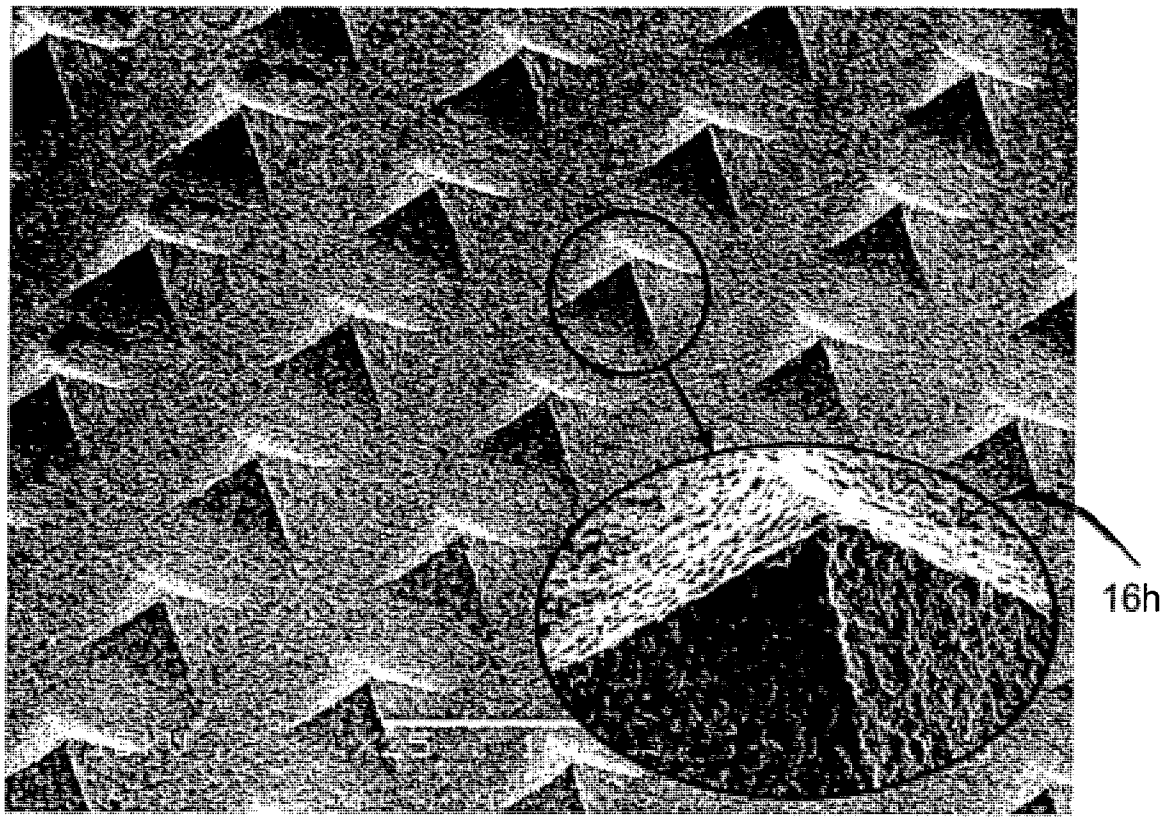


FIG. 9

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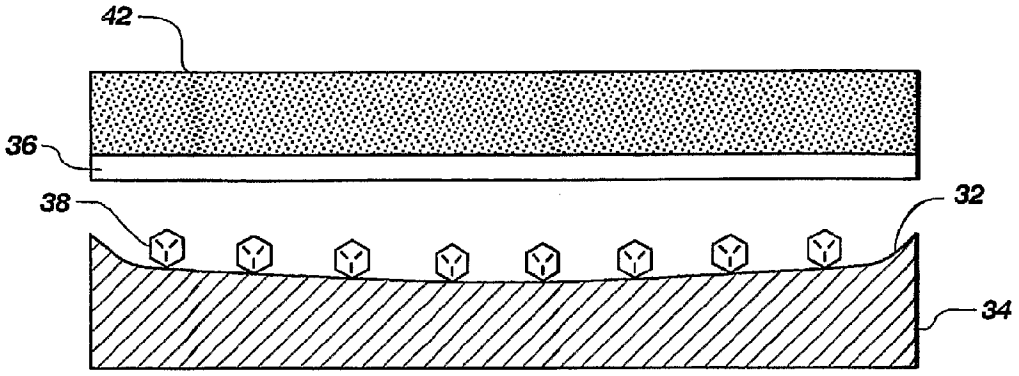
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(54) Title: METHODS OF BONDING SUPERABRASIVE PARTICLES IN AN ORGANIC MATRIX



(57) Abstract: Superabrasive tools and their methods of manufacture are disclosed. In one aspect, a method of improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool, a portion of each of said superabrasive particles protruding out of the solidified organic material layer is provided. The method may include securing a plurality of superabrasive particles (12) in the solidified organic material layer (14) in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle (12) when used to abrade a work piece. As an example, the arrangement of the plurality of superabrasive particles (12) may be configured to uniformly distribute frictional forces across substantially each superabrasive particle (12).

WO 2007/032946 A2

METHODS OF BONDING SUPERABRASIVE PARTICLES IN AN ORGANIC MATRIX

FIELD OF THE INVENTION

The present invention relates generally to tools having superabrasive particles embedded in an organic material matrix and associated methods. Accordingly, the present invention involves the chemical and material science fields.

BACKGROUND OF THE INVENTION

Many industries utilize a chemical mechanical polishing (CMP) process for polishing certain work pieces. Particularly, the computer manufacturing industry relies heavily on CMP processes for polishing wafers of ceramics, silicon, glass, quartz, and metals. Such polishing processes generally entail applying the wafer against a rotating pad made from a durable organic substance such as polyurethane. A chemical slurry is utilized that contains a chemical capable of breaking down the wafer substance and an amount of abrasive particles which act to physically erode the wafer surface. The slurry is continually added to the rotating CMP pad, and the dual chemical and mechanical forces exerted on the wafer cause it to be polished in a desired manner.

Of particular importance to the quality of polishing achieved is the distribution of the abrasive particles throughout the pad. The top of the pad holds the particles by means of fibers or small pores, which provide a friction force sufficient to prevent the particles from being thrown off of the pad due to the centrifugal force exerted by the pad's spinning motion. Therefore, it is important to keep the top of the pad as flexible as possible, to keep the fibers as erect as possible, and to assure that there is an abundance of open pores available to receive newly applied abrasive particles.

One problem that arises with regard to maintaining the pad surface, however, is an accumulation of polishing debris coming from the work piece, the abrasive slurry, and the pad dresser. This accumulation causes a "glazing" or hardening of the top of the pad, mats the fibers down, and thus makes the pad surface less able to hold the abrasive particles of the slurry. These effects significantly decrease the pad's overall polishing performance. Further, with many pads, the pores used to hold the slurry, become clogged, and the overall asperity of the pad's polishing surface becomes depressed and matted. A CMP pad dresser can be used to revive the pad surface by "combing" or

"cutting" it. This process is known as "dressing" or "conditioning" the CMP pad. Many types of devices and processes have been used for this purpose. One such device is a disk with a plurality of superhard crystalline particles such as diamond particles attached to a metal-matrix surface.

Ultra-large-scale integration (ULSI) is a technology that places at least 1 million circuit elements on a single semiconductor chip. In addition to the tremendous density issues that already exist, with the current movement toward size reduction, ULSI has become even more delicate, both in size and materials than ever before. Therefore, the CMP industry has been required to respond by providing polishing materials and techniques that accommodate these advances. For example, lower CMP polishing pressures, smaller size abrasive particles in the slurry, and polishing pads of a size and nature that do not over polish the wafer must be used. Furthermore, pad dressers that cut asperities in the pad which can accommodate the smaller abrasive particles, and that do not overdress the pad must be used.

There are a number of problems in attempting to provide such a pad dresser. First, the superabrasive particles must be significantly smaller than those typically used in currently know dressing operations. Generally speaking, the superabrasive particles are so small that a traditional metal matrix is often unsuitable for holding and retaining them. Further, the smaller size of the superabrasive particles, means that the particle tip height must be precisely leveled in order to uniformly dress the pad. Traditional CMP pad dressers can have particle tip height variations of more than 50 μm without compromising dressing performance. However, such a variation would render a dresser useless if it were required to dress a CMP pad and achieve a uniform asperity depth of 20 μm or less, for example.

In addition to issues with properly holding very small superabrasive particles, the tendencies of metal to warp and buckle during a heating process, cause additional issues in obtaining a CMP pad dresser having superabrasive particle tips leveled to within a narrow tolerance range. While other substrate materials such as polymeric resins have been know, such materials typically are not able to retain superabrasive particles to a degree that is sufficient for CMP pad dressing.

As a result, a CMP pad dresser that is suitable for dressing a CMP pad that meet the demands placed upon the CMP industry by the continual reductions in semiconductor size is still being sought.

SUMMARY OF THE INVENTION

Accordingly, the present invention provides superabrasive tools and methods that are, without limitation, suitable to groom the CMP pads used for the delicate polishing applications as recited above. In one aspect, a method is provided for improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool, where a portion of each of the superabrasive particles protrude out of the solidified organic material layer. The method may include securing a plurality of superabrasive particles in the solidified organic material layer in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle when used to abrade a work piece. As an example, the arrangement of the plurality of superabrasive particles may be configured to uniformly distribute drag forces across substantially each superabrasive particle.

Various methods are contemplated for minimizing the mechanical stress impinging on the superabrasive particles held in the abrading tool. One example may include superabrasive particle arrangement according to protrusion height. As such, each of the plurality of superabrasive particles may protrude to a predetermined height above the solidified organic material layer. In one aspect, the predetermined height may produce a cutting depth of greater than about 20 microns when used to abrade a work piece. In another aspect, the predetermined height may produce a cutting depth of from about 1 micron to about 20 microns when used to abrade a work piece. In yet another aspect, the predetermined height may produce a cutting depth of from about 10 micron to about 20 microns when used to abrade a work piece.

Arranging superabrasive particles such that they define a profile may also prove to be useful in distributing impinging mechanical forces. As such, the superabrasive particles may protrude to a predetermined height that is along a designated profile. In one aspect, the plurality of superabrasive particles may be arranged such that their tips protrude to less than about 40 microns above the organic material matrix. In another aspect, the plurality of superabrasive particles may be arranged such that their tips protrude to less than about 30 microns above the organic material matrix. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips protrude to less than about 20 microns above the organic material matrix. Thus the designated profile defines the extent to which a plurality of superabrasive particles protrude from the

solidified organic material layer. In one aspect, the designated profile may be a plane. In another aspect, the designated profile may have a slope. In yet another aspect, the designated profile may have a curved shape. In a further aspect, the designated profile may have a dome shape. Additionally, though it is intended that the plurality of superabrasive particles be arranged according to the designated profile, a small amount of deviation therefrom may be likely.

The size of the plurality of superabrasive particles may also affect the distribution of mechanical forces. In one aspect, the plurality of superabrasive particles may be of substantially the same size. Any superabrasive particle size that would provide benefit to the methods and tools of the present invention are considered to be within the present claim scope. In one specific aspect, the plurality of superabrasive particle may be from about 30 microns to about 250 microns in size. In another aspect, the plurality of superabrasive particles are from about 100 microns to about 200 microns in size. Additionally, variations in the size of the plurality of superabrasive particles or the variation thereof may also affect the distribution of mechanical forces. This is particularly true for tools in which impinging mechanical forces vary depending on superabrasive particle location, such as with circumferentially rotating tools. In one aspect, superabrasive particles in a central location of the abrading tool may be larger in size than superabrasive particles in a peripheral location on the abrading tool.

The orientation of the plurality of superabrasive particles may also affect the distribution of mechanical forces in the abrading tool. In one aspect, securing the plurality of superabrasive particles includes arranging the plurality of superabrasive particles according to a predetermined attitude. Though various attitudes are possible, in one specific aspect the predetermined attitude is a uniform attitude across substantially all of the plurality of superabrasive particles. In another aspect, the plurality of superabrasive particles are substantially configured with an apex portion oriented towards a work piece. In addition to uniform attitudes, some aspects include variations in attitude across the abrading tool. For example, in one aspect superabrasive particles in a central location on the abrading tool may be configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the abrading tool may be configured with a face oriented towards the work piece.

The arrangement or distribution of superabrasive particle along the surface of an abrading tool may also function to effectively distribute mechanical forces. In one aspect,

the plurality of superabrasive particles may be arranged as a grid. In another aspect, the plurality of superabrasive particles may be evenly spaced at a distance of from about 2 times to about 4 times the average size of the superabrasive particles. In yet another aspect, the plurality of superabrasive particles may be evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles. In a further aspect, superabrasive particles in a central location on the abrading tool may be spaced farther apart than superabrasive particles in a peripheral location on the abrading tool.

The present invention further encompasses superabrasive tools having improved superabrasive particle retention. As such, in one aspect a superabrasive tool may include a solidified organic material layer and a plurality of superabrasive particles secured in the solidified organic material layer in an arrangement according to the methods recited herein.

Any superabrasive material capable of being utilized according to the methods provided herein would be considered to be within the scope of the present invention. For example, the plurality of superabrasive particles may include, without limitation, diamond, polycrystalline diamond, cubic boron nitride, polycrystalline cubic boron nitride, and combinations thereof.

Various organic materials are also contemplated to hold and secure the superabrasive particles. For example, and without limitation, the solidified organic material layer may include amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof. The solidified organic material layer may also include additional components that modify the characteristics of the material. In one aspect, a reinforcing material may be disposed within at least a portion of the solidified organic material layer. The reinforcing material may be, without limitation, ceramics, metals, or combinations thereof. Examples of ceramic materials include alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof.

There has thus been outlined, rather broadly, various features of the invention so that the detailed description thereof that follows may be better understood, and so that the present contribution to the art may be better appreciated. Other features of the present invention will become clearer from the following detailed description of the invention, taken with the accompanying claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a CMP pad dresser made in accordance with one embodiment of the present invention.

FIG. 2 is a cross-sectional view of superabrasive particles disposed on a temporary substrate in accordance with one embodiment of the present invention.

FIG. 3 is a cross-sectional view of superabrasive particles disposed on a temporary substrate in accordance with one embodiment of the present invention.

FIG. 4 is a cross-sectional view of superabrasive particles disposed on a temporary substrate in accordance with one embodiment of the present invention.

FIG. 5 is a cross-sectional view of superabrasive particles disposed in an organic material layer in accordance with one embodiment of the present invention.

FIG. 6 is a cross-sectional view of a CMP pad dresser in accordance with one embodiment of the present invention.

FIG. 7 is a cross-sectional view of superabrasive particles disposed along a layer of organic material in accordance with one embodiment of the present invention.

FIG. 8 is a cross-sectional view of superabrasive particles being pressed into a layer of organic material in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

The singular forms "a," "an," and, "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a particle" includes reference to one or more of such particles, and reference to "the resin" includes reference to one or more of such resins.

As used herein, "organic material" refers to a semisolid or solid complex amorphous mix of organic compounds. As such, "organic material layer" and "organic material matrix" may be used interchangeably, refer to a layer or mass of a semisolid or solid complex amorphous mix of organic compounds. Preferably the organic material will be a polymer or copolymer formed from the polymerization of one or more monomers.

As used herein, "superhard" and "superabrasive" may be used interchangeably, and refer to a crystalline, or polycrystalline material, or mixture of such materials having a Vicker's hardness of about 4000 Kg/mm^2 or greater. Such materials may include without limitation, diamond, and cubic boron nitride (cBN), as well as other materials known to those skilled in the art. While superabrasive materials are very inert and thus difficult to form chemical bonds with, it is known that certain reactive elements, such as chromium and titanium are capable of chemically reacting with superabrasive materials at certain temperatures.

As used herein, "metallic" refers to a metal, or an alloy of two or more metals. A wide variety of metallic materials is known to those skilled in the art, such as aluminum, copper, chromium, iron, steel, stainless steel, titanium, tungsten, zinc, zirconium, molybdenum, etc., including alloys and compounds thereof.

As used herein, "particle" and "grit" may be used interchangeably, and when used in connection with a superabrasive material, refer to a particulate form of such material. Such particles or grit may take a variety of shapes, including round, oblong, square, euhedral, etc., as well as a number of specific mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes.

As used herein, "mechanical bond" and "mechanical bonding" may be used interchangeably, and refer to a bond interface between two objects or layers formed primarily by frictional forces. In some cases the frictional forces between the bonded objects may be increased by expanding the contacting surface areas between the objects, and by imposing other specific geometrical and physical configurations, such as substantially surrounding one object with another.

As used herein, "leading edge" means the edge of a CMP pad dresser that is a frontal edge based on the direction that the CMP pad is moving, or the direction that the pad is moving, or both. Notably, in some aspects, the leading edge may be considered to encompass not only the area specifically at the edge of a dresser, but may also include

portions of the dresser which extend slightly inward from the actual edge. In one aspect, the leading edge may be located along an outer edge of the CMP pad dresser. In another aspect, the CMP pad dresser may be configured with a pattern of abrasive particles that provides at least one effective leading edge on a central or inner portion of the CMP pad dresser working surface. In other words, a central or inner portion of the dresser may be configured to provide a functional effect similar to that of a leading edge on the outer edge of the dresser.

As used herein, "centrally located particle," "particle in a central location" and the like mean any particle of a tool that is located in an area of the tool that originates at a center point of the tool and extends outwardly towards the tool's edge for up to about 90% of the radius of the tool. In some aspects, the area may extend outwardly from about 20% to about 90% of the radius. In other aspects, the area may extend out to about 50% of the radius. In yet another aspect, the area may extend out to about 33% of the radius of a tool.

As used herein, "peripherally located," "particles in a peripheral location" and the like, mean any particle of a tool that is located in an area that originates at the leading edge or outer rim of a tool and extends inwardly towards the center for up to about 90% of the radius of the tool. In some aspects, the area may extend inwardly from about 20% to 90% of the radius. In other aspects, the area may extend in to about 50% of the radius. In yet another aspect, the area may extend in to about 33% of the radius of a dresser (i.e. 66% away from the center).

As used herein, "working end" refers to an end of a particle which is oriented towards the work piece being abraded by a tool. Most often the working end of a particle will be distal from a substrate to which the particle is attached.

As used herein, "ceramic" refers to a hard, often crystalline, substantially heat and corrosion resistant material which may be made by firing a non-metallic material, sometimes with a metallic material. A number of oxide, nitride, and carbide materials considered to be ceramic are well known in the art, including without limitation, aluminum oxides, silicon oxides, boron nitrides, silicon nitrides, and silicon carbides, tungsten carbides, etc.

As used herein, "grid" means a pattern of lines forming multiple squares.

As used herein, "attitude" means the position or arrangement of a superabrasive particle in relation to a defined surface, such as a substrate to which it is attached, or a

work piece to which it is to be applied during a work operation. For example, a superabrasive particle can have an attitude that provides a specific portion of the particle in orientation toward the work piece.

As used herein, "substantially" refers to situations close to and including 100%. Substantially is used to indicate that, though 100% is desirable, a small deviation therefrom is acceptable. For example, substantially all superabrasive particles includes groups of all superabrasive particles and groups of all superabrasive particles minus a relatively small portion of superabrasive particles.

As used herein, "mechanical force" and "mechanical forces" refer to any physical force that impinges on an object that causes mechanical stress within or surrounding the object. Example of mechanical forces would be frictional forces or drag forces. As such, the terms "frictional force" and "drag force" may be used interchangeably, and refer to mechanical forces impinging on an object as described.

As used herein, "mechanical stress" refers to a force per unit area that resists impinging mechanical forces that tend to compact, separate, or slide an object.

As used herein, the term "profile" refers to a contour above an organic material layer surface to which the superabrasive particles are intended to protrude.

As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

Concentrations, amounts, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc.

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This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides organic material-based CMP pad dressers including methods for their use and manufacture. Though much of the following discussion relates to CMP pad dressers, it should be understood that the methods and tools of the presently claimed invention are equally applicable to any tool that utilizes abrasive or superabrasive materials, all of which are considered to be within the scope of the present invention. The inventor has found that the retention of a superabrasive particle in an organic material layer can be improved by arranging the superabrasive particles in the organic material layer such that mechanical stress impinging on any individual superabrasive particle is minimized. By reducing the stress impinging on each individual superabrasive particle they can be more readily retained in a solidified organic material layer, particularly for delicate tasks.

Accordingly, one aspect of the present invention provides a method of improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool having a portion of the superabrasive particles protruding out of the solidified organic material layer. The method can include securing a plurality of superabrasive particles in the solidified organic material layer in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle when used to abrade a work piece. Though various methods of minimizing mechanical stress are possible, in one aspect the arrangement of the plurality of superabrasive particles may be configured to uniformly distribute frictional forces across substantially each superabrasive particle. Such a uniform distribution of frictional force prevents any individual superabrasive particle from being overstressed and pulling out of the solidified organic material layer.

Various configurations or arrangements are contemplated for minimizing the mechanical stress impinging on the superabrasive particles held in the abrading tool. One potentially useful parameter may include the height that the superabrasive particles protrude above the organic material layer. A superabrasive particle that protrudes to a significantly greater height than other superabrasive particles will experience a greater proportion of the impinging mechanical forces and thus is more prone to pull out of the

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solidified organic material layer. Thus an even height distribution of superabrasive particles may function to more effectively preserve the integrity of the abrading tool as compared to abrading tools lacking such an even height distribution. As such, in one aspect, a majority of the plurality of superabrasive particles may protrude to a predetermined height above the solidified organic material layer. Though any predetermined height that would be useful in an abrading tool would be considered to be within the presently claimed scope, in one specific aspect the predetermined height may produce a cutting depth of less than about 20 microns when used to abrade a work piece. In another specific aspect, the predetermined height may produce a cutting depth of from about 1 micron to about 20 microns when used to abrade a work piece. In yet another specific aspect, the predetermined height may produce a cutting depth of from about 10 micron to about 20 microns when used to abrade a work piece. It should also be noted that the leveling of superabrasive particles to a predetermined height may be dependent on superabrasive particle spacing. In other words, the farther superabrasive particles are separated, the more the impinging forces will affect each superabrasive particle. As such, patterns with increased spacing between the superabrasive particles may benefit from a smaller variation from predetermined height.

It may also be beneficial for the superabrasive particles to protrude from the solidified organic material layer to a predetermined height or series of heights that is/are along a designated profile. Numerous configurations for designated profiles are possible, depending on the particular use of the abrading tool. In one aspect, the designated profile may be a plane. In planar profiles, the highest protruding points of the superabrasive particles are intended to be substantially level. It is important to point out that, though it is preferred that these points align with the designated profile, there may be some height deviation between superabrasive particles that occur due to limitations inherent in the manufacturing process.

In addition to planar profiles, in another aspect of the present invention the designated profile has a slope. Tools having sloping surfaces may function to more evenly spread the frictional forces impinging thereon across the superabrasive particles, particularly for rotating tools such as disk sanders and CMP pad dressers. The greater downward force applied by higher central portions of the tool may offset the higher rotational velocity at the periphery, thus reducing the mechanical stress experienced by superabrasive particles in that location. As such, the slope may be continuous from a

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central point of the tool to a peripheral point, or the slope may be discontinuous, and thus be present on only a portion of the tool. Similarly, a given tool may have a single slope or multiple slopes. In certain aspects, the tool may slope in a direction from a central point to a peripheral point, or it may slope from a peripheral point to a central point. Various slopes are contemplated that may provide a benefit to solidified organic material layer tools. It is not intended that the claims of the present invention be limited as to specific slopes, as a variety of slopes in numerous different tools are possible. In one aspect, however, a CMP pad dresser may benefit from an average slope of 1/1000 from the center to the periphery.

As a variation on tools having a slope, in certain aspects the designated profile may have a curved shape. One specific example of a curved shape is a dome shape tool. Such curved profiles function in a similar manner to the sloped surfaces. Tools may include such curved profiles in order to more effectively distribute the frictional forces between all of the superabrasive particles, thus reducing failures of individual particles and prolonging the life of the tool.

As has been mentioned herein, while it is intended that the tips of the superabrasive particles align along the designated profile, some level of deviation may occur. These deviations may be a result of the design or manufacturing process of the tool. Given the wide variety of sizes of superabrasive particles that may potentially be utilized in a given tool, such deviations may be highly dependent on a particular application. Also, when referring to the designated profile, it should be noted that the term "tip" is intended to include the highest protruding point of a superabrasive particle, whether that point be an apex, an edge, or a face. As such, in one aspect a majority of the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 1 micron to about 150 microns. In another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 5 microns to about 100 microns. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 10 microns to about 75 microns. In a further aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 10 microns to about 50 microns. In another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 50 microns to about 150 microns. In yet another aspect,

the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 20 microns to about 100 microns. In a further aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 20 microns to about 50 microns. In another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 20 microns to about 40 microns. Additionally, in one aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 20 microns. In another aspect the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 10 microns. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 5 microns. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 1 microns. In a further aspect, a majority of the plurality of superabrasive particles are arranges such that their tips vary from the designated profile to less than about 10% of the average size of the superabrasive particles.

Variations in superabrasive particle size between different locations on the tool may also help to more evenly distribute the frictional forces impinging thereon. Larger superabrasive particles will most likely experience greater frictional force than would smaller particles. Additionally, in the case circumferentially rotating tools such as CMP pad dressers, superabrasive particles located near the periphery will most likely experience greater frictional force than particles located more centrally due to the greater rotational velocity at the periphery. In such a case, frictional forces may be distributed across the CMP pad by locating larger superabrasive particles more centrally to offset this increase. As a result, the frictional forces are more evenly spread across all superabrasive particles, thus reducing particle failure. As such, in one aspect superabrasive particles in a central location of the abrading tool are larger in size than superabrasive particles in a peripheral location on the abrading tool. In another aspect, superabrasive particles in a central location of the abrading tool may be smaller than superabrasive particles in a peripheral location on the abrading tool. This configuration may provide benefit to circumferentially rotating tools, where the mechanical stresses on superabrasive particles are greater at the periphery. The larger superabrasive particles extend deeper into the organic material layer, and are thus more firmly supported therein. Also, for CMP pad

dressers, larger particles at the periphery may provide more slurry clearance than smaller particles. Additionally, although a variety of sizes are contemplated, in one aspect the plurality of superabrasive particle may be from about 30 microns to about 500 microns in size. In another aspect the plurality of superabrasive particles are from about 100 microns to about 200 microns in size. It is also contemplated that the plurality of superabrasive particles may be of substantially the same size.

Variations in the attitude of superabrasive particles in the solidified organic material layer may also function to more effectively distribute frictional forces across the abrading tool. Orienting superabrasive particles in particular locations of the abrading tool such that similar apexes, edges, and/or faces are exposed may allow a more even distribution of frictional forces, particularly if the densities of superabrasive particles in those locations are concomitantly arranged. As such, in one aspect securing the plurality of superabrasive particles in the solidified organic material layer may include arranging the plurality of superabrasive particles according to a predetermined attitude. In various aspects, the predetermined attitude may be a uniform attitude across substantially all of the plurality of superabrasive particles. In other words, similar apexes, edges, or faces for substantially all of the superabrasive particles in the abrading tool may be facing the same direction. In one aspect, the plurality of superabrasive particles may be substantially configured with an apex portion oriented towards a work piece. As such, impinging frictional forces may be reduced by orienting the plurality of superabrasive particles such that their tips or apexes are substantially oriented towards the work piece. This may be partially due to the smaller surface area of the apex region of the superabrasive particles coming in contact with the work piece during abrading as compared to the larger surface areas of the edge or face regions. Also, the attitude of the plurality of superabrasive particles can also vary depending on the location of particles on the abrading tool. For example, in one aspect superabrasive particles in a central location on the abrading tool may be configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the abrading tool may be configured with a face oriented towards the work piece. In another aspect, superabrasive particles in a central location on the abrading tool may be configured with an apex portion oriented towards a work piece, superabrasive particles in a peripheral location on the abrading tool may be configured with a face oriented towards the work piece, and superabrasive

particles in a middle location on the abrading tool may be configured with an edge oriented towards the work piece.

It may be preferable to utilize superabrasive particles smaller than about 40 microns when orienting face portions towards the work piece. In this case, the face is not big enough to overstress those superabrasive particles. Faces also have the advantage of having four edges that can be used to cut the work piece.

The distribution of frictional forces may also be varied through the arrangement or distribution of the superabrasive particles in the solidified organic material layer. For example, in one aspect the plurality of superabrasive particles may be arranged as a grid. Though the even or uniform spacing of the superabrasive particle can exhibit wide variation across abrading tools, in one specific aspect the plurality of superabrasive particles may be evenly spaced at a distance of from about 2 times to about 4 times the average size of the superabrasive particles. In another specific aspect the plurality of superabrasive particles may be evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles. In yet another specific aspect the plurality of superabrasive particles may be evenly spaced at a distance of from about 3 times to about 4 times the average size of the superabrasive particles. In a further aspect, the plurality of superabrasive particles may be evenly spaced at a distance of from about 4 times to about 5 times the average size of the superabrasive particles. In yet another aspect, the plurality of superabrasive particles may be evenly space at a distance of from about 100 microns to about 800 microns. As has been discussed herein, however, if all superabrasive particles are evenly spaced, those particles near the periphery will experience greater mechanical stress due to the higher rotational velocity of the abrading tool at that location. The larger the tool, the greater the disparity in the impinging mechanical forces between the center of the tool and the periphery. Because of this, it may be beneficial to vary the spacing of the superabrasive particle depending on location to more effectively distribute frictional forces across the abrading tool. In one aspect, for example, superabrasive particles in a central location on the abrading tool may be spaced farther apart than superabrasive particles in a peripheral location on the abrading tool. In this way, the increased frictional forces due to the greater density of superabrasive particles in the central location may offset the increased frictional forces at the periphery due to the greater rotational velocity of the abrading tool.

Turning to organic material layers, numerous organic materials are known to those skilled in the art which would be useful when utilized in embodiments of the present invention, and are considered to be included herein. The organic material layer can be any curable resin material, resin, or other polymer with sufficient strength to retain the superabrasive grit of the present invention. It may be beneficial to use an organic material layer that is relatively hard, and maintains a flat surface with little or no warping. This allows the abrading tool to incorporate very small superabrasive particles at least partially therein, and to maintain these small superabrasive particles at relatively level and consistent heights. Additionally, various organic materials may act to absorb mechanical forces impinging on the superabrasive particles disposed therein, and thus spread and equalize such forces across the abrading tool.

Methods of curing the organic material layer can be any process known to one skilled in the art that causes a phase transition in the organic material from at least a pliable state to at least a rigid state. Curing can occur, without limitation, by exposing the organic material to energy in the form of heat, electromagnetic radiation, such as ultraviolet, infrared, and microwave radiation, particle bombardment, such as an electron beam, organic catalysts, inorganic catalysts, or any other curing method known to one skilled in the art. In one aspect of the present invention, the organic material layer may be a thermoplastic material. Thermoplastic materials can be reversibly hardened and softened by cooling and heating respectively. In another aspect, the organic material layer may be a thermosetting material. Thermosetting materials cannot be reversibly hardened and softened as with the thermoplastic materials. In other words, once curing has occurred, the process is essentially irreversible.

Organic materials that may be useful in embodiments of the present invention include, but are not limited to: amino resins including alkylated urea-formaldehyde resins, melamine-formaldehyde resins, and alkylated benzoguanamine-formaldehyde resins; acrylate resins including vinyl acrylates, acrylated epoxies, acrylated urethanes, acrylated polyesters, acrylated acrylics, acrylated polyethers, vinyl ethers, acrylated oils, acrylated silicons, and associated methacrylates; alkyd resins such as urethane alkyd resins; polyester resins; polyamide resins; polyimide resins; reactive urethane resins; polyurethane resins; phenolic resins such as resole and novolac resins; phenolic/latex resins; epoxy resins such as bisphenol epoxy resins; isocyanate resins; isocyanurate resins; polysiloxane resins including alkylalkoxysilane resins; reactive vinyl resins; resins

marketed under the Bakelite trade name, including polyethylene resins, polypropylene resins, epoxy resins, phenolic resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, ethylene copolymer resins, acrylonitrile-butadiene-styrene (ABS) resins, acrylic resins, and vinyl resins; acrylic resins; polycarbonate resins; and mixtures and combinations thereof. In one aspect of the present invention, the organic material may be an epoxy resin. In another aspect, the organic material may be a polyimide resin. In yet another aspect, the organic material may be a polyurethane resin. In yet another aspect, the organic material may be a polyurethane resin.

Numerous additives may be included in the organic material to facilitate its use. For example, additional crosslinking agents and fillers may be used to improve the cured characteristics of the organic material layer. Additionally, solvents may be utilized to alter the characteristics of the organic material in the uncured state. Also, a reinforcing material may be disposed within at least a portion of the solidified organic material layer. Such reinforcing material may function to increase the strength of the organic material layer, and thus further improve the retention of the superabrasive particles. In one aspect, the reinforcing material may include ceramics, metals, or combinations thereof. Examples of ceramics include alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof.

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of each superabrasive particle to facilitate the retention of the superabrasive particles in the organic material matrix via chemical bonding. A wide variety of organic and organometallic compounds are known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive particles and the organic material matrix, thus increasing the retention of the particles therein. In this way, the organometallic coupling agent acts as a bridge to form bonds between the organic material matrix and the surface of the superabrasive particles. In one aspect of the present invention, the organometallic coupling agent can be a titanate, zirconate, silane, or mixture thereof.

Specific non-limiting examples of silanes suitable for use in the present invention include: 3- glycidoxypropyltrimethoxy silane (available from Dow Corning as Z-6040); γ-methacryloxy propyltrimethoxy silane (available from Union Carbide Chemicals Company as A-174); β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, γ-aminopropyltriethoxy silane, N-(β-aminoethyl)-γ-aminopropylmethyldimethoxy silane

(available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.); and additional examples of suitable silane coupling agents can be found in U.S. Pat. Nos. 4,795,678, 4,390,647, and 5,038,555, which are each incorporated herein by reference.

Specific non-limiting examples of titanate coupling agents include: isopropyltriisostearoyl titanate, di(cumylphenylate)oxyacetate titanate, 4-aminobenzenesulfonyldodecylbenzenesulfonyl titanate, tetraoctylbis (ditridecylphosphite) titanate, isopropyltri(N-ethylamino-ethylamino) titanate (available from Kenrich Petrochemicals. Inc.), neoalkyoxy titanates such as LICA-01, LICA-09, LICA-28, LICA-44 and LICA-97 (also available from Kenrich), and the like.

Specific non-limiting examples of aluminum coupling agents include acetoalkoxy aluminum diisopropylate (available from Ajinomoto K.K.), and the like.

Specific non-limiting examples of zirconate coupling agents include: neoalkoxy zirconates, LZ-01, LZ-09, LZ- 12, LZ-38, LZ-44, LZ-97 (all available from Kenrich Petrochemicals, Inc.), and the like. Other known organometallic coupling agents, e.g., thiolate based compounds, can be used in the present invention and are considered within the scope of the present invention.

The amount of organometallic coupling agent used depends on the coupling agent and on the surface area of the superabrasive particles. Typically, 0.05% to 10% by weight of the organic material layer is sufficient.

The superabrasive particles used in embodiments of the present invention may be selected from a variety of specific types of diamond (e.g., polycrystalline diamond) and cubic boron nitride (e.g., polycrystalline cBN). It may be useful to select a superabrasive material capable of chemically bonding with a reactive material, such as those described herein. Further, these particles may take a number of different shapes as required to accommodate a specific purpose for the tool into which it is anticipated that they will be incorporated. However, in one aspect, the superabrasive particle may be diamond, including natural diamond, synthetic diamond, and polycrystalline diamond (PCD). In yet another aspect, the superabrasive particle may be cubic boron nitride (cBN), either single crystals or polycrystalline. In yet another aspect, the superabrasive particle may be a member selected from the group consisting of SiC, Al_2O_3, Zr O_2, and WC.

Numerous uses of aspects of the present invention will be apparent to one skilled in the art in possession of the present disclosure. Superabrasive particles can be arranged into tools of various shapes and sizes, including one-, two-, and three-dimensional tools.

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Tools may incorporate a single layer or multiple layers of superabrasive particles and may exhibit improved retention through the distribution of impinging frictional forces. In one aspect, for example, a superabrasive tool having improved superabrasive particle retention is provided. The superabrasive tool may include a solidified organic material layer and a plurality of superabrasive particles secured in the solidified organic material layer in an arrangement according to the methods recited herein.

Superabrasive particles can be arranged in various configurations that may help to distribute the frictional forces impinging on the too. For example, in one aspect each of the plurality of superabrasive particles may protrude to a predetermined height above the solidified organic material layer. By minimizing the variance in the protrusion of the plurality of superabrasive particles above the solidified organic material layer, mechanical forces impinging on individual superabrasive particles can be minimized. Though the predetermined height may vary between tool applications, in one aspect the predetermined height may be greater than about 20 microns. In another aspect the variation from the predetermined height may be from about 1 micron to about 20 microns. In yet another aspect the variation from the predetermined height may be from about 5 microns to about 20 microns. In a further aspect the variation from the predetermined height may be from about 10 microns to about 20 microns. Superabrasive particles may also be arranged according to the methods disclosed herein with respect to arrangement or distribution, attitude, size, etc.

One example of a tool incorporating a single layer of superabrasive particles in an organic material matrix is a CMP pad dresser. As recited herein, traditional metal matrix CMP pad dressers are not suitable for bonding very small superabrasive particles. It is intended that the scope of the present invention include superabrasive particles of all conceivable sizes that would be useful in dressing a CMP pad. Aspects of the present invention, however, specifically allow the retention of superabrasive particles in a CMP pad dresser of sizes that have not previously been feasible for use in metal tools with particles exposed and arranged in a pattern. In one aspect, superabrasive particles may range in size from about 30 microns to about 250 microns. In another aspect, superabrasive particles may range in size from about 100 microns to about 200 microns. In yet another aspect, superabrasive particles can range from 100 microns to 150 microns.

Embodiments of the present invention also provide CMP pad dressers with improved superabrasive particle retention as recited herein. Referring to FIG. 1, the CMP

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pad dresser 20 may include an organic material layer 14 and superabrasive particles 12 held in the organic material layer 14 in an arrangement according to the various methods presented herein. Such an arrangement may increase the retention of the superabrasive particles 12 in the organic material layer 14 due to a substantially even distribution of frictional forces across all the superabrasive particles in the tool. This distribution of forces improves retention by minimizing mechanical stress impinging on any individual particle. Additionally, in one aspect the organic material layer 14 may be coupled to a support substrate 22.

In order for the CMP pad dresser 20 to condition a CMP pad, the superabrasive particles 12 should protrude at least partially from the organic material layer 14. The protruding superabrasive particles 12 can cut into the CMP pad to a depth that is essentially the distance of the protrusion. In one aspect of the present invention, the superabrasive particles can protrude to a predetermined height. The heights of each superabrasive particle can be essentially the same, or they may vary depending on the particular application of the dresser. For example, superabrasive particles near the center of the CMP pad dresser may protrude to a greater height than the superabrasive grit near the dresser periphery.

Various methods for making a CMP pad dresser according to embodiments of the present invention may be contemplated by one of skill in the art. Generally, a method for making a CMP pad dresser may include disposing superabrasive particles in an organic material layer according to an arrangement such that the superabrasive particles protrude at least partially from the organic material layer. As described herein, the superabrasive particles may be arranged in order to distribute frictional forces across the tool in order to improve retention. In one aspect of the present invention, a reinforcing material may also be applied to at least a portion of the organic material layer in the proximity of the superabrasive grit to further improve retention. The reinforcing material may also protect the organic material layer from acid and provide wear resistance. In one aspect, the reinforcing material may be a ceramic powder. As discussed herein, the ceramic powder may be any ceramic powder known to one skilled in the art, including alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof. In one aspect the ceramic powder is silicon carbide. In another aspect, the ceramic powder is aluminum carbide. In yet another aspect, the ceramic powder is silica.

Disposing superabrasive grit according to an arranged pattern may be accomplished by applying spots of glue to a substrate, by creating indentations in the substrate to receive the particles, by adhesive transfer, vacuum transfer, or by any other means known to one skilled in the art. Additional methods may be found in U.S. Pat. Nos. 6,039,641 and 5,380,390, which are incorporated herein by reference.

Orienting superabrasive particles according to a particular attitude can be accomplished by various methods, all of which would be considered to be within the scope of the present invention. For example, in various aspects the plurality of superabrasive particles may have an apex oriented away from the plane of the organic material matrix. In one specific aspect, superabrasive particles may be picked up and positioned with a surface containing numerous flared holes providing suction. An apex portion of a superabrasive particle is sucked into the flared section of each of the holes in the surface. Because the flared portion and the holes are smaller than the superabrasive particles, the particles will be held in a pattern along the surface. Also, due to the shape of the flared sections, the apex portions of the superabrasive particles will be oriented towards the surface. This pattern of superabrasive particles can then be disposed along a substrate having an adhesive or directly into an organic material matrix. Accordingly, the tips of the superabrasive particles will have the same orientation or attitude and also be substantially leveled.

In another aspect, it may be desired to orient apexes and edges away from the plane of the organic material matrix. This can be accomplished by applying a micro sieve such as nylon or other similar template-like material to a substrate that is coated with an adhesive. The holes in the micro sieve may be, without limitation, approximately ½ the size of the superabrasive particles. A template oriented on the micro sieve can position the superabrasive particles in a pattern. Apexes and edges but not the faces of the superabrasive particles can pass through the micro sieve and into the adhesive. Those faces that do adhere to the adhesive through the micro sieve will not affect the cutting of the tool, as they will be recessed in height as compared to superabrasive particles having tips and edges oriented towards the adhesive, and thus will not contact the CMP pad during dressing.

Following casting of such a tool in an organic material matrix, a portion of the organic material can be removed along with the sieve to expose the superabrasive particles. Care should be taken, however, to carefully control the amount of organic

material matrix removed when exposing the superabrasive particles. Removing too much will overexposed the superabrasive particles, and thus cause increased pullout. Removing too little will not expose the superabrasive particles sufficiently to allow efficient penetration for cutting, debris removal, and slurry flow.

One potential method for controlling the depth of removal of the organic material matrix may include disposing stopping aids in the organic material matrix at a controlled depth. The stopping aids can be any material known to one skilled in the art, and may be disposed in the organic material matrix prior to, during, or following curing of the organic material matrix. The stopping aids may also be disposed onto a tool substrate prior to adding the organic material matrix. In one aspect, graphite strips can be glued to stainless steel bars that are placed radially within the organic material matrix where superabrasive particle placement is not required. After curing the organic material matrix, the epoxy and graphite can be abraded away. Abrading will stop when the abrading tool reaches the harder stainless steel bars.

Various reverse casting methods may be utilized to manufacture the CMP pad dresser of the present invention. As shown in FIG. 2, a spacer layer 36 may be applied to a working surface 32 of a temporary substrate 34. The spacer layer 36 has superabrasive particles 38 at least partially disposed therein, which protrude at least partially from the spacer layer 36 opposite the working surface 32 of the temporary substrate 34. Any method of disposing superabrasive particles into a spacer layer such that the superabrasive particles protrude to a predetermined height may be utilized in the present invention. In one aspect, as shown in FIG. 3, the spacer layer 36 is disposed on working surface 32 of the temporary substrate 34. A fixative may be optionally applied to the working surface 32 to facilitate the attachment of the spacer layer 36 to the temporary substrate 34. Superabrasive particles 38 are disposed along one side of the spacer layer 36 opposite to the working surface 32. A fixative may be optionally applied to the spacer layer 36 to hold the superabrasive particles 38 essentially immobile along the spacer layer 36. The fixative used on either surface of the spacer layer may be any adhesive known to one skilled in the art, such as, without limitation, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a pariffin, a phenolic resin, a wax emulsion, an acrylic resin, or combinations thereof. In one aspect, the fixative is a sprayed acrylic glue.

A press 42 may be utilized to apply force to the superabrasive particles 38 in order to dispose the superabrasive particles 38 into the spacer layer 36, as shown in FIG 2. The press 42 may be constructed of any material know to one skilled in the art able to apply force to the superabrasive particles 38. Examples include, without limitation, metals, wood, plastic, rubber, polymers, glass, composites, ceramics, and combinations thereof. Depending on the application, softer materials may provide a benefit over harder materials. For example, if unequal sizes of superabrasive particles are used, a hard press may only push the largest superabrasive particles through the spacer layer 36 to the working surface 32. In one aspect of the present invention, the press 42 is constructed of a porous rubber. A press 42 constructed from a softer material such as a hard rubber, may conform slightly to the shape of the superabrasive particles 38, and thus more effectively push smaller as well as larger superabrasive particles through the spacer layer 36 to the working surface 32.

The spacer layer may be made from any soft, deformable material with a relatively uniform thickness. Examples of useful materials include, but are not limited to, rubbers, plastics, waxes, graphites, clays, tapes, grafoils, metals, powders, and combinations thereof. In one aspect, the spacer layer may be a rolled sheet comprising a metal or other powder and a binder. For example, the metal may be a stainless steel powder and a polyethylene glycol binder. Various binders can be utilized, which are well known to those skilled in the art, such as, but not limited to, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a pariffin, a phenolic resin, a wax emulsions, an acrylic resin, and combinations thereof.

In another aspect, shown in FIG. 4, the superabrasive particles 38 may be disposed along the working surface 32 of the temporary substrate 34. An adhesive may be optionally applied to the working surface 32 to hold the superabrasive particles 38 essentially immobile along the temporary substrate 34. A spacer layer 36 may then be applied to the working surface 32 such that the superabrasive particles 38 become disposed therein, as shown in FIG. 2. A press 42 may be utilized to more effectively associate the spacer layer 36 with the working surface 32 and the superabrasive particles 38.

Referring now to FIG. 5, an at least partially uncured organic material 62 may be applied to the spacer layer 36 opposite the working surface 32 of the temporary substrate 34. A mold 66 may be utilized to contain the uncured organic material 62 during

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manufacture. Upon curing the organic material 62, an organic material layer 64 is formed, bonding at least a portion of each superabrasive particle 38. A permanent substrate 68 may be coupled to the organic material layer 64 to facilitate its use in dressing a CMP pad. In one aspect, the permanent substrate 68 may be coupled to the organic material layer 64 by means of an appropriate fixative. The coupling may be facilitated by roughing the contact surfaces between the permanent substrate 68 and the organic material layer 64. In another aspect, the permanent substrate 68 may be associated with the organic material 62, and thus become coupled to the organic material layer 64 as a result of curing. The mold 66 and the temporary substrate 34 can subsequently be removed from the CMP pad dresser.

As shown in FIG. 6, the spacer layer has been removed from the organic material layer 64. This may be accomplished by peeling, grinding, sandblasting, scraping, rubbing, abrasion, etc. The distance of the protrusion of the superabrasive particles 38 from the organic material layer 64 will be approximately equal to the thickness of the now removed spacer layer. The organic material layer 64 may be acid etched to further expose the superabrasive particles 38.

One distinction between the various methods of disposing superabrasive particles into the spacer layer may be seen upon removal of the spacer layer. In those aspects where the superabrasive particles are pressed into the spacer layer, the spacer layer material in close proximity to a superabrasive particle will be deflected slightly towards the working surface of the temporary substrate. In other words, the spacer layer material surrounding an individual superabrasive particle may be slightly concave on the side opposite of the working surface due to the superabrasive particle being pushed into the spacer layer. This concave depression will be filled with organic material during the manufacture of the dresser, and thus the organic material will wick up the sides of the superabrasive particle once the organic material layer is cured. For those aspects where the spacer layer is pressed onto the superabrasive particles, the opposite is true. In these cases, the spacer layer material in close proximity to a superabrasive particle will be deflected slightly away from the working surface of the temporary substrate. In other words, the spacer layer material surrounding an individual superabrasive particle may be slightly convex on the side opposite of the working surface due to the spacer layer being forced around the superabrasive particle. This convex protrusion may cause a slight concave depression in the organic material layer surrounding each superabrasive particle.

This slight concave depression may decrease retention, resulting in premature superabrasive grit pullout from the organic material layer. For these aspects, various means of improving retention may be employed by one skilled in the art. For example, the spacer layer may be heated to reduce the slightly convex protrusion of the spacer layer surrounding a superabrasive particle prior to curing the organic material layer. Also, additional organic material may be applied to the slight concave depression in the organic material layer surrounding the superabrasive particle.

The temporary substrate may be made of any material capable of supporting the organic material layer and withstanding the force of the press as described herein. Example materials include glasses, metals, woods, ceramics, polymers, rubbers, plastics, etc. Referring back to FIG. 2, the temporary substrate 34 has a working surface 32 upon which the spacer layer 36 is applied. The working surface 32 can be level, sloped, flat, curved, or any other shape that would be useful in the manufacture of a CMP pad dresser. The working surface 32 may be roughened to improve the orientation of the superabrasive particles 38. When a superabrasive particle is pressed onto a very smooth temporary substrate, it may be more likely that a flat surface of the superabrasive particle will align parallel to the temporary substrate. In this situation, when the spacer layer is removed the flat surface of the superabrasive particle will protrude from the organic material layer. Roughening the surface of the temporary substrate will create pits and valleys that may help to align the superabrasive grit such that the tips of individual superabrasive particle will protrude from the organic material layer.

An alternative aspect of the present invention comprises a method of disposing superabrasive particles in an organic material layer. The method may include providing an organic material arranged as a layer, disposing superabrasive particles on the organic material, pressing the superabrasive particles into the organic material, and curing the organic material to form an organic material layer. FIG. 7 shows a permanent substrate 82 upon which a layer of organic material 84 is applied. Superabrasive particles 86 are disposed along the surface of the layer of organic material 84. A fixative may be utilized to at least partially immobilize the superabrasive particles 86 to the layer of organic material 84. The superabrasive particles 86 may be arranged according to an arrangement by any means known to one skilled in the art. Figure 7 shows superabrasive particles arranged by means of a template 88.

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Turning to FIG. 8, a press 92 may be utilized to dispose the superabrasive particles 86 at least partially into the layer of organic material 84. In one aspect, the superabrasive particles 86 protrude above the layer of organic material 84 to a predetermined height. The layer of organic material 84 is subsequently cured to form a solidified organic material layer. In one aspect the organic material layer is a thermoplastic resin. In this case the thermoplastic can be softened by heating in order to receive the superabrasive particles 86, and subsequently cooled to cure the thermoplastic into a solidified organic material layer. The layer of organic material 84 can be any organic material known to one skilled in the art, with the proviso that the uncured organic material be viscous enough to support the superabrasive particles prior to curing, or another form of physical support for the superabrasive particles be provided.

The following examples present various methods for making the coated superabrasive particles and tools of the present invention. Such examples are illustrative only, and no limitation on present invention is meant thereby.

Examples

Example 1

80/90 mesh diamond particles (MBG-660, Diamond Innovations) are arranged with a template on a 100 mm diameter, 10 mm thick flat base plate. The diamond particles form a grid pattern with an inter-diamond pitch of about 500 microns. The plate is placed at the bottom of a steel mold and covered with a polyimide resin powder. Subsequently, the entire assembly is pressed to 50 MPa pressure and 350° C for 10 minutes. The polyimide consolidated plate is 7 mm thick with nickel coated diamond particles forming a grid on one side. A conventional grinding wheel with silicon carbide grit is used to grind the surface to expose the diamond particles to about 60 microns. The final product is a pad conditioner with uniformly exposed diamonds.

Example 2

The same procedure is followed as Example 1, however a phenolic resin is used in place of the polyimide resin, and the forming temperature is reduced to 200° C.

Example 3

The same procedure is followed as Example 1, however the base plate is precoated with a layer of clay that is about 60 microns thick. After hot pressing, the clay is scraped off, exposing the diamond particles protruding from the polyimide resin layer.

Example 4

The same procedure is followed as Example 1, however the pressed polyimide resin disk is 1 mm thick and is glued on a 420 stainless steel backing to form a pad conditioner.

Example 5

80/90 mesh diamond particles are mixed with an epoxy binder to form a slurry. The slurry is spread over a polyethylene terephthalate (PET) sheet. A blade is used to thin the slurry so that it contains one layer of diamond particles. The epoxy is then cured by an UV light to harden. Subsequently, circular disks are punched out of the epoxy sheet. The disks are glued with an acrylic onto stainless steel substrates with the diamond facing away from the glue. A fine sand paper is used to polish the exposed surface and remove the epoxy until approximately half the height of the diamond particles are exposed. The final product is a pad conditioner with diamond particles securely embedded in an epoxy matrix.

Example 6

80/90 mesh diamond particles are arranged by a template on a PET sheet. Subsequently, an epoxy resin is deposited to cover the single layer of diamond particles. After curing, the PET sheet is punched to form disks. The disks are then glued on stainless steel substrates, and the top surface is then sanded off.

Example 7

A 108 mm diameter plastic sheet is covered on both sides with an adhesive. One side is pressed into a steel mold with a smooth surface that exhibits a slightly concave profile. The slope of the concave profile is about 1/1000. A transition in the concave profile toward the center of the mold functions to avoid a sharp point at the center of the completed tool. About 5 mm from the peripheral edge of the mold the slope increases in order to smoothly transition to the mold edge.

80/90 mesh diamond particles are distributed onto a thin sheet coated with an adhesive that is less tacky than the adhesive coated on the plastic sheet. The diamond particles are arranged on the sheet in a grid having a diamond-to-diamond spacing of about 700 microns. The diamond particles are then transferred to the plastic sheet in the mold. The mold is then enclosed in a ring mold.

An epoxy is poured into the ring mold until the thickness exceeds about 10 mm. The mold system is enclosed in a vacuum environment (10^{-3} torr) to remove air bubbles during the curing of the epoxy. After hardening, the epoxy layer is removed from the

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mold and the diamond particles are exposed to about 1/3 of the average diamond size. Excess epoxy is machined away from the back of the epoxy layer opposite to the diamond particles to leave a thickness of about 1 mm. The diamond attached epoxy layer is glued to a stainless steel (410) substrate, with the diamonds facing away from the substrate.

Example 8

An acrylic mold is machined to exhibit a radius with a very gentle dishing having an average tangential slope of no greater than 1/1000. The mold is covered with a double stick adhesive. A nylon sieve with an opening of about 100 microns is pressed against the other side of the adhesive. A stainless steel template with holes larger than one diamond size but smaller than two diamond sizes is placed on the top of the nylon sieve. Diamond particles (80/90 mesh, MBG-660 manufactured by Diamond Innovations) are dispersed over the template. The mold is turned upside down to allow diamonds not stuck in the adhesive to fall out. The remaining diamond particles are stuck to the adhesive but, because of the nylon sieve, the large portions of the diamond particles cannot penetrate though to the adhesive. As a result, the diamond particles are stuck with an edge or a tip in the adhesive.

The acrylic mold is placed in a retaining ring and epoxy resin is mixed and poured over the mold and diamond particles. The mold is placed under vacuum to remove air during curing of the epoxy material. The mold is removed mechanically, and the nylon sieve is removed by using a lathe to trim the surface.

Of course, it is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use may be made without departing from the principles and concepts set forth herein.

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CLAIMS

What is claimed is:

1. A method of improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool, a portion of each of said superabrasive particles protruding out of the solidified organic material layer, comprising:

securing a plurality of superabrasive particles in the solidified organic material layer in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle when used to abrade a work piece.

2. The method of claim 1, wherein the arrangement of the plurality of superabrasive particles is configured to uniformly distribute drag forces across substantially each superabrasive particle.

3. The method of claim 1, wherein a majority of the plurality of superabrasive particles protrudes to a predetermined height above the solidified organic material layer.

4. The method of claim 3, wherein the predetermined height produces a cutting depth of less than about 20 microns when used to abrade a work piece.

5. The method of claim 3, wherein the predetermined height produces a cutting depth of from about 1 micron to about 20 microns when used to abrade a work piece.

6. The method of claim 3, wherein the predetermined height produces a cutting depth of from about 10 micron to about 20 microns when used to abrade a work piece.

7. The method of claim 3, wherein the superabrasive particles protrude to a predetermined height that is along a designated profile.

8. The method of claim 7, wherein the designated profile is a plane.

9. The method of claim 7, wherein the designated profile has a slope.

10. The method of claim 7, wherein the designated profile has a curved shape.

11. The method of claim 10, wherein the designated profile has a dome shape.

12. The method of claim 7, wherein a majority of the plurality of superabrasive particles are arranged such that their tips vary from the designated profile to less than about 10% of the average size of the superabrasive particles.

13. The method of claim 3, wherein a majority of the plurality of superabrasive particles are arranged such that their tips protrude to less than about 40 microns.

14. The method of claim 3, wherein a majority of the plurality of superabrasive particles are arranged such that their tips protrude to less than about 30 microns.

15. The method of claim 3, wherein a majority of the plurality of superabrasive particles are arranged such that their tips protrude to about 20 microns.

16. The method of claim 1, wherein the plurality of superabrasive particles are of substantially the same size.

17. The method of claim 1, wherein the plurality of superabrasive particle are from about 30 microns to about 500 microns in size.

18. The method of claim 1, wherein the plurality of superabrasive particles are from about 100 microns to about 200 microns in size.

19. The method of claim 1, wherein superabrasive particles in a central location of the abrading tool are smaller in size than superabrasive particles in a peripheral location on the abrading tool.

20. The method of claim 1, wherein securing the plurality of superabrasive particles includes arranging the plurality of superabrasive particles according to a predetermined attitude.

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21. The method of claim 20, wherein the predetermined attitude is a uniform attitude across substantially all of the plurality of superabrasive particles.

22. The method of claim 20, wherein the plurality of superabrasive particles are substantially configured with an apex portion oriented towards a work piece.

23. The method of claim 20, wherein superabrasive particles in a central location on the abrading tool are configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the abrading tool are configured with a face portion oriented towards the work piece.

24. The method of claim 1, wherein the plurality of superabrasive particles are arranged as a grid.

25. The method of claim 24, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles.

26. The method of claim 24, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 100 microns to about 800 microns.

27. The method of claim 20, wherein arranging the superabrasive particles according to a predetermined attitude further comprises:

applying an adhesive to a substrate;

applying a flexible sieve to the adhesive;

disposing superabrasive particles across a template positioned on the flexible sieve such that a portion of the superabrasive particles adhere to the adhesive by either an edge or an apex portion; and

removing the template and the un-adhered superabrasive particles from the flexible sieve.

28. The method of claim 27, wherein the flexible sieve is a nylon sieve.

29. The method of claim 1, wherein superabrasive particles in a central location on the abrading tool are spaced farther apart than superabrasive particles in a peripheral location on the abrading tool.

30. A superabrasive tool having improved superabrasive particle retention, comprising:

a solidified organic material layer; and

a plurality of superabrasive particles secured in the solidified organic material layer in an arrangement as recited in claim 1.

31. The tool of claim 30, wherein each of the plurality of superabrasive particles protrudes to a predetermined height above the solidified organic material layer.

32. The tool of claim 31, wherein the predetermined height is greater than about 20 microns.

33. The tool of claim 31, wherein variation from the predetermined height is from about 1 micron to about 20 microns.

34. The tool of claim 31, wherein variation from the predetermined height is from about 5 microns to about 20 microns.

35. The tool of claim 31, wherein variation from the predetermined height is from about 10 microns to about 20 microns.

36. The tool of claim 31, wherein the plurality of superabrasive particles protrude to a predetermined height is along a designated profile.

37. The tool of claim 36, wherein the designated profile is a plane.

38. The tool of claim 36, wherein the designated profile has an average slope from a high point near a center location of the tool to a low point near a peripheral edge of the tool.

39. The tool of claim 38, wherein the average slope is about 1/1000.

40. The tool of claim 36, wherein the designated profile has a curved shape.

41. The tool of claim 31, wherein the plurality of superabrasive particles are arranged such that their tips protrude to about 10% of the average size of the superabrasive particles.

42. The tool of claim 31, wherein the plurality of superabrasive particles are arranged such that their tips protrude from about 20 to about 30 microns.

43. The tool of claim 30, wherein the arrangement is a grid.

44. The tool of claim 43, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles.

45. The tool of claim 43, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 100 microns to 800 microns.

46. The tool of claim 30, wherein superabrasive particles in a central location on the tool are spaced farther apart than superabrasive particles in a peripheral location on the tool.

47. The tool of claim 30, wherein superabrasive particles in a central location on the tool are larger in size than superabrasive particles in a peripheral location on the tool.

48. The tool of claim 30, wherein the plurality of superabrasive particles are arranged according to a predetermined attitude.

49. The tool of claim 48, wherein the plurality of superabrasive particles are substantially configured with an apex portion oriented towards a work piece.

50. The tool of claim 48, wherein superabrasive particles in a central location on the tool are configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the tool are configured with a face portion oriented towards the work piece.

51. The tool of claim 30, wherein the plurality of superabrasive particles include a member selected from the group consisting of diamond, polycrystalline diamond, cubic boron nitride, polycrystalline cubic boron nitride, and combinations thereof.

52. The tool of claim 51, wherein the plurality of superabrasive particles includes diamond.

53. The tool of claim 30, wherein the plurality of superabrasive particles are from about 30 microns to about 500 microns in size.

54. The tool of claim 53, wherein the plurality of superabrasive particles are from about 100 microns to about 200 microns in size.

55. The tool of claim 30, wherein the solidified organic material layer comprises a member selected from the group consisting of amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof.

56. The tool of claim 55, wherein the solidified organic material layer is an epoxy resin.

57. The tool of claim 55, wherein the solidified organic material layer is a polyurethane resin.

58. The tool of claim 55, wherein the solidified organic material layer is a polyimide resin.

59. The tool of claim 30, further comprising a reinforcing material disposed within at least a portion of the solidified organic material layer.

60. The tool of claim 59, wherein the reinforcing material is a material selected from the group consisting of ceramics, metals, or combinations thereof.

61. The tool of claim 60, wherein the reinforcing material is a ceramic.

62. The tool of claim 61, wherein the ceramic comprises a member selected from the group consisting of alumina, aluminum carbide, tungsten carbide, silica, silicon carbide, silicon nitride, zirconia, zirconium carbide, and mixtures thereof.

63. The tool of claim 59, wherein the reinforcing material is an organometallic coupling agent.

64. The tool of claim 30, wherein the tool is a polishing or grinding pad.

65. The tool of claim 30, wherein the tool is a CMP pad dresser.

66. The tool of claim 30, wherein the tool is for shaping dental materials.

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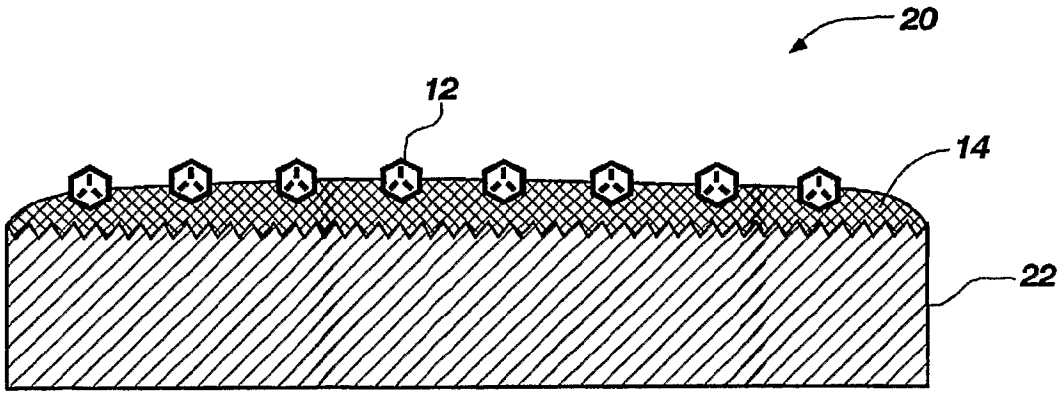


FIG. 1

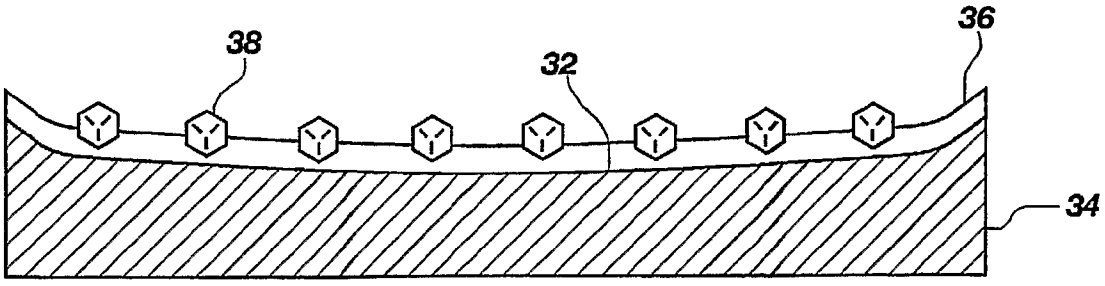


FIG. 2

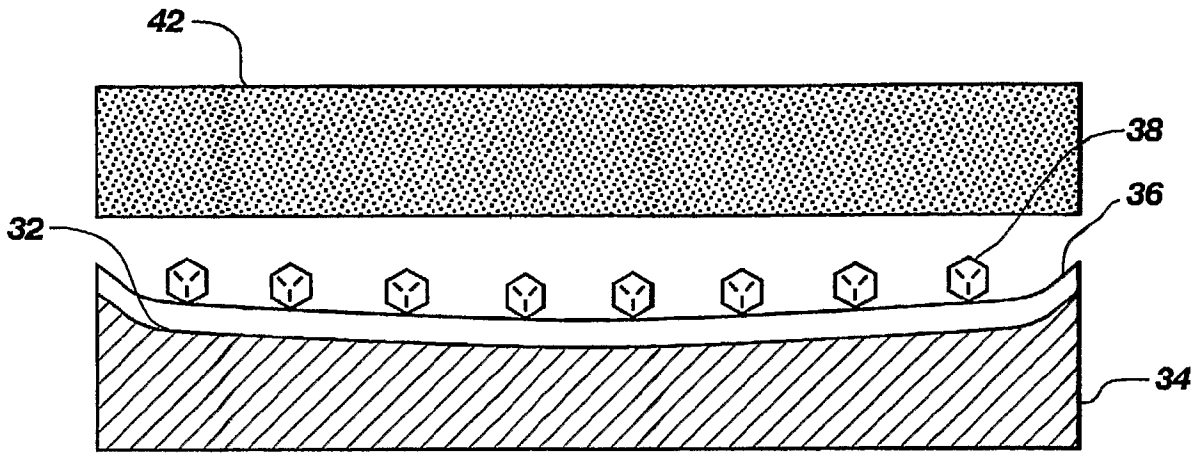


FIG. 3

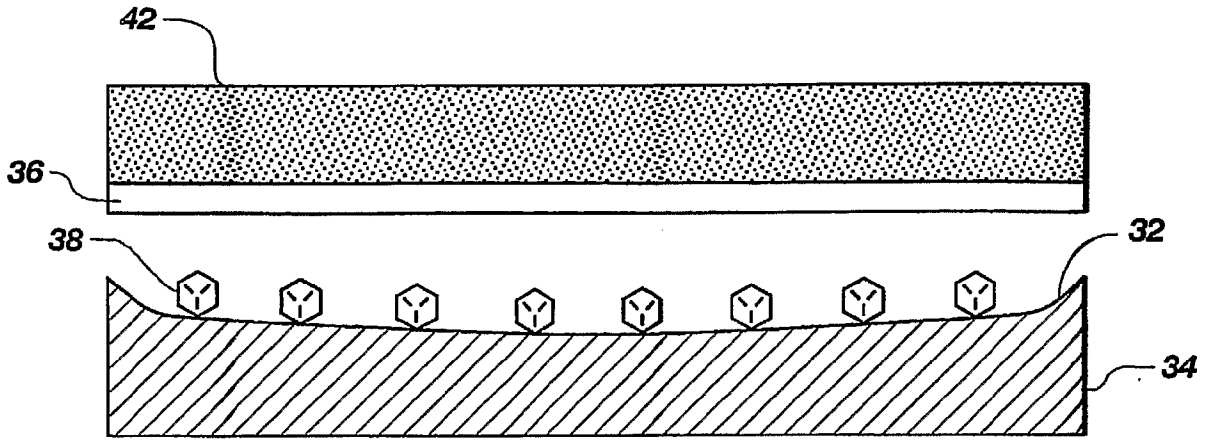


FIG. 4

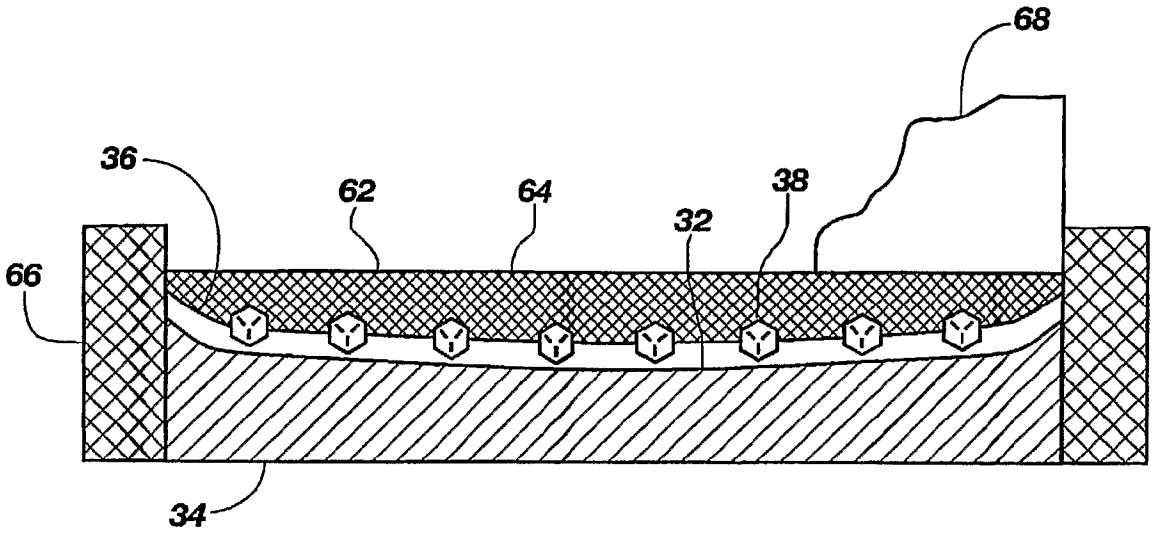


FIG. 5

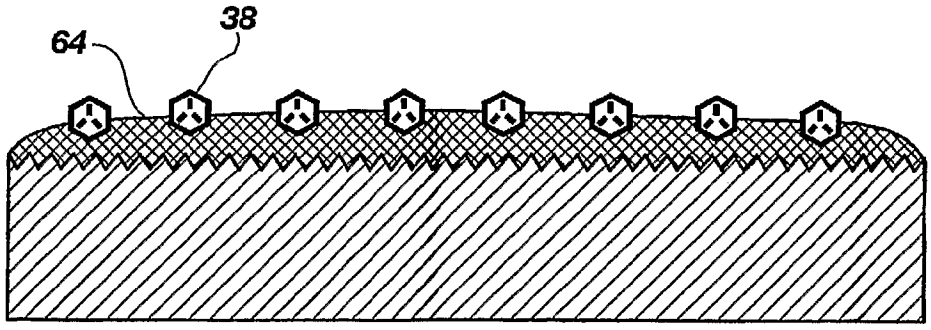


FIG. 6

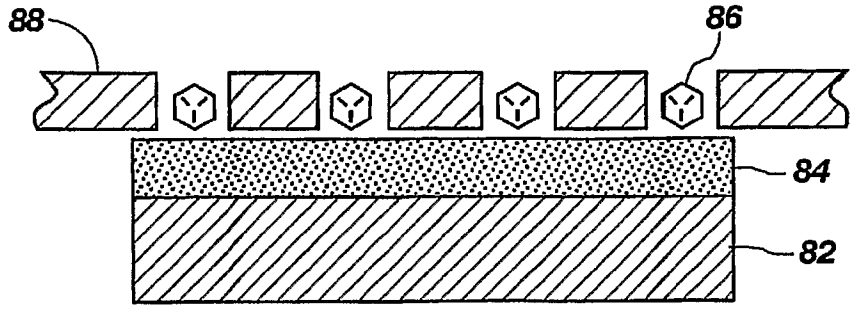


FIG. 7

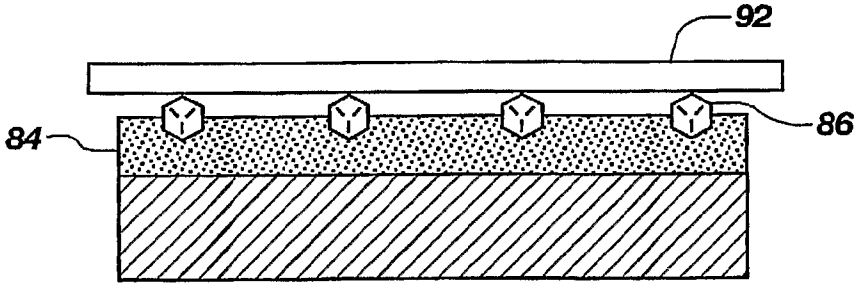


FIG. 8

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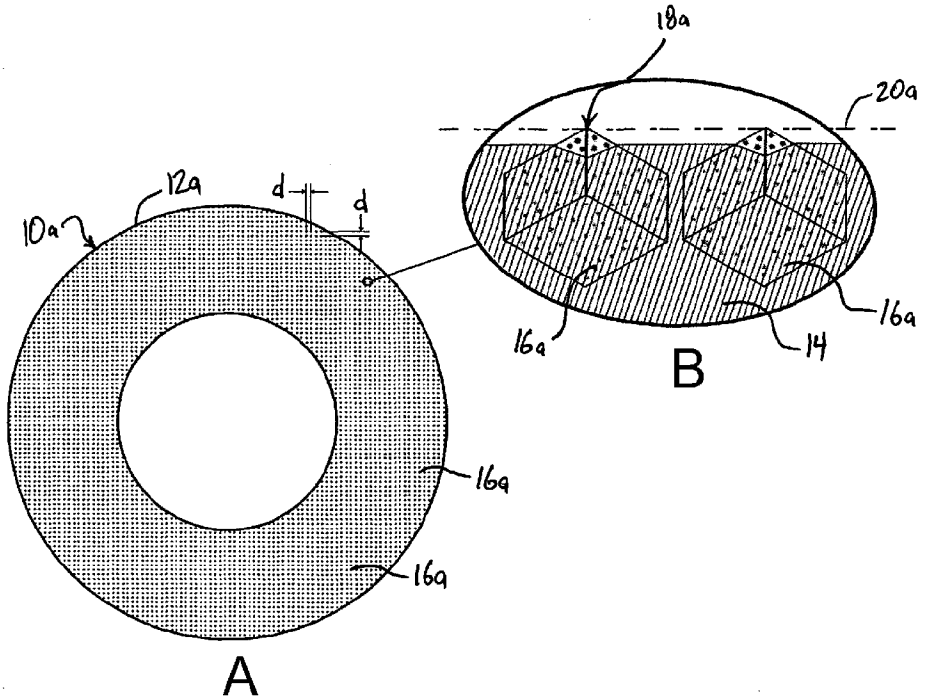
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(54) Title: SUPERHARD CUTTERS AND ASSOCIATED METHODS



(57) Abstract: A cutting device comprises a base having a solidified organic material layer disposed thereon. A plurality of individual polycrystalline cutting elements are secured in the solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements has a substantially matching geometric configuration.

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SUPERHARD CUTTERS AND ASSOCIATED METHODS

FIELD OF THE INVENTION

The present invention relates generally to cutting devices used to remove material from (e.g., plane, smooth, polish, dress, etc.) workpieces formed of various materials. Accordingly, the present invention involves the fields of chemistry, physics, and materials science.

BACKGROUND OF THE INVENTION

It is estimated that the semiconductor industry currently spends more than one billion U.S. Dollars each year manufacturing silicon wafers that exhibit very flat and smooth surfaces. Typically, chemical mechanical polishing ("CMP") is used in the manufacturing process of semiconductor devices to obtain smooth and even-surfaced wafers. In a conventional process, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movement of the platen and the carrier.

While this well-known process has been used successfully for many years, it suffers from a number of problems. For example, this conventional process is relatively expensive and is not always effective, as the silicon wafers may not be uniform in thickness, nor may they be sufficiently smooth, after completion of the process. In addition to becoming overly "wavy" when etched by a solvent, the surface of the silicon wafers may become chipped by individual abrasive grits used in the process. Moreover, if the removal rate is to be accelerated to achieve a higher productivity, the grit size used on the polishing pad must be increased, resulting in a corresponding increase in the risk of scratching or gouging expensive wafers. Furthermore, because surface chipping can be discontinuous, the process throughput can be very low. Consequently, the wafer surface preparation of current state-of-the-art processes is generally expensive and slow.

In addition to these considerations, the line width (e.g., nodes) of the circuitry on semiconductors is now approaching the virus domain (e.g., 10-100 nm). In addition, more layers of circuitry are now being laid down to meet the increasing demands of advanced logic designs. In order to deposit layers for making nanometer sized features,

each layer must be extremely flat and smooth during the semiconductor fabrication. While diamond grid pad conditioners have been effectively used in dressing CMP pads for polishing previous designs of integrated circuitry, they have not been found suitable for making cutting-edge devices with nodes smaller than 65 nm. This is because, with the decreasing size of the copper wires, non-uniform thickness due to rough- or over-polishing will change the electrical conductivity dramatically. Moreover, due to the use of coral-like dielectric layers, the fragile structure must be polished very gently to avoid disintegration. Hence, the pressure used in CMP processes must be reduced significantly.

In response, new CMP processes, such as those utilizing electrolysis (e.g. Applied Materials ECMP) of copper or those utilizing air film cushion support of wafer (e.g. Tokyo Semitsu), are being pursued to reduce the polishing pressure on the contact points between wafer and pad. However, as a consequence of gentler polishing action, the polishing rate of the wafer will decrease. To compensate for the loss of productivity, polishing must occur simultaneously over the entire surface of the wafer. In order to do so, the contact points between the wafer and the pad must be smaller in area, but more numerous in frequency. This is in contrast to current CMP practice in which the contacted areas are relatively large but relatively few in number.

Thus, in order to polish fragile wafers more and more gently, the CMP pad asperities must be reduced. However, to prevent the polishing rate from declining, more contact points must be created. Consequently, the pad asperities need to be finer in size but more in number. However, the more delicate the polishing process becomes, the higher the risk of scratching the surface of the wafer becomes. In order to avoid this risk, the highest tips of all asperities must be fully leveled. Otherwise, the protrusion of a few "killer asperities" can ruin the polished wafer.

SUMMARY OF THE INVENTION

The present invention provides a cutting device, including a base having a plurality of individual polycrystalline cutting elements secured in a solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements can have a matching geometric configuration.

In accordance with another aspect of the invention, a cutting device is provided, including a base having a solidified organic material layer attached thereto, and a plurality

of individual polycrystalline cutting elements secured in a solidified organic material layer, wherein each of the plurality of individual polycrystalline cutting elements can include at least one cutting tip. The cutting tips of the cutting elements can be aligned in a common plane.

In accordance with another aspect of the invention, a method of forming a cutting device is provided, including: obtaining a substrate; arranging on the substrate a plurality of individual polycrystalline cutting elements in an uncured organic material, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration, and curing the organic material to form a solidified organic material layer, such that each of the plurality of individual polycrystalline cutting elements are secured therein.

There has thus been outlined, rather broadly, various features of the invention so that the detailed description thereof that follows may be better understood, and so that the present contribution to the art may be better appreciated. Other features of the present invention will become clearer from the following detailed description of the invention, taken with the accompanying exemplary claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic, top plan view of a cutting device in accordance with an embodiment of the invention;

FIG. 1B is an enlarged view of a portion of the cutting device of FIG. 1A;

FIG. 2A is a schematic, top plan view of a cutting device in accordance with another embodiment of the invention;

FIG. 2B is an enlarged view of a portion of the cutting device of FIG. 2A;

FIG. 3A is a schematic, top plan view of a polycrystalline blank, and a cutting device including individual polycrystalline cutting elements formed from the blank, in accordance with an embodiment of the invention;

FIG. 3B is an enlarged view of a portion of one cutting element of FIG. 3A, taken along section B-B of FIG. 3A;

FIG. 4 is a schematic, top plan view of a polycrystalline blank, and a cutting device including individual polycrystalline cutting elements formed from the blank, in accordance with another embodiment of the invention;

FIG. 5 is a schematic, top plan view of another polycrystalline blank in accordance with an embodiment of the invention, shown with the blank divided into a series of individual cutting elements;

FIG. 6 is a schematic, top plan view of a cutting device including individual polycrystalline cutting elements formed from the blank of FIG. 5 in accordance with another embodiment of the invention;

FIG. 7 is a schematic, top plan view of another cutting device, including the individual polycrystalline cutting elements formed from the blank of FIG. 5 in accordance with another embodiment of the invention;

FIG. 8 is a schematic, top plan view of another polycrystalline blank in accordance with an embodiment of the invention, shown with the blank divided into a series of individual cutting elements;

FIG. 9 is a schematic, top plan view of a cutting device, including the individual polycrystalline cutting elements formed from the blank of FIG. 8 in accordance with another embodiment of the invention;

FIG. 10 is a schematic, top plan view of another cutting device, including the individual polycrystalline cutting elements formed from the blank of FIG. 8 in accordance with another embodiment of the invention;

FIG. 11 is a schematic, top plan view of another polycrystalline blank in accordance with an embodiment of the invention, shown with the blank divided into a pair of individual cutting elements; and

FIG. 12 is a schematic, top plan view of a cutting device including the individual polycrystalline cutting elements formed from the blank of FIG. 11 in accordance with another embodiment of the invention.

It will be understood that the above figures are merely for illustrative purposes in furthering an understanding of the invention. Further, the figures may not be drawn to scale, thus dimensions, particle sizes, and other aspects may, and generally are, exaggerated to make illustrations thereof clearer. Therefore, departure can be made from

the specific dimensions and aspects shown in the figures in order to produce the cutting devices of the present invention.

DETAILED DESCRIPTION

Before the present invention is disclosed and described, it is to be understood that this invention is not limited to the particular structures, process steps, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

It must be noted that, as used in this specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a cutting element" includes one or more of such elements.

Definitions

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

All mesh sizes referred to herein are U.S. mesh unless otherwise indicated. Further, mesh sizes are generally understood to indicate an average mesh size of a given collection of particles since each particle within a particular "mesh size" may actually vary over a small distribution of sizes.

As used herein, a "common plane" refers to a profile, including planar or contoured profiles, above a base surface with which the peaks or tips of cutting elements are to be aligned. Examples of such profiles may include, without limitation, flat profiles, wavy profiles, convex profiles, concave profiles, multi-tiered profiles, and the like.

As used herein, cutting "edge" refers to a portion of a cutting element that includes some measurable width across a portion that contacts and removes material from a workpiece. As an exemplary illustration, a typical knife blade has a cutting edge that extends longitudinally along the knife blade, and the knife blade would have to be oriented transversely to a workpiece to scrape or plane material from the workpiece in order for the cutting "edge" of the knife blade to remove material from the workpiece.

As used herein, cutting "tip" refers to a portion of a cutting element that protrudes

the greatest distance from a bonding material, e.g., that is the first portion of the cutting element that contacts a workpiece when the article of the present invention is in use. It is to be understood that a cutting "tip" can include a planar surface, a pointed surface, or an edge; so long as the planar surface, pointed surface or edge of the cutting element is the first portion of the cutting element that contacts a workpiece from which material is to be removed with a cutting device to which the cutting element is attached.

As used herein, "sintering" refers to the joining of two or more individual particles to form a continuous solid mass. The process of sintering involves the consolidation of particles to at least partially eliminate voids between particles. Sintering may occur in either metal or carbonaceous particles, such as diamond. Sintering of metal particles occurs at various temperatures depending on the composition of the material. Sintering of diamond particles generally requires ultrahigh pressures and the presence of a carbon solvent as a diamond sintering aid, and is discussed in more detail below. Sintering aids are often present to aid in the sintering process and a portion of such may remain in the final product.

As used herein, "superhard" may be used to refer to any crystalline, or polycrystalline material, or mixture of such materials which has a Mohr's hardness of about 8 or greater. In some aspects, the Mohr's hardness may be about 9.5 or greater. Such materials include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), polycrystalline cubic boron nitride (PcBN) as well as other superhard materials known to those skilled in the art. Superhard materials may be incorporated into the present invention in a variety of forms including particles, grits, films, layers, etc. However, in most cases, the superhard materials of the present invention are in the form of polycrystalline superhard materials, such as PCD and PcBN materials. It is important to note that distinctions are made in the present disclosure between conventional superhard grits and polycrystalline superhard materials.

As used herein, "geometric configuration" refers to a shape that is capable of being described in readily understood and recognized mathematical terms. Examples of shapes qualifying as "geometric configurations" include, without limitation, cubic shapes, polyhedral (including regular polyhedral) shapes, triangular shapes (including equilateral triangles, isosceles triangles and three-dimensional triangular shapes), pyramidal shapes, spheres, rectangles, "pie" shapes, wedge shapes, octagonal shapes, circles, etc.

As used herein, "organic material" refers to a semisolid or solid complex amorphous mix of organic compounds. As such, "organic material layer" and "organic material matrix" may be used interchangeably, refer to a layer or mass of a semisolid or solid complex amorphous mix of organic compounds. Preferably the organic material will be a polymer or copolymer formed from the polymerization of one or more monomers.

As used herein, "metal" and "metallic" can be used interchangeably, and refer to a metal, or an alloy of two or more metals. A wide variety of metal or metallic materials is known to those skilled in the art, such as aluminum, copper, chromium, iron, steel, stainless steel, titanium, tungsten, zinc, zirconium, molybdenum, etc., including alloys and compounds thereof.

As used herein, "particle," when used in connection with a superabrasive material, refer to a particulate form of such material. Such particles may take a variety of shapes, including round, oblong, square, euhedral, etc., as well as a number of specific mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes.

As used herein, "particle" and "grit" may be used interchangeably.

As used herein, "cutting element" describes a variety of structures capable of removing (e.g., cutting) material from a workpiece. A cutting element can be a mass having several cutting points, ridges or mesas formed thereon or therein. It is notable that such cutting points, ridges or mesas may be from a multiplicity of protrusions or asperities included in the mass. Furthermore, a cutting element can also include an individual particle that may have only one cutting point, ridge or mesa formed thereon or therein.

As used herein, "grid" means a pattern of lines forming multiple squares.

As used herein, "mechanical force" and "mechanical forces" refer to any physical force that impinges on an object that causes mechanical stress within or surrounding the object. Example of mechanical forces would be frictional forces or drag forces. As such, the terms "frictional force" and "drag force" may be used interchangeably, and refer to mechanical forces impinging on an object as described.

As used herein, "mechanical stress" refers to a force per unit area that resists impinging mechanical forces that tend to compact, separate, or slide an object.

As used herein, the term "profile" refers to a contour above an organic material layer

surface to which the superabrasive particles are intended to protrude.

As used herein, "mechanical bond" and "mechanical bonding" may be used interchangeably, and refer to a bond interface between two objects or layers formed primarily by frictional forces. In some cases the frictional forces between the bonded objects may be increased by expanding the contacting surface areas between the objects, and by imposing other specific geometrical and physical configurations, such as substantially surrounding one object with another.

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. For example, a composition that is "substantially free of" particles would either completely lack particles, or so nearly completely lack particles that the effect would be the same as if it completely lacked particles. In other words, a composition that is "substantially free of" an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.

As used herein, the term "about" is used to provide flexibility to a numerical range endpoint by providing that a given value may be "a little above" or "a little below" the endpoint.

As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

Concentrations, amounts, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used

merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc., as well as 1, 2, 3, 4, and 5, individually.

This same principle applies to ranges reciting only one numerical value as a minimum or a maximum. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides a cutting device and associated methods that can be utilized in cutting or otherwise affecting a workpiece to remove material from the workpiece and provide a finished, smooth and/or flat surface to the workpiece. Cutting devices of the present invention can be advantageously utilized, for example, as planing devices that plane material from a workpiece, as dressing devices that dress various workpieces, and as polishing devices that polish various workpieces.

In the embodiment of the invention illustrated in FIGs. 1A and 1B, a cutting device (e.g., disk) 10a is provided that optionally includes a base 12a that can have a solidified organic material layer (14 in FIGs. 1B and 2B) disposed thereon, attached thereto, or otherwise associated therewith. A plurality of individual polycrystalline cutting elements 16a can be secured in the solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements can have or exhibit a substantially matching geometric configuration, e.g., the geometric configuration of the cutting elements can substantially match that of other of the cutting elements. In the example illustrated in FIG. 1B, each of the plurality of individual polycrystalline cutting elements 16a has geometric configuration that is substantially cubic in nature. In the embodiment illustrated in FIG. 2B, the individual polycrystalline cutting elements 16b have a geometric configuration that can be characterized as a three-dimensional triangular configuration.

As illustrated in both FIGs. 1B and 2B, in one aspect of the invention, the plurality of individual polycrystalline cutting elements 16a, 16b can include at least one cutting tip (18a and 18b, respectively), with the cutting tips of the cutting elements being aligned in a common plane (20a, 20b, respectively). In this example, the common plane is a flat plane of predetermined height above the solidified organic matrix. Thus, the plurality of individual polycrystalline cutting elements can be held within the solidified organic material layer in a very precise manner such that each of the cutting elements contacts a workpiece (not shown) from which material is to be removed at substantially the same depth. In this way, each of the individual polycrystalline cutting elements can be subject to substantially the same level of drag force as the cutting device is moved relative to a workpiece. This feature of the invention can advantageously limit the premature removal of individual cutting elements that might otherwise shorten the life of the tool, and/or damage the workpiece being treated.

The individual cutting elements 16a, 16b can be formed from a variety of materials including, in one embodiment, a polycrystalline material or a superhard polycrystalline material. While not so limited, the superhard polycrystalline material can be a polycrystalline diamond compact ("PCD") or a polycrystalline cubic boron nitride compact ("PcBN"). The PCD or PcBN compact can be formed in a variety of manners, as discussed in more detail below. By forming the individual cutting elements from a polycrystalline material, and attaching the cutting elements individually to the cutting device, the beneficial properties of polycrystalline cutting elements can be achieved without requiring that portions of the cutting device not used for cutting also be formed from the polycrystalline material. Thus, considerable cost savings can be achieved.

The cutting devices of the present invention can be utilized in a number of applications, and in one embodiment are particularly well adapted for use in planing substantially brittle materials, such as silicon wafers, glass sheets, metals, used silicon wafers to be reclaimed by planarization, LCD glass, LED substrates, SiC wafers, quartz wafers, silicon nitride, zirconia, etc. In conventional silicon wafer processing techniques, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movements of the platen and the carrier. Thus,

the silicon wafer is essentially ground or polished, by very fine abrasives, to a relatively smooth surface.

While grinding of silicon wafers has been used with some success, the process of grinding materials such as silicon wafers often results in pieces of the material being torn or gouged from the body of the material, resulting in a less than desirable finish. This is due, at least in part, to the fact that grinding or abrasive processes utilize very sharp points of abrasive materials (which are often not level relative to one another) to localize pressure to allow the abrasives to remove material from a workpiece.

The PCD or PcBN cutting elements of the present invention are generally superhard, resulting in little yielding by the cutting elements when pressed against a wafer. As hardness is generally a measure of energy concentration, e.g., energy per unit volume, the PCD or PcBN compacts of the present invention are capable of concentrating energy to a very small volume without breaking. These materials can also be maintained with a very sharp cutting edge due to their ability to maintain an edge within a few atoms.

While not so required, in one embodiment of the invention shown in FIG. 1A, the individual polycrystalline cutting elements 16a can be arranged in or across the organic material layer or base in a grid pattern, e.g., in a pattern of squares. The cutting elements can be evenly spaced from one another at a distance "d" of from about 100 microns to about 800 microns. In one aspect of the invention, the individual polycrystalline cutting elements can be evenly spaced from one another at a distance "d" of about 500 microns.

In the embodiment of the invention illustrated in FIG. 2A, the individual polycrystalline cutting elements 16b can be arranged in or across the organic material layer or base as a series of concentric circles. As in the embodiment discussed above, the individual cutting elements can be evenly spaced from one another at a distance "d" of from about 100 microns to about 800 microns. In one aspect, the individual polycrystalline cutting elements can be evenly spaced from one another at a distance "d" of about 500 microns. By evenly spacing the individual cutting elements one from another, the drag force applied to the cutting elements during the cutting process can be evenly distributed among each of the cutting elements, eliminating or reducing the risk of premature pullout of one or more individual cutting elements. Premature pullout of one or more individual cutting elements can result in serious damage being done the workpiece being worked upon.

The retention of an individual polycrystalline cutting element in an organic material layer can be greatly improved by arranging the cutting elements the organic material layer such that mechanical stress impinging on any individual cutting element is minimized. By reducing the stress impinging on each individual cutting element they can be more readily retained in a solidified organic material layer, particularly for delicate tasks.

Various configurations or arrangements are contemplated for minimizing the mechanical stress impinging on the cutting elements held in the abrading tool. In addition to the spacing considerations discussed above, one potentially useful parameter may include the relative heights that the elements protrude above the organic material layer. A cutting element that protrudes to a significantly greater height than other cutting elements will experience a greater proportion of the impinging mechanical forces and thus is more prone to pull out of the solidified organic material layer. Thus, an even height distribution of the cutting elements may function to more effectively preserve the integrity of the abrading tool as compared to abrading tools lacking such an even height distribution.

As such, in one aspect, substantially all of the plurality of individual cutting elements may protrude to a predetermined height above the solidified organic material layer. Though any predetermined height that would be useful in an abrading or cutting tool would be considered to be within the presently claimed scope, in one specific aspect the predetermined height may produce a cutting depth of less than about 20 microns when used to abrade a workpiece. In another specific aspect, the predetermined height may produce a cutting depth of from about 1 micron to about 20 microns when used to abrade a workpiece. In yet another specific aspect, the predetermined height may produce a cutting depth of from about 10 micron to about 20 microns when used to abrade a workpiece. In yet another aspect, the predetermined height may produce a depth of up to or more than 50 or 100 microns.

It should also be noted that the leveling of the individual cutting elements to a predetermined height may be dependent on cutting element spacing. In other words, the farther the cutting elements are separated, the more the impinging forces will affect each cutting element. As such, patterns with increased spacing between the cutting elements may benefit from a smaller variation from predetermined height.

It may also be beneficial for the cutting elements to protrude from the solidified

organic material layer to a predetermined height or series of heights that is/are along a designated profile. Numerous configurations for designated profiles are possible, depending on the particular use of the abrading tool. In one aspect, the designated profile may be a plane. In planar profiles, the highest protruding points of the cutting elements are intended to be substantially level. It is important to point out that, though it is preferred that these points align with the designated profile, there may be some height deviation between cutting elements that occur due to limitations inherent in the manufacturing process.

In addition to planar profiles, in another aspect of the present invention the designated profile has a slope. Tools having sloping surfaces may function to more evenly spread the frictional forces impinging thereon across the cutting elements, particularly for rotating tools such as disk sanders and CMP pad dressers. The greater downward force applied by higher central portions of the tool may offset the higher rotational velocity at the periphery, thus reducing the mechanical stress experienced by cutting elements in that location. As such, the slope may be continuous from a central point of the tool to a peripheral point, or the slope may be discontinuous, and thus be present on only a portion of the tool. Similarly, a given tool may have a single slope or multiple slopes. In certain aspects, the tool may slope in a direction from a central point to a peripheral point, or it may slope from a peripheral point to a central point.

Various slopes are contemplated that may provide a benefit to solidified organic material layer tools. It is not intended that the claims of the present invention be limited as to specific slopes, as a variety of slopes in numerous different tools are possible. In one aspect, however, a CMP pad dresser may benefit from an average slope of 1/1000 from the center to the periphery.

As a variation on tools having a slope, in certain aspects the designated profile may have a curved shape. One specific example of a curved shape is a dome shape tool. Such curved profiles function in a similar manner to the sloped surfaces. Tools may include such curved profiles in order to more effectively distribute the frictional forces between all of the cutting elements, thus reducing failures of individual particles and prolonging the life of the tool.

As has been mentioned herein, while it is intended that the tips of the cutting elements align along the designated profile, some level of deviation may occur. These

deviations may be a result of the design or manufacturing process of the tool. Given the wide variety of sizes and shapes of cutting elements that may potentially be utilized in a given tool, such deviations may be highly dependent on a particular application. Also, when referring to the designated profile, it should be noted that the term "tip" is intended to include the highest protruding point of a cutting element, whether that point be an apex, an edge, or a face. Orientational positioning, tip leveling, and other techniques of manipulating superabrasive particles are further described in U.S. Patent Application No. 11/223,786, filed on September 9, 2005, and U.S. Patent Application No. 11/733,325, filed April 10, 2007, both of which are incorporated herein by reference.

As such, in one aspect a majority of the plurality of cutting elements is arranged such that the tips vary from the designated profile by from about 1 micron to about 150 microns. In another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 5 microns to about 100 microns. In yet another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 10 microns to about 75 microns. In a further aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 10 microns to about 50 microns. In another aspect, they are arranged such that their tips vary from the designated profile by from about 50 microns to about 150 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by from about 20 microns to about 100 microns. In a further aspect, they are arranged such that their tips vary from the designated profile by from about 20 microns to about 50 microns.

In another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 20 microns to about 40 microns. Additionally, in one aspect, they are arranged such that their tips vary from the designated profile by less than about 20 microns. In another aspect, they are arranged such that their tips vary from the designated profile by less than about 10 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by less than about 5 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by less than about 1 micron. In a further aspect, a majority of the plurality of the cutting elements are arranged such that their tips vary from the designated profile to less than about 10% of the average size of the cutting elements.

The determination of the distance that the tips of the cutting elements extend from the organic binder can also be affected by considering how much of the cutting elements extend above the binder compared to how much of the cutting elements remain submerged beneath the binder surface. In the embodiment illustrated in FIGs. 1A and 1B, a ratio of an amount the cutting elements 16a protrude above the binder to an amount submerged beneath the binder is about 4 to 1. In the embodiment illustrated in FIGs. 2A and 2B, about 2/3 of the cutting elements 16b are submerged, with about 1/3 being exposed above the binder. Other ratios are also possible, from a 20 to 1 ratio to about 0.2 to 1, inclusive of ranges therebetween.

By forming the individual cutting elements in the shapes described herein, a relatively large portion of the cutting elements 16a, 16b can be submerged beneath the organic binder. In this manner, the area that affords the greatest cross section for engagement with the binder material is "buried" beneath the greatest amount of binder. This feature of the invention, namely that the widest (i.e. largest cross section of the cutting element) is closer to one end of the particle than the other, and thus the wider end can be placed below the surface of the organic matrix, provides great retention advantages over conventional diamond, or synthetic diamond, grits wherein a largest cross section of the grit is concentrated near a midpoint of the grit, and thus is placed at or near the surface of a matrix in which the grit is held. The widest portion may be at or near the end that is most distal from the working (e.g., cutting) end of the cutting element.

In addition to the shapes of cutting elements illustrated in the figures, in one embodiment of the invention, the cutting elements are formed in pyramidal shapes. The present inventor has found that such a configuration provides a number of advantages. For example, pyramidal-shaped cutting elements concentrate most of the volume/mass of the cutting element toward a lowermost portion of the cutting element, ensuring that the cutting element is more securely held to whichever type of base (e.g., cutting tool) the elements are bonded to, integrated with, or other associated with. In addition, by forming pyramids with a triangular base, the support base of the pyramids is even more massive relative to the tip, and the tip can be made sharper (e.g., 60 degrees) without breaking or fracturing during the dressing of CMP pads.

In general, sharper tips will cut pads faster, leading to a corresponding reduction in total dressing time. Moreover, the asperities formed on the pad are also sharper and more

dense. Such asperities can polish wafers, and/or dress CMP pads faster without causing undesirable non-uniformity on the wafer. Alternatively, square pyramids can be used when a lower cut rate is desired, as the tip angle likely has a larger magnitude (e.g. 90 degrees). Thus creating a wider cut path with greater drag and resulting in a lower cut rate. However, the square PCD cutter can be formed more sharply than conventional, single crystal diamond grits that have variable tip angles ranging from 90 degrees to over 125 degrees. Thus, pyramids formed of polycrystalline materials are generally much more effective cutters, with triangular pyramids (i.e. 3 sided) being particularly effective.

In addition, as the cutting elements of the present invention can be made with very closely controlled geometry, the present polycrystalline cutting elements can cut pads with less tearing. Also, with the addition of the secondary cutting elements formed on the major cutting elements, the present cutting elements can perform even better. In other words, serrations in the cutting surface may improve the cutting action of the cutting elements. In contrast, single crystal grits are generally very smooth, so they can cause a lot of plastic deformation on the pad and tearing of cut "shreds." It should be noted that the irregular surface of the polycrystalline cutting elements additionally improves retention in the organic material layer. Such irregular surfaces allow the organic material to "grip" a cutting element to a greater extent than would be possible with the smooth surfaces of a single crystal cutting element.

In addition, oftentimes pad conditioners dress pads under conditions in which work load is unevenly distributed across the cutting elements. Specifically, the outer rim of cutting elements often must do the most cutting work, with the interior elements not being subject to a as high a degree of stress. One manner in which the present invention addresses this problem is by configuring the "outer" cutting elements, some times as PCD grits, (e.g., those located closer to the outer perimeter of the cutting or dressing tool) more robust, and/or the inner elements slightly higher (e.g. about 10 microns higher) than the outer elements. The outer cutting elements can also be disposed on the cutting tool at a greater density, e.g., they can be spaced closer together, and/or be positioned at a slightly lower elevation. In this design, the distribution of cutting elements may not be in grid form, but can include a series of concentric rings that can be radially symmetric.

In one embodiment of the invention, the outer elements can be formed with larger support bases relative to the cutting tips (in one aspect they can have triangular bases),

and they may also have an edge formed on the cutting tip rather than just a point. Also, the outermost cutting elements may have a small (e.g. 50 microns) mesa formed at their cutting tips that can cut the pad with edge of the mesa rather than with a straight edge or a point.

In one embodiment of the invention, the cutting elements can be pyramids that are asymmetrical in shape. For example, since the cutting force is generally applied from "outside to inside," the pyramid design may have a relatively steeply sloped wall facing the outer perimeter of the cutting device, but with a relatively gentler slope (e.g. 10 degrees from the horizontal plane) in the trailing side. That is, the table portion on the tip of the pyramid may not be horizontal, but may exhibit a slight "tilt" toward inward to allow debris to escape more easily. This aspect of the invention differs from diamond grit cutting pads, as such conventional cutting pads include a negative angle such that the tearing or cutting force is superimposed with a compressive force. This embodiment of the invention can allow cutting without a great deal of compression so the removal of pad "shread" is much easier.

In other words, the present invention allows a majority of the energy consumed to be used in cutting, rather than plastic deformation. This advantage can be further improved upon by forming the vertical wall of the pyramids such that they slope slightly less than 90 degrees (e.g., about 80 degrees). In this case the table of the pyramids can be sharper on the top of the mesa, similar to an inverted pyramid. This can improve the efficiency of pad cutting because the cutting is performed with a positive angle, similar to a razor blade used in shaving. Such a design has not been possible with single crystal diamond designs, as the cutting edge contact with such designs is always negative in angle. The present pyramidal cutting elements can provide positive cutting edges that are not subject to premature failure due, at least in part, to its ability to support such a cutting edge with a more gently sloping wall on the trailing side of the cutting interface (e.g., with the asymmetrical shape of the pyramids). In one aspect, such an asymmetry can be formed by wire-EDM cutting, and it can be formed with pyramids with tips of point, edge, and mesa tops. Also, when the cutting elements are individual particles or grits, such particle or grit can receive the intended configuration, including an assymetrical configuration as described above by using a mold with a proper shape for processing of the PCT particle.

In one embodiment of the invention, the spacing of the pyramids can be adjusted to adjust the contact pressure of each cutting point, edge or mesa. In general, the farther the pyramids are spaced from one another, the higher the contact pressure between the pyramid and the pad. Thus, the fewer tips present to support the applied force, the deeper the penetration of each of the tips and the larger the formed asperities. Generally, the polishing rate of the wafer is dependent on the number and size of the asperities. Denser, smaller asperities can polish as fast as fewer, larger asperites. But the former is more uniform with no excessive force that may cause non-uniformity, scratching, erosion or dishing of the delicate wafer, etc. This can be particularly true with copper smaller than 90 nm and with low-k dielectric having greater than 20% pores.

The individual polycrystalline cutting elements can be formed in a variety of manners and from a variety of materials, as would occur to one having ordinary skill in the relevant art. In one aspect of the invention, the cutting elements are sintered polycrystalline diamond cubes with silicon/SiC as the matrix. Each of the cubes can contain about 90 V% of diamond (about 10 microns in grain size) and the remaining phase can be either silicon or SiC. A very small amount of titanium can be used facilitate the sintering process. The cubes can be pressed in a graphite mold and formed in a size of about 1 mm on each side. While the cubic examples provided above have proven particularly efficacious, it is to be understood that a variety of sizes and configurations of polycrystalline materials can be utilized in the present invention.

By forming the cutting elements from individual units of superhard polycrystalline material, in defined geometric shapes, arrangement of the cutting elements in a very precise manner becomes much easier. As the defined geometric shapes can be replicated fairly precisely from one cutting element to another, the positioning of, and accordingly, the stress impinged upon, each cutting element can be accomplished fairly consistently across the face off the cutting device in question. With prior art abrasive grits, for example, the overall shape and size of each a plurality of grits might change considerably from one grit to another, making precise placement of the grits difficult to accomplish.

The material utilized in the organic material layer 14 can vary widely. Numerous organic materials are known to those skilled in the art which would be useful when utilized in embodiments of the present invention, and are considered to be included herein. The organic material layer can be any curable resin material, resin, or other

polymer with sufficient strength to retain the individual polycrystalline cutting elements of the present invention. It may be beneficial to use an organic material layer that is relatively hard, and maintains a flat surface with little or no warping. This allows the abrading tool to incorporate very small individual polycrystalline cutting elements at least partially therein, and to maintain these small cutting elements at relatively level and consistent heights.

Additionally, various organic materials may act to absorb mechanical forces impinging on the cutting elements disposed therein, and thus spread and equalize such forces across the abrading tool.

Methods of curing the organic material layer can be any process known to one skilled in the art that causes a phase transition in the organic material from at least a pliable state to at least a rigid state. Curing can occur, without limitation, by exposing the organic material to energy in the form of heat, electromagnetic radiation, such as ultraviolet, infrared, and microwave radiation, particle bombardment, such as an electron beam, organic catalysts, inorganic catalysts, or any other curing method known to one skilled in the art.

In one aspect of the present invention, the organic material layer may be a thermoplastic material. Thermoplastic materials can be reversibly hardened and softened by cooling and heating respectively. In another aspect, the organic material layer may be a thermosetting material. Thermosetting materials cannot be reversibly hardened and softened as with the thermoplastic materials. In other words, once curing has occurred, the process is essentially irreversible.

Organic materials that may be useful in embodiments of the present invention include, but are not limited to: amino resins including alkylated urea-formaldehyde resins, melamine-formaldehyde resins, and alkylated benzoguanamine-formaldehyde resins; acrylate resins including vinyl acrylates, acrylated epoxies, acrylated urethanes, acrylated polyesters, acrylated acrylics, acrylated polyethers, vinyl ethers, acrylated oils, acrylated silicons, and associated methacrylates; alkyd resins such as urethane alkyd resins; polyester resins; polyamide resins; polyimide resins; reactive urethane resins; polyurethane resins; phenolic resins such as resole and novolac resins; phenolic/latex resins; epoxy resins such as bisphenol epoxy resins; isocyanate resins; isocyanurate resins; polysiloxane resins including alkylalkoxysilane resins; reactive vinyl resins; resins

marketed under the Bakelite trade name, including polyethylene resins, polypropylene resins, epoxy resins, phenolic resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, ethylene copolymer resins, acrylonitrile-butadiene-styrene (ABS) resins, acrylic resins, and vinyl resins; acrylic resins; polycarbonate resins; and mixtures and combinations thereof. In one aspect of the present invention, the organic material may be an epoxy resin. In another aspect, the organic material may be a polyimide resin. In yet another aspect, the organic material may be a polyurethane resin. In yet another aspect, the organic material may be a polyurethane resin.

Numerous additives may be included in the organic material to facilitate its use. For example, additional crosslinking agents and fillers may be used to improve the cured characteristics of the organic material layer. Additionally, solvents may be utilized to alter the characteristics of the organic material in the uncured state. Also, a reinforcing material may be disposed within at least a portion of the solidified organic material layer. Such reinforcing material may function to increase the strength of the organic material layer, and thus further improve the retention of the individual polycrystalline cutting elements. In one aspect, the reinforcing material may include ceramics, metals, or combinations thereof. Examples of ceramics include alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof.

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of each superabrasive particle to facilitate the retention of the superabrasive particles in the organic material matrix via chemical bonding. A wide variety of organic and organometallic compounds are known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive particles and the organic material matrix, thus increasing the retention of the particles therein. In this way, the organometallic coupling agent acts as a bridge to form bonds between the organic material matrix and the surface of the superabrasive particles. In one aspect of the present invention, the organometallic coupling agent can be a titanate, zirconate, silane, or mixture thereof.

Specific non-limiting examples of silanes suitable for use in the present invention include: 3- glycidoxypropyltrimethoxy silane (available from Dow Corning as Z-6040); γ-methacryloxy propyltrimethoxy silane (available from Union Carbide Chemicals Company as A-174); β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, γ-

aminopropyltriethoxy silane, N-(β-aminoethyl)-γ-aminopropylmethyldimethoxy silane (available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.); and additional examples of suitable silane coupling agents can be found in U.S. Pat. Nos. 4,795,678, 4,390,647, and 5,038,555, which are each incorporated herein by reference.

Specific non-limiting examples of titanate coupling agents include: isopropyltriisostearoyl titanate, di(cumylphenylate)oxyacetate titanate, 4-aminobenzenesulfonyldodecylbenzenesulfonyl titanate, tetraoctylbis (ditridecylphosphite) titanate, isopropyltri(N-ethylamino-ethylamino) titanate (available from Kenrich Petrochemicals. Inc.), neoalkyoxy titanates such as LICA-01, LICA-09, LICA-28, LICA-44 and LICA-97 (also available from Kenrich), and the like.

Specific non-limiting examples of aluminum coupling agents include acetoalkoxy aluminum diisopropylate (available from Ajinomoto K.K.), and the like.

Specific non-limiting examples of zirconate coupling agents include: neoalkoxy zirconates, LZ-01, LZ-09, LZ- 12, LZ-38, LZ-44, LZ-97 (all available from Kenrich Petrochemicals, Inc.), and the like. Other known organometallic coupling agents, e.g., thiolate based compounds, can be used in the present invention and are considered within the scope of the present invention.

The amount of organometallic coupling agent used depends on the coupling agent and on the surface area of the individual polycrystalline cutting elements. Typically, 0.05% to 10% by weight of the organic material layer is sufficient.

Turning now to FIG. 3A, in one aspect of the invention, the individual polycrystalline cutting elements can be obtained and/or formed from a polycrystalline blank of material. One such blank of material is shown at 30 in FIG. 3A, with the polycrystalline blank being formed in a disk having a diameter of roughly 30 mm and a thickness that can vary from around 0.2 mm to upwards of 2 mm.

The disk 30 can be divided into a series of individual cutting elements in a variety of manners known to those having ordinary skill in the art, including, without limitation, electro-chemical machining, by laser ablation, by plasma etching, by oxidation (to form carbon dioxide or monoxide gas), hydrogenation (to form methane gas), etc. Laser beams with relatively longer wavelengths (e.g. ND:YAG) have been shown to form cutting grooves on PCD effectively (laser beams with relatively short wavelengths (e.g. excimers) may be used to carve out the secondary cutting elements on top of the primary cutting

elements, as shown and discussed in connection with FIG. 3B. While the latter may be slower in cutting speed, it is generally more precise due to the shorter wavelength used. Moreover, the surface damage can be less with more concentrated energy in higher frequencies. This has been found suitable for shaving or planing a silicon wafer in accordance with the present invention.

In one aspect of the invention, the material is removed from the PCD or PcBN compact by electrical discharge machining ("EDM"). In this aspect, the EDM process can utilize one or more electrodes that include diamond. For example, the cathode used in the EDM process can be a boron doped diamond material and the anode used in the EDM process can be the PCD (in this case, the PCD would generally need to be at least partially electrically conductive). As current is applied through the boron doped diamond material, the material of the PCD can be carefully and controllably removed to form various cutting elements from the PCD.

As will be appreciated, the disk 30 is divided into 8 similarly shaped and sized wedges 32. In one embodiment of the invention, the wedges 32 can be attached to a base 12b by way of the solidified organic material layer discussed above. In the embodiment of the invention illustrated in FIG. 3A, the wedges 32 are radially distributed about the face of the cutting device and/or base or substrate. In this manner, the wedges 32 can be arranged so as to each be subject to substantially the same force (and each be substantially as likely to be retained within the organic matrix) when used to abrade or treat a workpiece (not shown). While not so required, in one embodiment of the invention, the PCD blank 30 can be on the order of about 30 mm in diameter, while the base 12b can be on the order of about 100 mm in diameter. Thus, a cutting device with a diameter of around 100 cm can be formed from superhard material taken from a PCD of only about 30 mm.

As shown in FIG. 4, in one aspect of the invention, a longitudinal axis of each of the individual polycrystalline cutting elements (e.g., wedges 32) is aligned along a radius R of the cutting device. In the embodiment shown, the individual polycrystalline cutting elements are distributed on the cutting device in alternating orientations. The manner of arranging the cutting elements across the face of the base or substrate 12b can be varied for particular applications. Due to the consistent shape and size of the individual polycrystalline cutting elements, however, arrangement and attachment of the cutting

elements to the base is made considerably easier. Accordingly, varying the arrangement for particular applications can be more easily and accurately accomplished.

By utilizing a relatively small amount of polycrystalline material (e.g., disk 30), relative to the size of the base 12b which is to be used to treat the workpiece (not shown), the amount polycrystalline material used can be greatly reduced, leading to considerable cost savings. The present inventor has found, however, that cutting devices of the present invention perform equally well, or nearly equally as well, as conventional cutting devices that utilize "full-face" polycrystalline cutting or grinding tools.

As will be appreciated, the blank 30 of FIG. 3A has been divided into 8 equal portions. However, as shown in FIGs. 5 through 12, the disks 30b, 30c and 30d can be divided into twelve equal portions (represented by wedges 32b), sixteen equal portions (represented by wedges 32c), two equal portions (represented by wedges 32d), and so forth. In this manner, the present invention provides additional flexibility for creation and arrangement of the individual polycrystalline cutting elements across the tool. It is contemplated that a variety of other configurations is also possible, including, without limitation, differently sized and shaped individual polycrystalline cutting elements.

Returning to FIG. 3B, in one aspect of the invention, the individual polycrystalline cutting elements 32 can include a series of secondary cutting elements 40 formed on a face of each of the individual polycrystalline cutting elements. The secondary cutting elements can be configured to maintain a sharpness of each of the cutting elements during use of the cutting device. The secondary cutting elements can vary in shape, and can include rectangular-shaped cutting elements, pyramidal-shaped cutting elements, triangular-shaped cutting elements, etc. The secondary cutting elements can also be formed in a truncated pyramidal shape (not shown). By utilizing secondary cutting elements on the primary cutting elements, the total cutting edge length of the cutting element can be extended by as much as 10,000 times.

In accordance with another aspect, the present invention provides a method of forming a cutting device, comprising: obtaining a substrate; arranging on the substrate a plurality of individual polycrystalline cutting elements, each of the plurality of individual polycrystalline cutting elements having a matching geometric configuration; and securing each of the plurality of individual polycrystalline cutting elements to the substrate with a solidified organic material layer.

The method can further comprise aligning at least one cutting tip of each of the plurality of individual polycrystalline cutting elements in a common plane.

Examples

The following examples present various methods for making the cutting tools of the present invention. Such examples are illustrative only, and no limitation on present invention is meant thereby.

Example 1:

Individual sintered polycrystalline diamond cubes with silicon/SiC as the matrix were used as the cutting elements for forming a CMP pad conditioner. Each of the cubes contains about 90 V% of diamond (about 10 microns in grain size) and the remaining phase is either silicon or SiC. A very small amount of titanium is also present to facilitate the sintering process. The cubes were pressed in a graphite mold and were formed in a size of about 1 mm on each side.

An epoxy mold was provided with cavities configured to receive one apex of the PCD cubes. A parting layer was spread on top of the mold. Subsequently, another epoxy is cast on the top in vacuum. After curing, the mold is removed, exposing the apex of each cube. The apexes become the cutting tip of a pad conditioner.

Example 2

A disk of sintered polycrystalline diamond with silicon/SiC as the matrix is divided into a series of wedges of substantially the same volume. The wedges are used as the cutting elements for forming a CMP pad conditioner. Each of the wedges contains about 90 V% of diamond (about 10 microns in grain size) and the remaining phase is either silicon or SiC. A very small amount of titanium is also present to facilitate the sintering process.

An epoxy mold was provided with cavities configured to receive each of the PCD wedges. A parting layer was spread on top of the mold. Subsequently, another epoxy is cast on the top in vacuum. After curing, the mold is removed, exposing the face of each wedge. The faces (and edges of the faces) of the wedges become the cutting elements of a pad conditioner.

Example 3

PCD blanks pressed from a cubic press were trimmed from both sides to remove refractary metal container (e.g. Ta). The outside diameter of the blanks were ground off. The PCD blanks were bonded to a cemented WC base and the PCD layer was EDM shaped to form pyramids distributed in a predetermined pattern. The PCD blanks were subsequently divided into a series of wedge-shaped cutting pieces and the cutting pieces were placed on a flat mold with the cutting pieces leveled with the mold.

The mold was placed in a vacuum chamber and epoxy is poured over the top. Finally, a stainless steel plate was placed on the top of the flowing epoxy and pressed toward the PCD until only a thin layer of epoxy remained between the backing of the PCD and the steel substrate. After curing of the epoxy, the PCD cutting tool was cleaned and mounting structure (e.g., holes) was formed on the back of the steel substrate.

The PCT cutting pieces can be arranged on the stainless steel plate in an annular ring pattern, circular plates, squares, etc. These patterns can be optimized to suit a particular CMP application.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use may be made without departing from the principles and concepts set forth herein.

CLAIMS

What is claimed is:

1. A cutting device, comprising:

a base having a solidified organic material layer disposed thereon; and

a plurality of individual polycrystalline cutting elements secured in the solidified organic material layer, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration.

2. The cutting device of claim 1, wherein each of the plurality of individual polycrystalline cutting elements includes at least one cutting tip, the tips of the cutting elements being aligned in a common plane.

3. The cutting device of claim 1, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

4. The cutting device of claim 3, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

5. The cutting device of claim 4, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

6. The cutting device of claim 4, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

7. The cutting device of claim 4, wherein the individual polycrystalline cutting elements are radially distributed about the face of the cutting device.

8. The cutting device of claim 7, wherein a longitudinal axis of each of the individual polycrystalline cutting elements is aligned along a radius of the cutting device.

9. The cutting device of claim 8, wherein the individual polycrystalline cutting elements are distributed on the cutting device in alternating orientations.

10. The cutting device of claim 1, further comprising a series of secondary cutting elements formed on a face of each of the individual polycrystalline cutting elements, the secondary cutting elements being configured to maintain a sharpness of each of the cutting elements during use of the cutting device.

11. A cutting device, comprising:

a plurality of individual polycrystalline cutting elements secured in a solidified organic material layer, each of the plurality of individual polycrystalline cutting elements including at least one cutting tip, the tips of the cutting elements being aligned in a common plane.

12. The cutting device of claim 11, wherein arrangement of the individual polycrystalline cutting elements uniformly distributes drag forces across substantially each individual polycrystalline cutting element.

13. The cutting device of claim 11, wherein a majority of each of the individual polycrystalline cutting elements protrudes to a predetermined height above the solidified organic material layer.

14. The cutting device of claim 13, wherein the predetermined height produces a cutting depth of less than about 20 microns when used to abrade a workpiece.

15. The cutting device of claim 11, wherein each of the plurality of individual polycrystalline cutting elements has a substantially matching geometric configuration.

16. The cutting device of claim 11, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

17. The cutting device of claim 16, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

18. The cutting device of claim 17, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

19. The cutting device of claim 17, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

20. The cutting device of claim 17, wherein the individual polycrystalline cutting elements are radially distributed in the organic material layer.

21. The cutting device of claim 11, wherein the individual polycrystalline cutting elements are of substantially the same size and substantially the same shape.

22. The cutting device of claim 11, wherein the individual polycrystalline cutting elements are arranged as a grid.

23. The cutting device of claim 22, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of from about 100 microns to about 800 microns.

24. The cutting device of claim 23, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of about 500 microns.

25. The cutting device of either of claim 1 or claim 11, wherein the solidified organic material layer comprises a member selected from the group consisting of amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone

resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof.

26. The cutting device of claim 25, wherein the solidified organic material layer is an epoxy resin.

27. The cutting device of claim 25, wherein the solidified organic material layer is a polyurethane resin.

28. The cutting device of claim 25, wherein the solidified organic material layer is a polyimide resin.

29. The cutting device of claim 25, further comprising a reinforcing material disposed within at least a portion of the solidified organic material layer.

30. The cutting device of claim 29, wherein the reinforcing material is a material selected from the group consisting of ceramics, metals, or combinations thereof.

31. A method of forming a cutting device, comprising:

obtaining a substrate;

arranging on the substrate a plurality of individual polycrystalline cutting elements, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration; and

securing each of the plurality of individual polycrystalline cutting elements to the substrate with a solidified organic material layer.

32. The method of claim 31, further comprising aligning at least one cutting tip of each of the plurality of individual polycrystalline cutting elements in a common plane.

33. The method of claim 31, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

34. The method of claim 33, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

35. The method of claim 34, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

36. The method of claim 34, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

37. The method of claim 34, wherein the individual polycrystalline cutting elements are radially distributed about the substrate.

38. The method of claim 31, wherein the individual polycrystalline cutting elements are of substantially the same size and substantially the same shape.

39. The method of claim 31, wherein the individual polycrystalline cutting elements are arranged as a grid.

40. The method of claim 39, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of from about 100 microns to about 800 microns.

41. The cutting device of either of claim 1 or claim 11, wherein the polycrystalline cutting elements comprise superhard polycrystalline cutting elements.

42. The cutting device of claim 41, wherein the superhard polycrystalline cutting elements comprise superhard polycrystalline particles.

43. The method of claim 31, where the polycrystalline cutting elements comprise superhard polycrystalline cutting elements.

44. The method of claim 43, wherein the superhard polycrystalline cutting elements comprise superhard polycrystalline particles.

45. The method of claim 43, wherein the superhard polycrystalline cutting elements are selected from the group consisting of: polycrystalline diamond and polycrystalline cubic boron nitride.

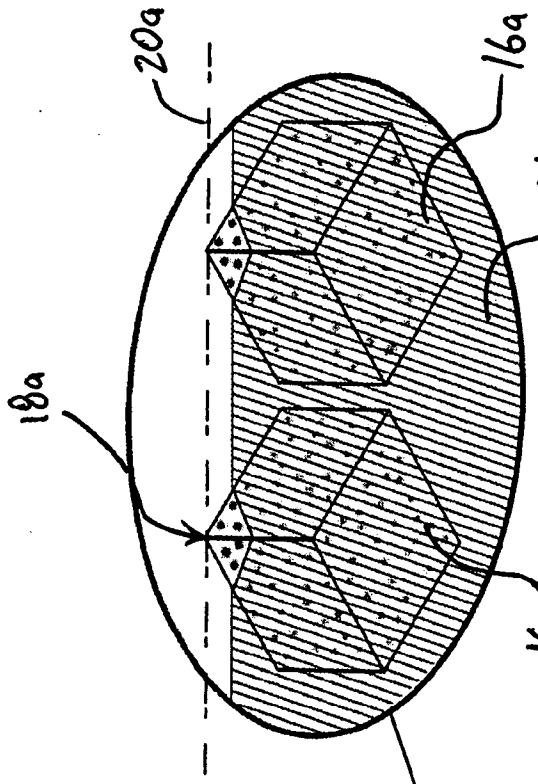


FIG. 1B

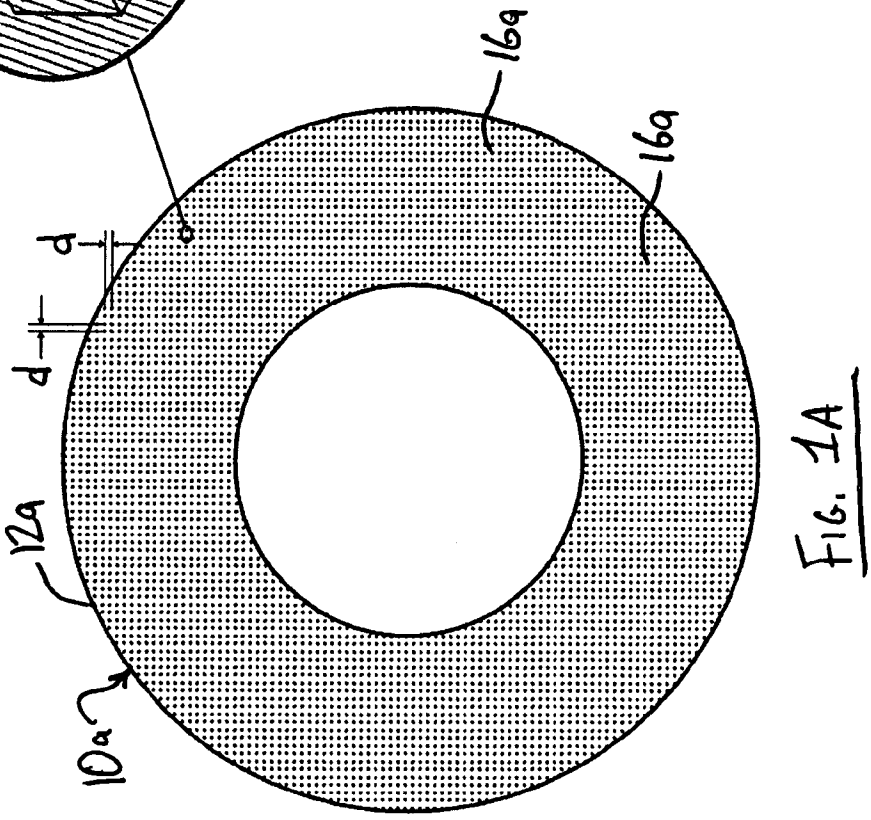


FIG. 1A

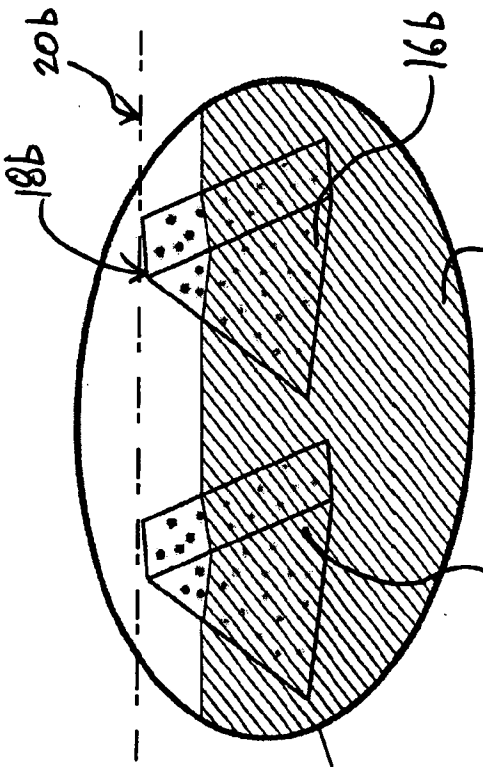


FIG. 2B

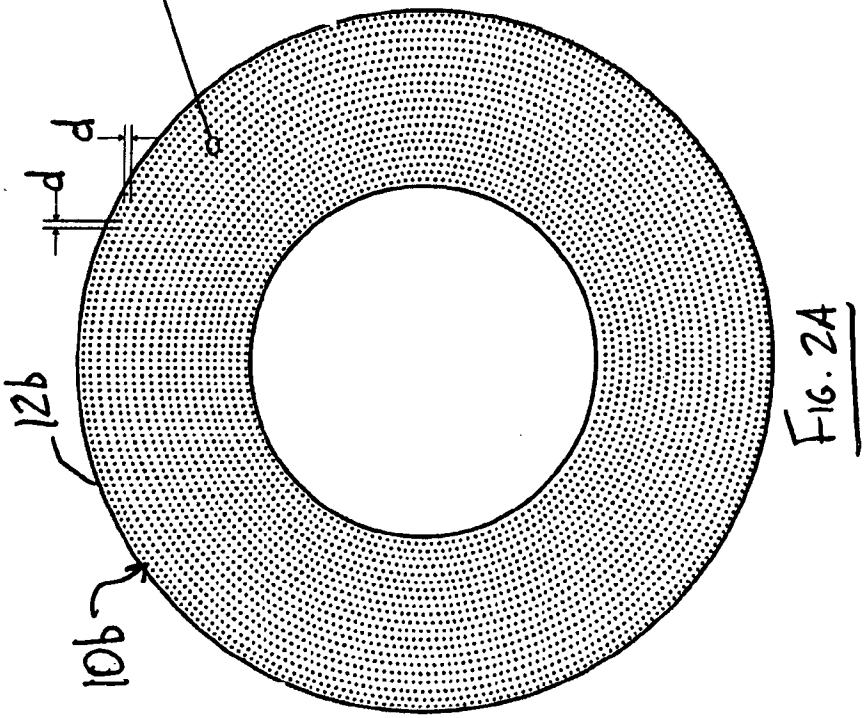


FIG. 2A

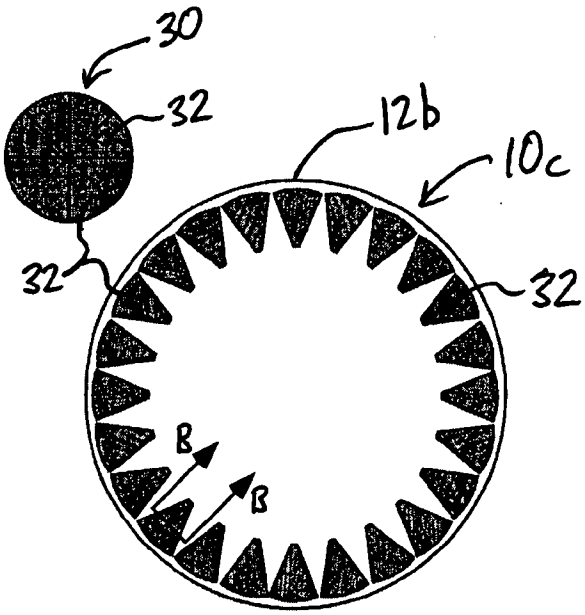


FIG. 3A

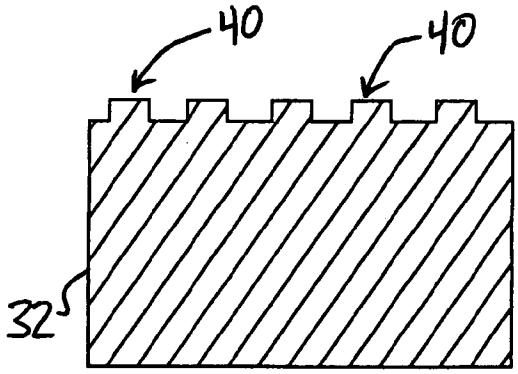


FIG. 3B

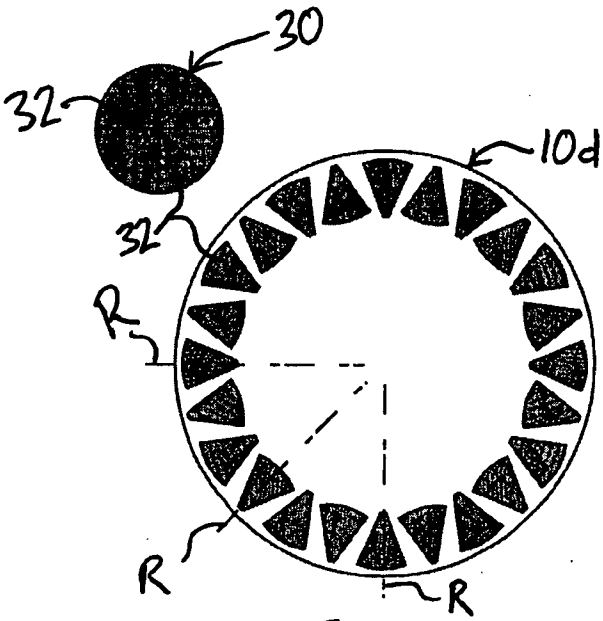


FIG. 4

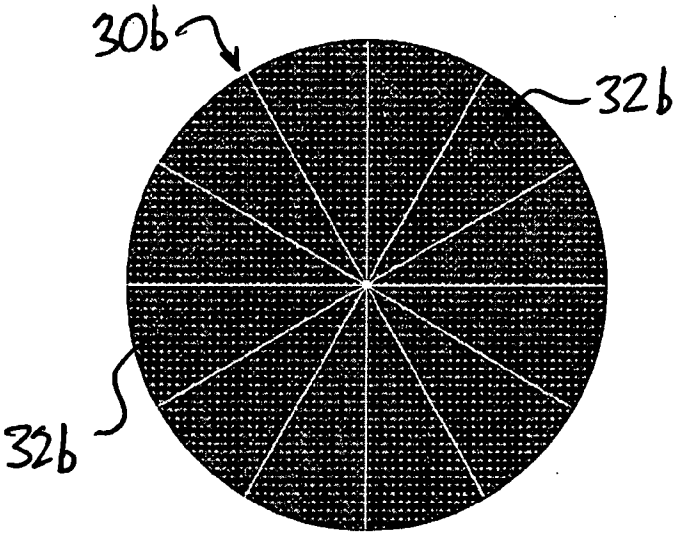


FIG. 5

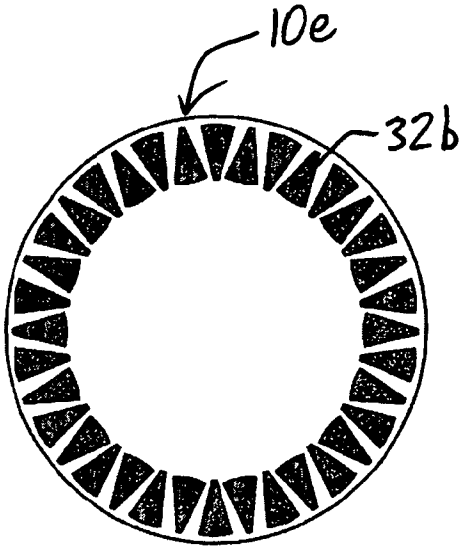


FIG. 6

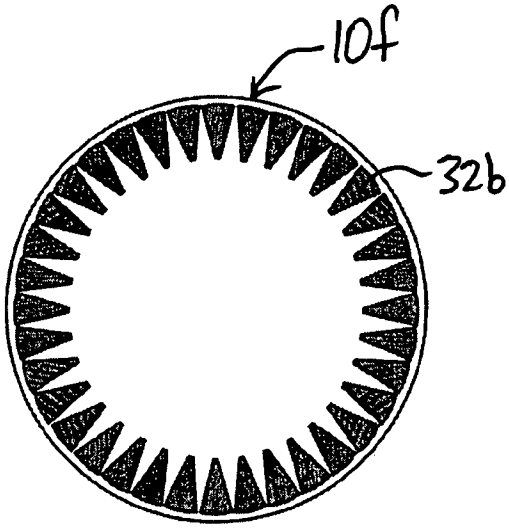


FIG. 7

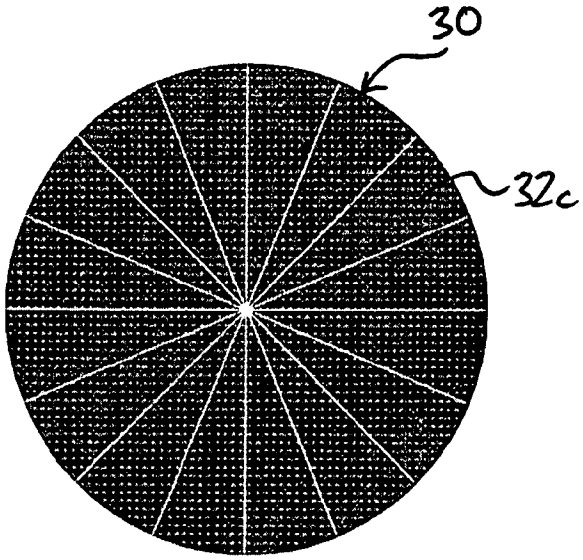


FIG. 8

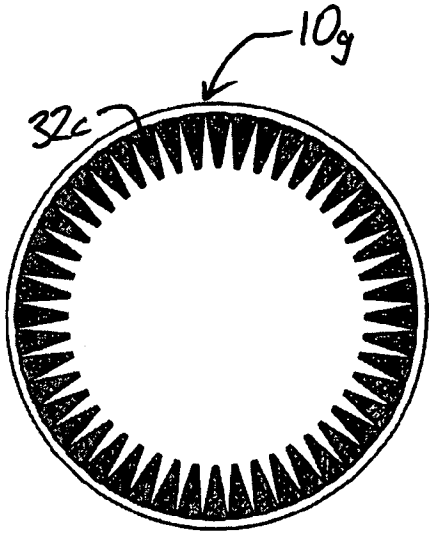


FIG. 9

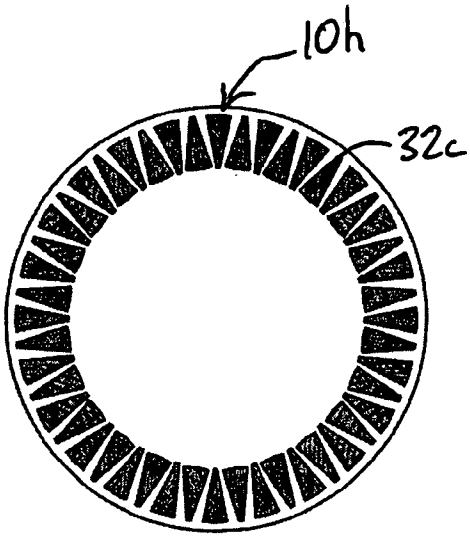


FIG. 10

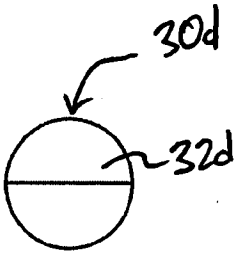


FIG. 11

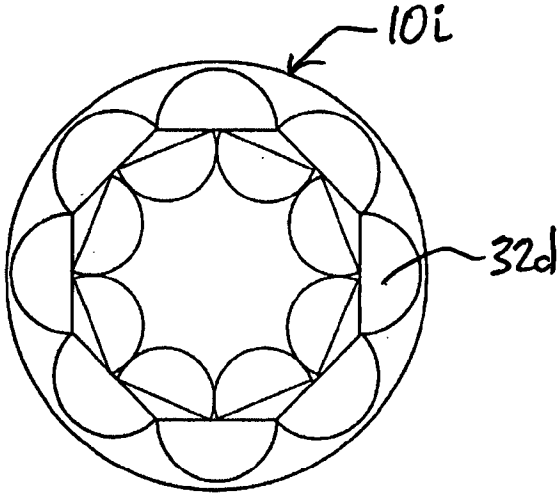


FIG. 12

Electronic Patent Application Fee Transmittal

Application Number:	13479148
Filing Date:	23-May-2012
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Warren Archibald
Attorney Docket Number:	02074-24012.NP

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Submission- Information Disclosure Stmt	2806	1	90	90
		Total in USD ($)		**90**

Electronic Acknowledgement Receipt

EFS ID:	19884219
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	16-AUG-2014
Filing Date:	23-MAY-2012
Time Stamp:	15:40:48
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$90
RAM confirmation Number	6051
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: August 16, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

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Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☐ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☒ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

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Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☒ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

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STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

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REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☒ Credit card payment in the amount of $ 90. (amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 16th day of August, 2014.

Respectfully submitted,

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Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2002/0182401 A1	12/2002	Lawing	
		2008/0153398	06/2008	Sung	
		2009/0215363	08/27/2009	Sung	
		2011/0252710 A1	10/2011	Hall et al.	
		4155721	05/1979	Fletcher	
		6899592	05/2005	Kojima et al.	
		7507267 B2	03/2009	Hall et al.	
		7954483 B2	06/2011	Kim et al.	
		8377158 B2	02/2013	Palmgren et al.	
		8398466	03/19/2013	Sung et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		EP1075898	02/2001	Tanaka et al.		
		JP 2007/044823	02/22/2007	Soken		
		WO02/31078	04/2002	Fries		

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NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 12/715,583; filed 03/02/2010; Chien-Min Sung; notice of allowance dated 12/07/2012	
		US Application 13/113,779; filed 05/23/2011; Chien-Min Sung; office action dated 11/12/2013	
		US Application 13/021,350; filed 02/04/2011; Chien-Min Sung; office action dated 03/20/2013	
		US Application 13/239,189; filed 09/21/2011; Chien-Min Sung; notice of allowance dated 05/03/2013	
		US Application 12/267,172; filed 11/07/2008; Chien-Min Sung; notice of allowance dated 01/07/2013	
		US Application 13/239, 189; filed 09/21/2011; Chien-Min Sung; notice of allowance dated 03/04/2014	
		US Application 13/644,790; filing date 10/04/2012; Chien-Min Sung; office action dated 06/17/2014	
		US Application 13/416,201; filing date -3/09/2012; Chien-Min Sung; office action dated 06/18/2014	
		US Application 13/153, 176; filing date 06/03/2011; Chien-Min Sung; office action dated 07/01/2014	
		US Application 13/113,779; filing date 05/23/2011; Chien-Min Sung office action dated 07/02.2014	
		US Application 13/794,164; filing date 03/11/2013; Chien-Min Sung; office action dated 07/16/2014	

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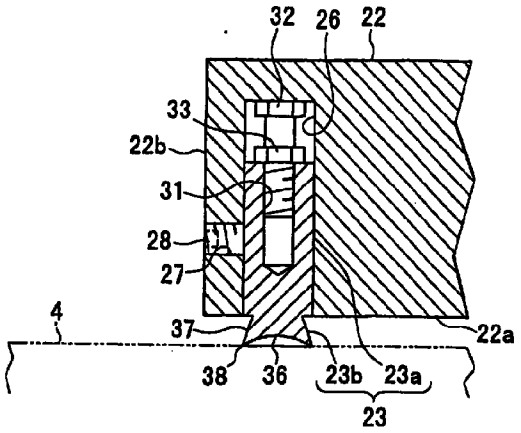
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(54) Dresser and dressing apparatus

(57) A dresser for dressing a polishing pad used for polishing a material to be polished is disclosed, the dresser comprising: a dresser principal and a dressing-working part which is provided as a body other than the dresser principal; and a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

Field of the invention:

[0001] The present invention relates to a dresser and a dressing apparatus for dressing the surface of a polishing pad which is used for polishing materials to be polished, for example, semiconductor wafer or the like.

[0002] The present specification is based on Japanese patent applications (N0. HEI 11-229495, N0. HEI 11-271176, N0. 2000-131784 and N0. 2000-131785) and the contents of these applications are incorporated herein as a part of the present specification.

Description of the Related Art:

[0003] A chemical and mechanical polishing method (CMP method) which provides a high flatness is used for polishing the surface of materials to be polished for which excellent polishing accuracy is required, for example, for polishing semiconductor wafers or the like.

[0004] The CMP method is a method where the surface of wafer is polished chemically and mechanically to obtain a flatness of the surface, using an alkali slurry containing SiO_2, a neutral slurry containing CeO_2, an acid slurry containing Al_2O_3 or a slurry containing abrasive grains. For example, the following polishing apparatus is known as an apparatus for polishing the surfaces of wafers.

[0005] As schematically shown in Fig 17 of an enlarged perspective view of an important part, a polishing pad 4 comprising, for example, hard urethane, is provided on a disc-shaped platen 3 attached to a center shaft 2 in a polishing apparatus 1 and a wafer-polishing head 5 which holds a wafer 6 is disposed facing the polishing pad 4 and in a position eccentric from the center shaft 2 of the platen 3 to the polishing pad such that the head can be rotated on its own axis.

[0006] In the polishing apparatus 1, the polishing pad 4 and the wafer 6 are moved relatively each other while the wafer 6 is held in the state of being pressed against the polishing pad 4 by the wafer-polishing head 5 and the above-mentioned slurry S is interposed between the wafer 6 and the polishing pad 4, thereby to polish one surface of the wafer 6.

[0007] A lot of fine pores, channels or the like are provided on the polishing pad 4 for holding the slurry S, whereby the wafer 6 is polished by the slurry S hold on the polishing pad 4.

[0008] However, repeating the polishing causes the decrease of the surface flatness of the polishing pad 4 and causes clogging and dulling thereof with the result of bringing about a problem to decrease the polishing accuracy and efficiency of the wafer 6.

[0009] Accordingly, a dressing apparatus 7 has conventionally been arranged in a CPM apparatus as shown in Fig 17, thereby to dress the surface of the polishing pad 4.

[0010] In the above-mentioned dressing apparatus, a dresser 11 is, through an arm 9, attached to a rotary shaft 8 which is disposed outside a platen 3, while the dresser 11 is moved to perform a reciprocating and oscillatory motion on the rotating polishing pad 4 by rotating the arm 9 with the rotary shaft 8 to shave a slight amount of the surface of the polishing pad 4, whereby the surface flatness and the like of the polishing pad are recovered and maintained, and the clogging, dulling and the like are dissolved. The surface of the polishing pad is shaved off little by little in such a manner that while pressed against the surface of the polishing pad 4, the dresser 11 is rotated by a friction force between the dresser and the polishing pad or is rotated by being driven by a drive unit which is not shown in the drawing.

[0011] The conventional dresser 11 has a nearly circular shape having an opening in the center, for example, as shown in Fig.18 (a) of a side cross-sectional view and Fig.19 of a plane view and is provided with a dresser principal 11a wherein a projection 11b is formed in the outer peripheral portion of one end face. As shown in Fig.18 (b) of a partially enlarged side sectional view, the conventional dresser having a dressing-working part is used which comprises a diamond electrodeposited part 11d formed by electrodepositing on the projection 11b abrasive grains 11c (super abrasive grain) such as diamond or cBN. The dressing-working part shaves little by little the polishing pad 4 (such a dresser is called electrodeposited grindstone). Fig.19 is a plane view illustrating the under surface of the dresser 11. A dressing apparatus using this type of dresser is disclosed in, for example, JP-A 9-168961.

[0012] In the conventional dresser 11, there has been encountered the dropping off of the abrasive grains 11 such as diamond grain during dressing. In this case, a trouble is brought about due to scratching the surface of the wafer 6, when the wafer is polished while the dropped grains are filled up in the surface of the polishing pad.

[0013] In order to dissolve the above-mentioned problem, there was a proposal in JP-A 10-217103 as in Fig.20. A dresser 12 shown in Fig.20 has the following construction as a dressing-working part: a lot of projections 13 having a shape of pyramid are formed in the surface of a metal base 12a by machining and a surface 13a of the metal base 12a having the formed projections 13 was coated by a hard film. Dressing is carried out by pressing the projections 13 against a polishing cloth (polishing pad). There is no fear in the dressing apparatus having the dresser 12 for dropping of abrasive grains such as diamond grain with the result that there is little anxiety for suffering from a damage in the surface of materials to be polished.

[0014] However, in the dressers 11 and 12 as men-

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tioned above, a cutting quality degreases due to reasons such as wear of the dressing-working part in proportion to repeated dressings. In this case, changing a dresser unit is required, which takes a high cost.

[0015] In addition, as shown in Fig.19, the dressing of the polishing pad 4 is carried out by the whole surface of the dressing-working part which is projected in a shape of ring in the under surface of the outer peripheral portion of a dresser principal 11a. Chatter is apt to be caused due to a force acting all over the whole surface of the dressing-working part. Further, if once the chatter is caused, the vibration of the dressing 11 continues due to reasons such as the resonance of the vibration, which causes cases leading to a failure to polish uniformly the surface of the polishing pad.

[0016] Further, chips generate from the polishing pad 4 shaved little by little during dressing with dresser 12. In the above-mentioned construction having a lot of projections 13, the chips clog the spaces between each projection, thereby to bring about a problem of degreasing the dressing performance.

[0017] Furthermore, it is difficult to maintain always a stable dressing performance, as it is difficult to estimate how much the wear of the hard film 14 proceeds with the passage of time and a criterion for use becomes unclear.

[0018] The Constitution of the dresser 11 is shown in a side sectional view illustrated in Fig.21 (a schematically illustrated view). A dresser 11 is attached to an arm 9 by the aid of a setting shaft 10 and on a dresser principal 11a connected to the setting shaft 10, there is formed a diamond-electrodepositing part 11d (an abrasive grain layer) including abrasive grains 11c, thereby to form a dressing-working face 15. The diamond-electro-depositing part 11d has the following construction: electroplating is carried out on a ground face positioned on the dresser principal 11a, whereby the abrasive grains 11c such as diamond, cBN or the like are fastened dispersedly on the ground face.

[0019] In the dresser 11, the dressing-working face 15 comprises the under surface of the diamond-electrodepositing part 11d (an abrasive grain layer). In Fig.21, the thickness of the diamond-electro-depositing part 11d and the size of abrasive grains are illustrated larger than actual ones so as to understand easily the shape of the dressing-working face 15.

[0020] If the dresser 11 contacts partially the polishing pad 4 during dressing the pad 4 with the dresser 11, the contact area of the dressing-working face 15 to the polishing pad 4 becomes small with the result that the dressing efficiency becomes lower and it takes a longer time to dress the pad than in unpartial contact cases, though the pad 4 can be dressed at any rate. Every time after polishing a wafer 6 has finished, the polishing pad 4 is dressed and it is carried out at every two and half to three minutes. Therefore, the working efficiency of polishing the wafer 6 becomes low when it takes a long time to dress the polishing pad 4.

[0021] Still further, when the dressing condition is unstable as mentioned above, the surface condition of the polishing pad varies widely and the polishing condition of the wafer 6 with the polishing pad 4 scatters. As the result, it becomes difficult to keep the rate of operation of CMP apparatus and the flatness of the wafer 6.

[0022] Because of the above-mentioned reasons, in order to stabilize the dressing condition, an arrangement is carried out such that the dressing-working face 15 is flat and the dressing-working face cross orthogonally the rotary axis of the dresser 11.

[0023] In a dresser having a prescribed shape formed by fixing abrasive grains by a binder, the above-mentioned arrangement is available by shaving the dressing-working face in the state that the dresser is attached to the setting shaft of a dressing apparatus 7 (this treatment is called "tooling"). However, the tooling can not be carried out in the case of an electrodeposited grindstone due to its own property.

[0024] Accordingly, in the case of using an electrodeposited grindstone for the dresser 11, it is necessary to increase the shape accuracy of the dresser principal 11a where the abrasive grain layer is formed and to increase the accuracy of attaching the dresser principal 11a to the setting shaft.

[0025] However, there are cases in the electrodeposited grindstone that the shape of the dresser principal 11a changes during the process of making thereof and the flatness of the dressing-working face 15 becomes inferior. The flatness of the dresser 11 is measured while contacing directly a dial gauge to the dressing-working face 15, and in the case of the electrodeposited grindstone, as the surface roughness of the dresser-working face is coarse which is a degree of #100, the measurement error is large and it is difficult to measure the flatness thereof accurately.

[0026] Further, there are cases during attaching the dresser 11 to the setting shaft that the dressing-working face 15 of the dresser 11 inclines against the rotary axis due to troubles such as an attaching error caused by a worker, dust interposed between the dresser 11 and the setting shaft, and so on. In order to detect the inclination, there is no way except measuring the deviation of the dressing-working face 15 while contacting directly the dial gauge to the dressing-working face, which has a problem in having a large measurement error. Therefore, it is difficult to obtain the attaching accuracy within a prescribed criterion.

[0027] In addition, as the polishing pad has a softness, it is difficult to detect the partial contact of the dresser 11 to the polishing pad 4 by observing the dressed state of the polishing pad 4, which is different from polishing materials having rigidity such as metal.

[0028] As mentioned above, it has been difficult to stabilize the dressing condition of the polishing pad 4 with the dresser 11.

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SUMMARY OF THE INVENTION

[0029] An object of the present invention is to provide a dresser which can be used economically and a dressing apparatus having the same.

[0030] In order to attain the above-mentioned object, the dresser of the present invention is one used for dressing a polishing pad for polishing materials to be polished and comprises a dresser principal, a dressing-working part which is provided as a body other than the dresser principal and a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

[0031] According to the dresser of the present invention, the dressing-working part can be attached and detached, and when a dressing performance thereof degreases due to reasons such as the wear of the dressing-working part, the dressing-working part is exchanged for a new one to recover the dressing performance. In this way, the dressing performance can be recovered only by exchanging a dressing-working part, thereby to degrease a cost for a dresser.

[0032] Another object of the present invention is to provide a dresser which enables a vibration hardly to take place, and which enables to suppress the vibration within a short time if the vibration takes place, and is to provide a dressing apparatus having the same.

[0033] In order to attain the above-mentioned object, the dresser of the present invention is one used for dressing a polishing pad for polishing materials to be polished and comprises a plurality of dressing-working parts which are disposed at unequal spaces in the circular direction of a dresser principal.

[0034] According to the dresser of the present invention, the dressing-working parts are disposed at unequal spaces in the circular direction of the dresser principal, whereby forces which cause the vibration of the dresser are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser.

[0035] As the result, a vibration hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0036] The interval between each dressing-working part can be decided by any way and for example, can be decided by using random numbers.

[0037] As another way, the interval can be unequal by arranging positions in such a manner that positions are designated as a standard position in the case of disposing dressing-working parts at an equal space each other, and each position is deviated from each standard position to the circular direction. In this case, the deviation of each dressing-working part from the corresponding standard position can be decided by using the random numbers or, for example, can be decided by designating as a starting point any position among each standard position, designating as θ an angle between the starting point and each standard position when looked from the center of axis, and specifying $x=\sin\theta$ as the deviation x of each dressing-working part from each standard position (or $x=\cos\theta$).

[0038] In the above-mentioned ways, when the deviation is too large, dressing-working parts having the too large deviation have a life shorter than the other dressing-working parts as a result of dressing more amount of a polishing pad. In contrast, when the deviation is too small, an effect on suppressing a resonance is lowered. Therefore, the deviation value is preferably by the absolute value within 10 to 30% of an interval between the corresponding standard positions.

[0039] The dresser is rotated in a position having an eccentric relation with the polishing pad, and the speed of the dresser relative to the polishing pad is lower in half a range of the circular direction (an inward peripheral side or an outward peripheral side of the polishing pad when looked from the center of axis of the dresser) than in the other half range and a load imposed on the dressing-working part is small. Therefore, it is estimated that the vibration of the dresser is hardly caused by a force imposed on a side which has a lower speed relative to the polishing pad. That is, dressing-working parts can be provided which are disposed in a same pattern every half a round.

[0040] A further object of the present invention is to provide a dresser which enables to always maintain an excellent dressing performance and can be used economically.

[0041] In order to attain the above-mentioned object, the dresser of the present invention is applied to an equipment which is used for polishing materials to be polished having a flat surface such as semiconductor wafer with a dressing pad, and is a dresser used for dressing the surface of the polishing pad, and is characterized by the following construction: the cutters are arranged in such a manner that the cutters are projected from the under surface of a dresser principal; the polishing pad surface is shaved by moving the edge of cutter which is a movement relative to and parallel to the polishing pad surface while the edge of the cutter is pressed against the polishing pad surface.

[0042] As the dressing pad is shaved with a cutter in the dresser of the present invention, the dresser is protected from the lowering of the dressing performance which is caused by clogging of the polishing pad with the shaved chips of the dressing pad in between abrasive grains, as compared with the conventional one, whereby a stable dressing performance is available. In addition, as an amount of wear can be decided from the flank of the cutter, a criterion for use is clear as compared with the conventional one, thereby to enable to maintain easily the dressing performance. Further, as a cutter is used, reusing the cutter is possible, which is different from the conventional one, with result of providing excellence in a cost for the dresser.

[0043] Still further object of the present invention is

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to provide a dresser wherein the polishing condition of the polishing pad can be stabilized.

[0044] In order to attain the above-mentioned object, the dresser of the present invention comprises: a dressing-working face formed by providing an abrasive grain layer including abrasive grains on the surface of a dresser principal, wherein the dresser principal comprises a ground face on which the abrasive grain layer is provided and a basic face which is disposed in a portion of the dresser principal more inward than the ground face and is formed in parallel to the ground face.

[0045] In the dresser of the present invention, as the basic face of the dresser principal is a plane parallel to the ground face, it is possible to predict the flatness of the ground face having the abrasive-grain layer formed thereon, that is, the flatness of the dressing-working face, by measuring the flatness of the basic face, whereby dressers can be selected which have a good flatness with regard to a dressing-working face.

[0046] In addition, when the dresser is attached to the dressing apparatus, the attaching situation can be confirmed according to the basic face as a basis, as the basic face is a plane parallel to the ground face.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047]

Fig.1 is a plan view illustrating the under surface of the dresser of Example 1 of the present invention.

Fig.2 is a sectional view looking in the direction of the arrows A-A in the Fig.1.

Fig.3 (a) is a side sectional view showing another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.3 (b) is an end surface view showing another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.4 (a) is a side sectional view showing a further embodiment of the dresser-working part used in the dresser of Example 1.

Fig.4 (b) is a side sectional view showing still another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.5 is a side sectional view illustrating another construction of the dresser in Example 1 of the present invention.

Fig.6 is an under surface view illustrating the shape of the dresser in Example 2 of the present invention.

Fig.7 (a) is a side sectional view illustrating the shape of the dresser in Example 2 of the present invention.

Fig.7 (b) is a side sectional view illustrating another shape of the dresser in Example 2 of the present invention.

Fig.8 is an under surface view illustrating the shape of the dresser in Example 3 of the present invention.

Fig.9 is a schematic view illustrating the dresser of Example 4 of the present invention, which is an enlarged side view of the important part of the dresser principal.

Fig.10 is a schematic view illustrating the dresser of Example 4 of the present invention, which is an under surface view of the dresser principal.

Fig.11 is a schematic view illustrating the dresser of Example 4 of the present invention, which is a side sectional view of the dresser principal.

Fig. 12 is an enlarged side view of a cutter used in the dresser shown in Figs.9 to 11.

Fig.13 is an enlarged under surface view of the cutter used in the dresser shown in Figs.9 to 11.

Fig.14 is a plan view showing a positional relationship between the dresser principal shown in Fig.9 to 13 and a platen to which a polishing pad is attached, when dressing is carried out.

Fig.15 is an enlarged side sectional view showing another embodiment of the cutter used in the dresser of Example 4.

Fig. 16 is a side sectional view illustrating the constitution and construction of the dresser in Example 5 of the present invention.

Fig.17 is an enlarged perspective view of the important part of the conventional polishing equipment and dressing apparatus, which is illustrating the schematic constitutions thereof.

Fig.18 (a) is a side sectional view illustrating the shape of the conventional dresser.

Fig. 18 (b) is a partially enlarged side sectional view of Fig. 18 (a).

Fig.19 is a plan view showing the under surface of the conventional dresser.

Fig.20 is an enlarged side sectional view of an important part illustrating the shape of the conventional dresser.

Fig.21 is a side sectional view illustrating the constitution and construction of the conventional dresser.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0048] The dresser of the present invention and the dressing apparatus having the same are described in detail hereunder.

[0049] Fig.1 is a plan view illustrating the under surface of the dresser of Example 1 of the present invention. Fig.2 is a sectional view looking in the direction of the arrows A-A in the Fig.1.

[0050] The dressing apparatus of the present invention comprises a constitution almost similar to that of, for example, a dressing apparatus 7 shown Fig.17, and a dresser 21 of the present invention is used as a dresser in place of a dresser 11.

[0051] The dresser 21 of the present invention comprises a dresser principal 22 having an approximately circular shape and a plurality of dressing-working parts

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23 disposed in the circular direction in the under surface of the outer peripheral portion of the dresser principal 22. The dresser-working parts 23 which are provided as bodies other than the dresser principal 22 are arranged and are held to the dresser 22 by a means mentioned after in such a manner that the dresser-working parts 23 can be attached to and detached from the dresser principal 22. The number and disposition of the dressing-working parts 23 shown in Fig.1 is only an example. The dressing-working parts 23 can be disposed at equal spaces in the circular direction of the dresser principal or at irregular spaces in the circular direction. The dressing-working parts 23 can be arranged in a plurality of lines in the circular direction of the dresser principal 22, which is similar to that of the conventional dresser.

[0052] In the present example, the dresser principal 22 is composed of an approximately circular shape having an opening in the center thereof.

[0053] As shown in Fig.2, the dressing-working part 23 is composed of a member having an approximately pin-like shape. A receiving hole 26 for receiving a part of the dressing-working part 23 is formed from the under surface 22a to a predetermined depth in the dresser principal 22. In the dresser principal 22, a tapped hole 27 is formed which leads to the intermediate position of the receiving hole 26 from the outer periphery 22b thereof. In the tapped hole 27, a clamp screw 28 is screwed such that the end of the clamp screw can be advanced and retreated in the receiving hole 26.

[0054] The dressing-working part 23 is fixed in the receiving hole 26 by pressing the side of dressing-working part 23 received in the receiving hole 26 to the inner wall of the receiving hole with the end of the clamp screw 28 and is released from being fixed by releasing the pressing of dressing-working part 23 with the end of the clamp screw.

[0055] The present example comprises a holding means which hold dressing-working part 23 to the dresser principal 22 in such a manner that the dressing-working part 23 can be attached to and detached from the dresser principal 22 by the receiving hole 26, the tapped hole 27 and the clamp screw 28.

[0056] Here, in the present example, the receiving hole 26 is approximately parallel to the axis of the dresser principal 22 and the bottom surface thereof is a plane which approximately crosses orthogonally the axis of the dresser principal 22.

[0057] As shown in Fig.2, the dressing-working part 23 is a cutter having approximately a pin-like shape, and comprises a base 23a having an approximately columnar shape and a cutting edge 23b formed in the end of the base 23a.

[0058] The base 23a is received in the receiving hole 26 of the dresser 22 and the side of the base is subjected to the pressure given by the clamp screw 28. A position-adjusting screw hole 31 is formed in the base 23a, which has a prescribed depth along the axis from the end face of the base.

[0059] A position-adjusting screw 32 is screw-clamped to the position-adjusting screw hole 31 and an amount of projection of the position-adjusting screw 32 from the base 23a can be adjusted by controlling a screwed length to the position-adjusting screw hole 31.

[0060] The upper surface of the head of the position-adjusting screw 32 is pressed against the bottom surface of the receiving hole 26 when the dressing-working part 23 is received in the receiving hole 26. An amount of projection of the dressing-working part 23 from the receiving hole 26, that is, an amount of projection of the dressing-working part 23 from the dresser principal 22 can be adjusted by controlling an amount of projection of the position-adjusting screw 32 from the base 23a. In the present example, the upper surface of the head of the position-adjusting screw 32 is a plane crossing approximately orthogonally to the axis thereof.

[0061] Further, a fixing nut 33 is screw-clamped to the position-adjusting screw 32 which is positioned on the position-adjusting screw hole 31. The position-adjusting screw 32 is fixed in a state projected at any distance from the base 23a by screwing the fixing nut toward the edge of the position-adjusting screw 32 while pressed against the base 23a.

[0062] The present example comprises a projection adjusting means having the position-adjusting screw hole 31, the position-adjusting screw 32 and the fixing nut 33 for controlling an amount of projection of the dresser-working part 23 from the dresser principal 22.

[0063] The cutting edge portion 23b of the dressing-working part 23 comprises: a flank 36 which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face 37 comprising a cicumferential surface in the end portion of the cutter; and a cutting edge 38 which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion of the cutter. Namely, the cutting edge portion 23b has a nearly Japanese soup cup-like shape.

[0064] Here, ceramics, diamond, cBN and the like can be used for the cutting edge 38, and the surface of the cutting edge portion 23b can be covered by a hard film comprising hard materials such as diamond or the like.

[0065] Almost in the same manner as in the dressing apparatus shown in Fig. 17, the surface of a polishing pad 4 is dressed by the dressing apparatus of the present invention, which comprises the steps of: oscillating a dresser 21 while the dresser 21 is pressed against the surface of the polishing pad 4; rotating of the dresser owing to a friction force caused by friction with the polishing pad 4 or rotating the dresser by driving by a drive unit which is not shown in Figs while the dresser 21 is pressed against the surface of the polishing pad.

[0066] In the dresser 21, the surface of the polishing pad 4 is shaved little by little by the dresser 21 by providing to the dresser a relative movement to a direction parallel to the polishing pad 4, while the cutting edge 38 of the dressing-working part 23 is pressed

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against the surface of the polishing pad 4.

[0067] As an amount of projection of the dressing-working part 23 from the dresser principal 22 can be adjusted, the dressing performance of the dresser 21 is controlled by adjusting the depth of cut of the dressing-working part 23 into the dressing pad 4 according to the material and hardness of the dressing pad.

[0068] The dressing apparatus of the present invention can be composed of a constitution other than the above-mentioned one, in which the dresser 21 is connected to an arm 9 through a ball bearing, and the dresser can freely be inclined according to the surface of the polishing pad 4. In this case, in the dressing apparatus, the dresser is pressed against the dressing pad 4 by the dead weight thereof or by a force obtained by pressing the arm 9, and a depth of cut of the dressing-working part 23 into the polishing pad 4 is adjusted by controlling an amount of force of the pressing.

[0069] Adjusting an amount of projection of the dressing-working part 23 is carried out as follows: first, an amount of the position-adjusting screw 32 from the base 23a is adjusted by turning round the position-adjusting screw 32 which is screw-clamped to the base 23a to any of two directions in the state of detaching the dressing-working part 23 from the dresser principal 22 and the position-adjusting screw 32 is fixed to the base 23a by the fixing nut 33; then, the dressing-working part 23 is inserted into the receiving hole 26 of the dresser principal 22 and the clamp screw 28 is driven and tightened which is screw-clamped to the tapped hole 27, whereby the dressing-working part 23 is fixed in such a state that the cutting edge 38 of the dressing-working part 23 is projected from the under surface 22a of the dresser principal 22 by a prescribed amount.

[0070] In addition, as the dressing-working part 23 has the cutting edge 38 in the whole round thereof, the shaving of the polishing pad 4 can be carried out for any direction thereto, thereby to enable to increase a dressing performance.

[0071] And, as the dressing-working part 23 is a cutter, the dressing performance can be recovered by repolishing the cutter edge 38 when the dressing performance degreases, thereby to enable to lower a cost for the dresser.

[0072] Furthermore, though shaved chips generate due to shaving a little the polishing pad 4, the polishing pad 4 is hardly clogged with the shaved chips, which is different from a dresser having a dressing-working part comprising an abrasive grain layer and projections, thereby to obtain a stable dressing performance.

[0073] Still further, as the dressing performance can be judged from an amount of wear of the cutting edge 38 to clear a criterion for use, the stable dressing performance can always be obtained.

[0074] Yet further, there is no fear to scratch the surfaces of materials to be polished due the dropping of abrasive grains, as the abrasive grains are not used in the dressing-working part 23.

[0075] Still furthermore, if a dressing performance lowers due to reasons such as the wear of the dressing-working part 23, the dressing performance can be recovered by exchanging only the dressing-working part 23, thereby to enable to decrease a cost for a dresser.

[0076] The example is exemplified by a case wherein the dressing-working part 23 is used which comprises a cutting edge portion 23b having a Japanese soup cup-like shape and the example is not limited to the case. For another example, a dressing-working part 39 can be used which has a plurality of projections in the end thereof as shown in Fig.3 (a) of a side sectional view and Fig.3 (b) of an end surface view. The projection 40 of a dressing-working part 39 has a cross section approximately equal to an end face 40a from one end of the projection to near another end of the projection from which the projection is started and a cutting edge 40b is provided by a ridgeline formed by crossing of the end face 40a and the side surface of the projection. The projections are disposed in any way, regularly or irregularly. In addition, any shape can be provided to the end face 40a of the projection 40, for examples, the end face 40a can be nearly circular (the projection 40 is approximately columnar) or can be a polygon (the projection 40 is a square pillar having a polygonal section).

[0077] Further, ceramics, diamond, cBN and the like can be used for the cutting edge 40b, and the surface of the cutting edge 40b can be covered by a hard film comprising hard materials such as diamond.

[0078] In the dressing-working part 39 formed as mentioned above, the surface of the polishing pad 4 is dressed by the cutting edge 40b of each projection 40. Here, as the cutting edge 40b is formed in the wholly around of each projection 40, the polishing pad 4 can be dressed from any direction. The projection 40 has a cross section approximately equal to an end face 40a from one end of the projection to near another end of the projection from which the projection is started and the change of shape and area of the end face 40a is small when the projection 40 wears with the result that the dressing performance hardly changes and the stable dressing performance can be obtained.

[0079] Further, for example, as shown in Fig.4 (a) of a side sectional view, a dressing-working part 41 can be used which has a cutting edge 42 having a cutting edge portion 41b directed to one direction of the circular direction of dressing-working part. Here, ceramics, diamond, cBN and the like can be used for the cutting edge 42 and the surface of the cutting edge portion 41b can be covered by a hard film comprising hard materials such as diamond.

[0080] In addition, the polishing pad can be shaved from any direction, as a whole dresser, by providing to the dressing-working part 41 the cutting edges 42 which are directed in various directions each other.

[0081] Further, a dressing-working part 43 can be used as a dressing-working part, which comprises a grindstone 44 in the end of the base 43a which is

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approximately columnar as shown in Fig.4 (b). In this case, the grindstone 44 can be a grindstone which is conventionally used for dressing the polishing pad 4, for examples, can be a grindstone formed by an abrasive grain layer prepared by electrodepositing abrasive grains such as diamond or can be a metal bonded grindstone.

[0082] Further, a means for controlling an amount of projection can be composed of a constitution other than the above-mentioned one, in which a bolt inserting hole 29 leading to the upper surface of the dresser principal 22 is formed in the bottom face of a receiving hole 26 as shown in Fig.5 of a side sectional view and a position-adjusting screw 32 is inserted into the bolt inserting hole 29 from the upper surface of the dresser principal 22 and screw-clamped to a position-adjusting screw hole 31 (a fixing nut becomes unnecessary). Here, the position adjusting screw 32 is attached to the dresser principal 22 in such a manner that the screw is possible to turn around an axis while the head of the screw is received in the bolt inserting hole 29. When a means for controlling an amount of projection is provided as mentioned above, as the dressing-working part 23 can be moved along the position adjusting screw 32 by handling the position adjusting screw 32 in the state of attaching the dresser-working part 23 to the dresser principal 22, an amount of projection of the dressing-working part 23 can be controlled without detaching the dressing-working part 23 from the dresser principal 22.

Example 2:

[0083] The dresser of Example 2 of the present invention and the dressing apparatus having the same are described in detail hereunder, referring to Figs.

[0084] Fig.6 is an under surface view illustrating the shape of the dresser of Example 2. Fig.7 is a side sectional view illustrating the dresser.

[0085] The dressing apparatus of the present invention comprises a constitution almost similar to that of a dressing apparatus 7 shown Fig. 17, and the dresser 51 of the present invention is used as a dresser in place of a dresser 11.

[0086] A dresser 51 of the present invention comprises a dresser principal 52 having an approximately circular shape and a plurality of dressing-working parts B disposed in the circular direction in the under surface of the outer peripheral portion of the dresser principal 52. The dresser principal 22 of the present invention is composed of a shape having an opening in the center thereof in the same manner as in the conventional dresser. The dresser-working parts B are provided as bodies other than the dresser principal 52 and are fixed to the dresser principal 52 by, for examples, brazing, a clamp method, a blade method and so on.

[0087] In the present example, the dressing-working parts are members having a approximately pin-like shape.

[0088] The dressing-working parts B are disposed at unequal spaces in the circular direction of the dresser principal 52. A space between each dressing-working part B is decided by any way. In the present example, the positions in the case of disposing dressing-working parts B at equal spaces are designated as a standard position P and any one among the standard positions is designated as a starting point P_0 and an angle between each standard position P and the starting point P_0 when looked from the center of axis O of the dresser 52 is designated as θ , and $x=\sin\theta$ is specified as a deviation x of each dressing-working part B from each standard position P. Here, in Fig.6, accompanied characters are provided to standard positions P (and a dressing-working part B, angle θ and an amount of deviation x corresponding to each standard position P), in a counterclockwise order starting from the starting point P_0.

[0089] In the above-mentioned way, when the deviation x of a dressing-working part B from the corresponding standard position P is too large, a distance becomes large which is between one dressing-working part B and another dressing-working part B next to the former dressing-working part. In this case, the life of the dressing-working parts B become shorter as an amount of dressing of the polishing pad 4 carried out by the dressing-parts B becomes always too much as compared with the other dressing-working parts B. In contrast, when the deviation is too small, an effect on suppressing a resonance is lowered. Therefore, a deviation value of each dressing working part B from the corresponding standard position P is preferable by the absolute value within 10 to 30% of a space H between standard positions P.

[0090] The dressing-working part is approximately pin-like and can comprise any construction such as a dressing-working part having a diamond-electro-deposited part formed by electrodepositing abrasive grains such as diamond in the end which is directed to the under surface side of the dresser principal 52 or a dressing-working part having a cutter having a cutting edge formed in the end which is directed to the under surface side of the dresser principal 52 if dressing the polishing pad 4 is possible.

[0091] In the present example, as shown in Fig.7 (a), there is provided to the dresser principal 52 a receiving hole 56 having a prescribed depth from an under surface 52a and there is provided thereto a tapped hole 57 which leads to the intermediate position of the receiving hole 56 from the outer periphery 52b of the dresser principal 52 and to which a clamp screw 58 is clamped. The dressing-working part B is fixed to the receiving hole 56 by the following mechanism: the side thereof is pressed by the clamp screw 58 which is screw-clamped to the tapped hole 57, whereby the dressing-working part B is fixed to the receiving hole 56. And, as shown in Fig.7 (a), in the dressing-working part B, a position-adjusting screw hole 59 having a prescribed depth is formed along an axis from the end face

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of the base end thereof and a position-adjusting screw 60 is screw-clamped to the position-adjusting screw hole 59. An amount of projection of the dressing-working part B from the base end can be controlled by controlling a screw-clamping length of the position-adjusting screw 60 to the position-adjusting screw hole 59, and the upper face of head of the position adjusting screw 60 can be contacted to the bottom face of the receiving hole 56 when the dressing-working B is received in the receiving hole 56. Here, an amount of projection of the dressing-working part B from the receiving hole 56, that is, an amount of projection of the dressing working part B from the under surface 52a of the dresser principal 52a can be controlled by adjusting an amount of projection of the position-adjusting screw 60 from of the base end of the dressing-working part B.

[0092] In the present example, the dressing-working part B is a cutter having approximately a pin-like shape. A cutting edge portion 54 formed in one end of the cutter comprises: a flank 54a which is formed by concaving the end face of the cutting edge portion toward the base end of the cutter; a rake face 54b comprising a circumferential surface in the end portion of the cutting edge portion; and a cutting edge 54c which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion. Namely, the cutting edge 54 has a nearly Japanese soup cup-like shape and whole the round of the edge makes it possible to shave the polishing pad 4.

[0093] For example, as shown in Fig.7 (b) of a side sectional view, the dresser 51 can be composed of a constitution other than the above-mentioned one, in which a bolt inserting hole 53 is formed in the dresser principal 52 from the bottom face of a receiving hole 56 to the upper surface of the dresser principal 52 and a position-adjusting screw 60 is inserted into the bolt inserting hole 53 from the upper side of the dresser principal 52, thereby to screw-clamped the screw to a position adjusting screw hole 59. In this case, the position-adjusting screw 60 is attached to the dresser principal 52 in such a manner that the screw is possible to turn around an axis while the head of the screw is received in the bolt inserting hole 53. When the dresser 51 is constituted as mentioned above, as the dressing-working part B can be moved along the position adjusting screw 60 by handling the position-adjusting screw 60 in the state of attaching the dresser-working part B to the dresser principal 52, an amount of projection of the dressing-working part B can be controlled without detaching the dressing-working part B from the dresser principal 52.

[0094] Dressing the polishing pad 4 by using a dressing apparatus having the dresser 51 constructed as mentioned above is carried out in the same manner as in the conventional dressing apparatus.

[0095] In the present example, as the dressing-working parts B are disposed at unequal spaces in the circular direction of the dresser principal 52, forces which cause the vibration of the dresser 51 are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser 51.

[0096] Thus, according to the dresser 51 of the present invention and the dressing apparatus having the same, the vibration of the dresser 51 hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0097] The number and disposition of arranged dressing-parts B are not limited to the example shown in Fig.6 and any embodiment is available as long as the dressing-working parts B are disposed at unequal spaces in the circular direction of a dresser principal 52.

Example 3:

[0098] The dresser of Example 3 of the present invention and the dressing apparatus having the same are described in detail hereunder, referring to Fig.8 showing an under surface view.

[0099] A dresser 61 of the present example comprises a dresser principal 62 having an approximately circular shape and a dressing-working part C comprising a grindstone disposed along the circular direction in the under surface of the outer peripheral portion of the dresser principal 62.

[0100] Nicks N are provided to the dressing-working part C by forming a plurality of notches at unequal spaces in the circular direction of the dresser principal 62.

[0101] The arrangement of the nicks N can be decided in the same manner as in the dressing-working parts of Example 2. In the present example, the positions in the case of disposing dressing-working parts C at equal spaces are designated as a standard position P, and any one among the standard positions P is designated as a starting point P_0, and an angle between each standard position and the starting point when looked from the center of axis of the dresser principal 62 is designated as θ , and $x=\sin\theta$ is specified as a deviation x of each dressing-working part C from each standard position P. Here, in Fig.8, accompanied characters are provided to standard positions P (and a dressing-working part C, nick N, angle θ and an amount of deviation x corresponding to each standard position P), in a counterclockwise order starting from the starting point P_0.

[0102] Dressing a polishing pad 4 is carried out in the thus-constituted dresser 61 and a dressing apparatus having the same, in the same manner as in the dresser 51 of Example 2 and the dressing apparatus having the same.

[0103] In this example, as the nicks N are disposed at unequal spaces in the circular direction of the dresser principal 62, forces which cause the vibration of the dresser 61 are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser 61.

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[0104] Thus, according to the dresser 61 of the present invention and the dressing apparatus having the same, the vibration of the dresser 61 hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0105] The number and disposition of arranged nicks N are not limited to the example shown in Fig.8 and any embodiment is available as long as the nicks are disposed at unequal spaces in the circular direction of a dresser principal 62.

Example 4:

[0106] Example 4 of the present invention is described in detail hereunder, referring to Figs.

[0107] Fig.10 and 11 are schematically illustrating the present example. In the Figs., symbol 71 shows a dresser.

[0108] As shown in the Figs., the dresser 71 comprises a plurality f cutters 75 disposed at a prescribed spaces in the circular direction of a dresser principal 72, in a peripheral edge portion 74 of an under surface 73 of the dresser principal 72 having a circular shape.

[0109] The cutters 75 are arranged in the state that the cutter is projected from the under surface73 of the dresser principal 72 as shown in Fig.9 of an enlarged view (a view illustrating the vicinity of the cutter 75 when looked from a p direction in Fig.11). As further enlarged in Fig.12, the cutter 75 comprises an edge of cutter 76 having a flat surface 77 parallel to a polishing pad surface to be dressed (not show in Figs.). The width of the flat surface (a land width:1) is 0.001 to 0.5mm.

[0110] The rake angle D of the cutter 75 is 10° and the clearance angle E thereof is also 10°. The edge of cutter 76 of the cutter 75 is arranged in such a manner having a -15° of an inclined angle α, wherein, as shown in Fig.13, the inclined angle is defined as an angle of the edge of the cutter 76 inclined from a straight line L1 passing through an edge of end 76a in the edge of cutter 76 at the center side of the dresser principal 72 (not shown in the Fig.) and the center of the dresser principal 72 (not shown in the Fig.), and a movement direction of the cutter 75 relative to the polishing pad, that is, a rotational direction of the dresser principal 72 (mentioned after) is defined as positive (a q direction in Fig.13). In addition, nicks 78 are provide to the edge of cutter 76 of the cutter 75 as shown in Fig.13.

[0111] Hard materials such as diamond having a single crystal, cBN, sintered compact produced under a high pressure such as polycrystalline diamond, and materials coated by hard materials as mentioned above are used for the edge of cutter 76.

[0112] When a polishing pad is dressed by using the dresser 71, the polishing pad is shaved by the cutter 75 by rotating a platen 79 having the polishing pad attached thereto to an h direction in the Fig.14 and rotating the dresser principal 72 to an i direction in the Fig.14 while pressing the under surface of the dresser principal 72 in such a manner that the flat surface 77 of the cutter 75 is pressed against the under surface of the dresser principal 72, thereby to dress the upper surface of the polishing pad. Here, the i direction is a movement direction of the cutter 75 mentioned above relative to the polishing pad (a q direction in Fig.13).

[0113] In the above-mentioned dresser 71, as the shaving of the polishing pad surface is carried out by providing to the edge of cutter 76 of the cutter 75 a movement relative to the polishing pad in a direction parallel to the polishing pad surface while the edge of cutter 76 is pressed against the polishing pad surface, the dresser is protected from the lowering of the dressing performance thereof which is caused by clogging of the polishing pad surface with the shaved chips in between abrasive grains, as compared with the conventional one, whereby a stable dressing performance is available. Further, as the polishing pad is shaved by using the cutter 75 as mentioned above, an amount of wear can be decided from the flank of the cutter 75 with result that the criterion for use is clear as compared with the conventional one, thereby to enable always to maintain easily a stable dressing performance. Furthermore, as the cutter 75 is used, reusing a cutter 75 which has worn is possible, which is different from the conventional one, with the result of providing excellence in a cost for the dresser.

[0114] In the dresser 71, as the flat surface 77 is formed in the edge of cutter 76 of the cutter 75, the edge of cutter 76 of the cutter 75 is disposed always at a settled position to the polishing pad without causing the vibration of the edge of cutter 76 of the cutter 75 when the dresser principal 72 is pressed against the polishing pad surface, whereby the flatness of the polishing pad can be obtained and in its turn, the polished performance of materials to polished such as semiconductor wafer can be increased.

[0115] Still further, in the dresser 71, the shaved chips of the polishing pad and the residues of slurries left in the polishing pad which have generated in polishing materials to be polished by methods such as a CMP method can be scooped up by the cutter 75 owing to providing a positive angle to a rake angle D of the cutter 75, whereby the dressing performance can be increased and the polishing pad can be easily cleaned.

[0116] In addition, in the dresser 71, the edge of cutter 76 of the cutter 75 is arranged in such a manner having a negative angle wherein a rotational direction of the dresser principal 72 (a q direction in Fig.13) is defined as positive to a straight line L1 passing through an edge of end 76a at the center side of the dresser principal 72 (not shown in the Fig.) and the center of the dresser principal 72. In such a construction, as a normal line L2 (refer to Fig.13) of the rank face 80 of the cutter 75 (refer to Figs.12 and 13) is always directed to the outward of the dresser principal, the shaved chips of the polishing pad scraped away and the residues left in the polishing pad of slurries which have generated in polish-

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ing materials to be polished by the CMP are scraped out by the edge of cutter 76 from the center side of the dresser 72 to the outward thereof. As mentioned above, as the shaved chips of the polishing pad and the residues of slurries left in the polishing pad which have generated in polishing materials to be polished by the CMP are scraped out to the outside by the cutter 75, the polishing pad can easily be cleaned.

[0117] It is to be understood that, within the spirit of the present invention, designs may be practiced otherwise than as specifically described in the present example.

[0118] For example, the rake angle D can be from -20 to 30°. Specifically, in case where channels having a embossed pattern or a latticed pattern are provide to the polishing pad, the rake angle D is preferably a negative angle such that the side wall of the channel can not be shaved off. In case where the polishing pad is too soft, a negative rake angle is also effective as the rake angle D in order to protect the polishing pad from an excessive shaving.

[0119] Further, in case where the rake angle D is from -5° to -15° , the mechanical strength of the cutter 75 can be ensured and it is useful for cases which require the strength of an edge of cutter.

[0120] Further, a width of land 1 can be within the range of 0.005 to 0.5mm and is preferably from 0.05 to 0.1mm. Further, the clearance angle can be from 3° to 15°. An amount of biting depth of the cutter to the polishing pad can be controlled by adjusting an amount of clearance angle E and a width of flank, as mentioned above. Thereby, an optimum shape can be adopted according to the materials and hardness of the polishing pads. Further, the angle α of inclination of the edge of cutter 76 of the cutter 75 can be within the rage of -10 to -30°. In addition, a construction is possible which has no nick 78.

[0121] Further, the edge of cutter 76 can be selected according to the materials of polishing pads to be dressed and slurry materials used in polishing materials to polished by a CMP method. With regard to a method for attaching the edge of cutter 75, brazing, a clamp method, a blade method and so on can be used.

[0122] Further, the clearance angle of the cutter 75 can comprise two steps as in shown in Fig.15 (for example, α 1=5° , β=15° ,in Fig.15). In this case, an amount of biting depth of the cutter 75 to the polishing pad is controlled by adjusting the clearance angle and the width of the first flank W, thereby to enable to obtain a pertinent dressing rate.

Example 5:

[0123] The dresser 81 of Example 5 of the present invention is described in detail hereunder, referring to Fig.16. The same symbols are provided to the same parts as those of the conventional dresser 11 described in the related art and the description thereon is omitted.

[0124] A dresser 81 is attached to an arm 9 of a dressing apparatus 7 by the aid of a setting shaft 82 in a CPM apparatus 1 shown in Fig.17, in the same manner as in the dresser 11.

[0125] Here, with regard to the setting shaft 82, one end of the setting shaft directed to a rotary shaft is connected to a drive unit (not shown in Figs.) by the aid of the arm and the setting shaft 82 is rotated around the rotary shaft. In the other end thereof, a flange 84 is formed for fixing the dresser 81 (refer to Fig.16 illustrating a side sectional view). In the flange 84, a plurality of bolt inserting holes 86 for bolts 85 for screw-clamping the dresser 81 to the flange 84 are disposed at appropriate spaces in the circular direction thereof (only one portion is illustrated in Fig. 16). Hereunder, in the present specification, the side of the dresser 81 contacting to the setting shaft 82 is defined as the upper side thereof and another side of the dresser 81 where a dressing-working part 15 is formed is defined as the lower side thereof.

[0126] The dresser 81 is an electrodeposited grindstone having a dressing-working face 15 formed by providing an abrasive grain layer 93 including abrasive grains 93 on the surface of a dresser principal 83 having a approximately annular shape, as shown in Fig.16, and the dresser is fixed to the setting shaft 82 while, the center of the dresser is matched with the center of the setting shaft 82.

[0127] The material of the dresser principal 83 comprises aluminum, stainless steel, steel or a combination of aluminum and steel and the section thereof is approximately a rectangle. A convex 87 of the outer peripheral side which is projected at the outer peripheral side of the under surface of the dresser principal 83 toward the lower side is formed all around the periphery, and the under surface of the convex 87 comprises a ground face 88 having an abrasive grain layer 93 formed thereon. The ground face is formed in such a manner that the face thereof is orthogonally crossed to a rotary axis AX of the dresser principal 83. In Fig.16, the thickness of the abrasive grain layer 93 is illustrated larger than the actual one so as to easily understand the shape of the dressing-working face 15.

[0128] A convex 89 of the inward peripheral side having an amount of projection to the lower side smaller than that of the convex 87 of the outer peripheral side is formed in a position closer to the center of rotation than the convex 87 of the outer peripheral side in such a manner that the convex 89 is concentric with the convex 87 and the under surface of the convex 89 comprises a basic face 90 which is parallel to the ground face 88. A recess 92 is formed between the convex 87 and the convex 89 so as to obtain the working accuracy thereof. A plurality of holes for bolt 91 for screw-clamping the bolts 85 are formed at appropriate spaces in the upper face of the dresser principal 83 all around the periphery (only one portion is illustrated in Fig.16).

[0129] Here, the dresser principal 83 is screw-

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clamped to the under surface of the flange 84 of the setting shaft 82 by screw-clamping the bolts 85 to the holes for bolt 91.

[0130] When the dressing of a polishing pad 4 is carried out with the dresser 81 constructed as mentioned above, the following operations are carried out so as to stabilize conditions for dressing the polishing pad 4.

[0131] First, dressers 81 are checked on whether or not a dresser 81 has a flatness of the dressing-working face 15 within a range which is proper to a use for the dressing apparatus 7, and dressers 81 are selected which have the proper flatness.

[0132] The flatness of a dressing-working face 15 can be predicted by inspecting the flatness of the ground face 88 for forming the dressing-working face 15, and the flatness of the ground face 88 can be predicted by inspecting the flatness of the basic face 90 parallel to the ground face 88.

[0133] Namely, if the flatness of a basic face 90 is within the range proper for a use in the dressing apparatus 7, the flatness of the corresponding ground face 88 and dressing-working face 15 can be predicted to be also within the range proper for the use, thereby to select dressers 81 which have the flatness of a basic face which is within the range proper for the use and to use the selected dressers.

[0134] Next, a dresser 81 which has been confirmed to have a flatness within the proper range is attached to the under surface of the flange 84 of the setting shaft 82 by the bolts 85.

[0135] Then, the deflection of the basic face 90 of the dresser 81 is measured with dial gauge, while rotating the setting shaft 82 together with the dresser 81 by a drive unit which is not shown in Figs., and the setting condition of the dresser is adjusted so as to attain a deflection having a proper range.

[0136] When the deflection is not within the proper range, it is considered as a reason that dust is contained in between the setting shaft 82 and the dresser 81, together with another reason due to an error in attaching the setting shaft 82. If the dust problem is considered, the dresser 81 is detached from the setting shaft 82 to confirm whether or not the dust is interposed in between. When the dust is interposed, the dust is removed, followed by attaching again the dresser 81 to the setting shaft 82.

[0137] According to the thus constructed dresser 81, as a ground face 88 having a dressing-working face 15 formed thereon can be predicted whether to be flat or not, dressers having a good flatness of the dressing-working face can be selected and used.

[0138] Further, the condition of attaching a dresser 81 to the setting shaft 82 of the dressing apparatus 7 is confirmed whether to be proper or not, the accuracy of attaching to the dressing apparatus 7 can be increased.

[0139] Thereby, the condition of dressing a polishing pad 4 with the dresser 81 can be stabilized.

[0140] Furthermore, as the basic face 90 is disposed in a position closer to the center of rotation as mentioned above than the ground face 88, that is, at the inward peripheral side of the dresser principal 83, a possibility of damaging the basic face 90 due to hitting the basic face 90 against something is decreased during delivering the dresser 81 or attaching the dresser 81 to the dressing apparatus 7, thereby to ensure an accuracy for predicting the flatness of the dressing-working face 15.

[0141] Still further, as the basic face 90 is disposed in a position close to the center of rotation, the outside diameter of the dresser 81 can be minimized and the dresser 81 can be easily handled.

[0142] In the above-mentioned example, a metal plating layer comprising the abrasive grain layer 93 can be formed by a metal which is not limited to Ni, and other metals can used. A method for forming the metal layer is not limited to electroplating, and the metal layer can be formed on the dresser principal 83 by PVD or CVD.

[0143] The present invention is not limited to the examples as mentioned above and various modified examples are included which contain the combinations of the examples (for examples, a combination of Example 1 and Example 2, and the combinations of any of Examples 1 to 4 and Example 5).

Claims

1. A dresser for dressing a polishing pad used for polishing a material to be polished, the dresser comprising:

   a dresser principal and a dressing-working part which is provided as a body other than the dresser principal; and
   a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

2. The dresser as claimed in claim 1, wherein a projection adjusting means is provided for controlling an amount of projection of said dressing-working part from said dresser principal.

3. The dresser as claimed in claim 2, wherein said dressing-working part is a cutter.

4. The dresser as claimed in claim 3, wherein said cutter has an approximately columnar shape and comprises: a flank which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face comprising a circumferential surface in the end portion of the cutter; and a cutting edge which is a ridgeline formed by crossing of the end face and the circumferential surface in the end

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portion.

5. The dresser as claimed in claim 3, wherein said cutter comprises:

a plurality of projections formed in one end of the cutter;
said projection having a cross section approximately equal to an end face of the projection from one end of the projection to near another end of the projection from which the projection is started; and
a cutting edge which is a ridgeline formed by crossing of the end face of the projection and the side surface of the projection.

6. The dresser as claimed in claim 1, wherein said dressing-working part is a cutter.

7. The dresser as claimed in claim 6, wherein said cutter has an approximately columnar shape and comprises: a flank which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face comprising a circumferential surface in the end portion of the cutter; and a cutting edge which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion.

8. The dresser as claimed in claim 6, wherein said cutter comprises:

a plurality of projections formed in one end of the cutter;
said projection having a cross section approximately equal to an end face of the projection from one end of the projection to near another end of the projection from which the projection is started; and
a cutting edge which is a ridgeline formed by crossing of the end face of the projection and the side surface of the projection.

9. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 1.

10. A dresser for dressing a polishing pad used for polishing a material to be polished, said dresser comprising a plurality of dressing-working parts for dressing the polishing pad which are disposed at unequal spaces in the circular direction of a dresser principal.

11. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 10.

12. A dresser for dressing a polishing pad used for polishing a material to be polished, said dresser comprising: a dressing-working part for dressing the polishing pad along the circular direction of a dresser principal; and a plurality of nicks formed in the dressing-working part at unequal spaces in the circular direction of the dresser principal.

13. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 12.

14. A dresser for dressing a polishing pad surface which is used for an apparatus for polishing, with the polishing pad, materials to be polished such as a semiconductor wafer having a flat surface, said dresser comprising at least one cutter projected from the under surface of a dresser principal,
wherein shaving the polishing pad surface is carried out by providing to the edge of cutter of the cutter a movement relative to the polishing pad surface in a direction parallel to the polishing pad surface, while the edge of cutter is pressed against the polishing pad surface.

15. The dresser as claimed in claim 14, wherein said edge of cutter comprises a flat surface which is parallel to the polishing pad surface and is pressed against the polishing pad surface.

16. The dresser as claimed in claim 14, wherein said cutter comprises a positive rake angle.

17. The dresser as claimed in claim 14, wherein said cutter comprises a rake angle having from -5° to -15°.

18. The dresser as claimed in claim 14, wherein said dresser principal has a circular shape and is constructed in such a manner that the dresser principal is rotated around a rotary shaft formed in the center thereof; and the edge of cutter of the cutter is arranged in such a manner that the edge of cutter has a negative angle wherein a rotational direction of the dresser principal is defined as positive to a straight line passing through the edge of end of the edge of cutter at the center side of the dresser principal and the center of the dresser principal.

19. A dresser which comprises a dresser principal and a dresser-working part having an abrasive grains layer including abrasive grains formed on the dresser principal,
wherein the dresser principal comprises a ground face on which the abrasive-grain layer is provided

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and a basic face which is disposed in a portion of the dresser principal more inward than the ground face and is formed in parallel to the ground face.

20. The dresser as claimed in claim 19, wherein said ground face comprises an approximately annular shape having a center which is the same as the center of rotation of said dresser principal; and the basic face is disposed in a position closer to the center of rotation than the ground face and is concentric with the ground face.

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FIG. 1

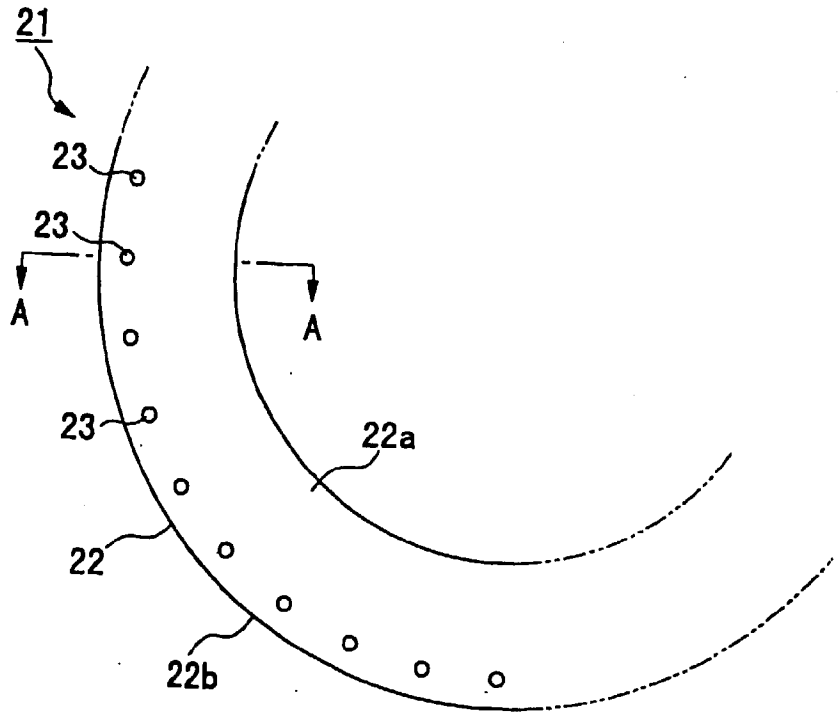


FIG. 2

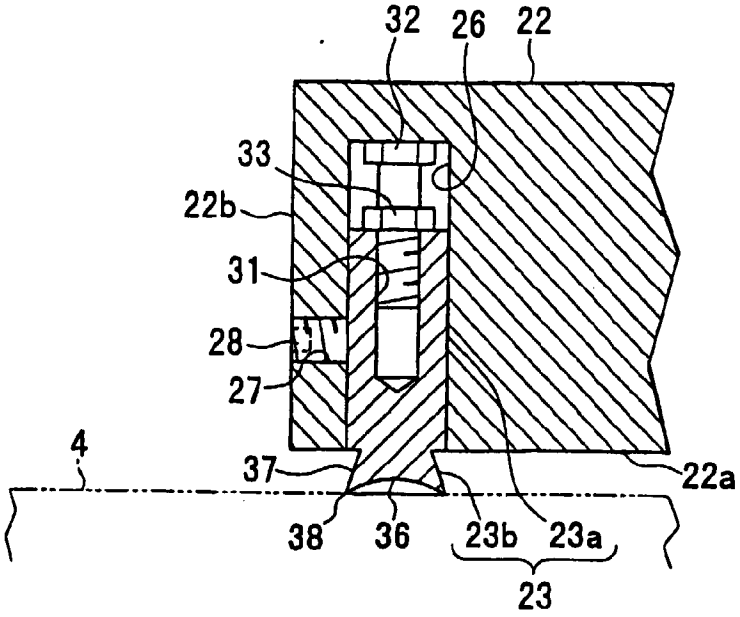

32
26
22
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22b
31
28
27
4
37
22a
38
36
23b
23a
23

FIG. 3

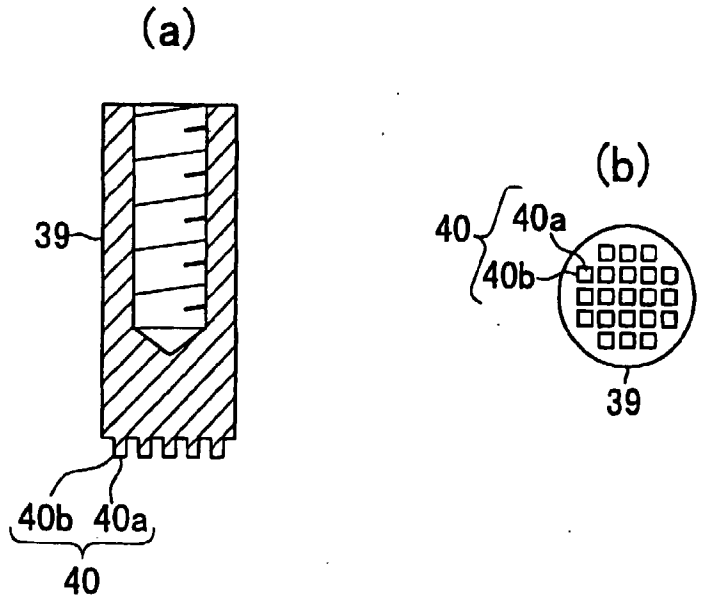

(a)
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40b
40a
40
(b)
40
40a
40b
39

FIG. 4

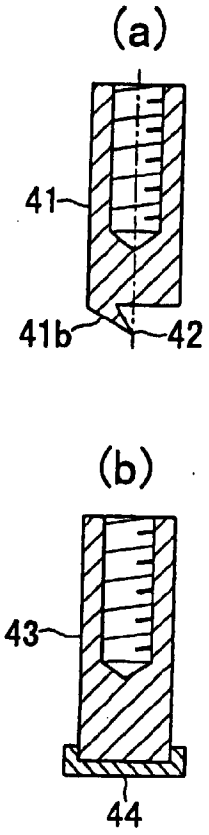


FIG. 5

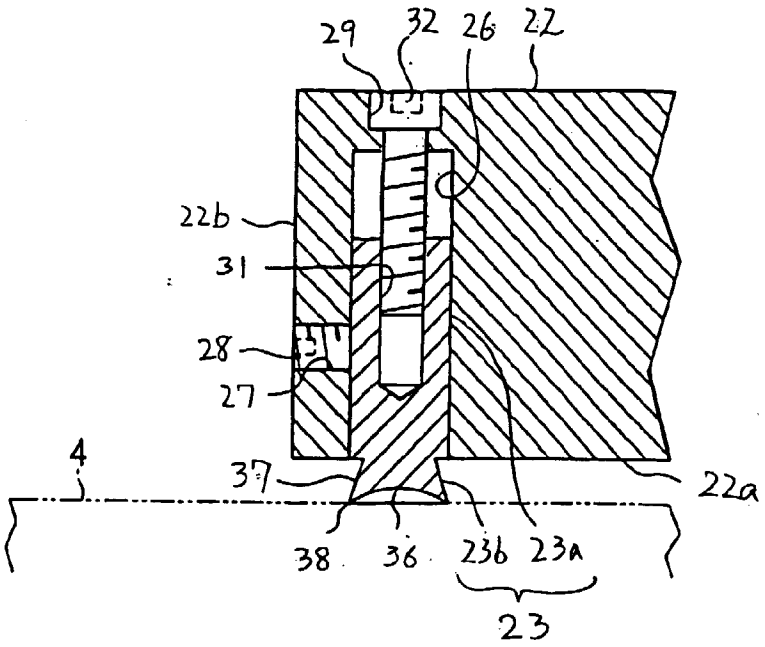


FIG. 6

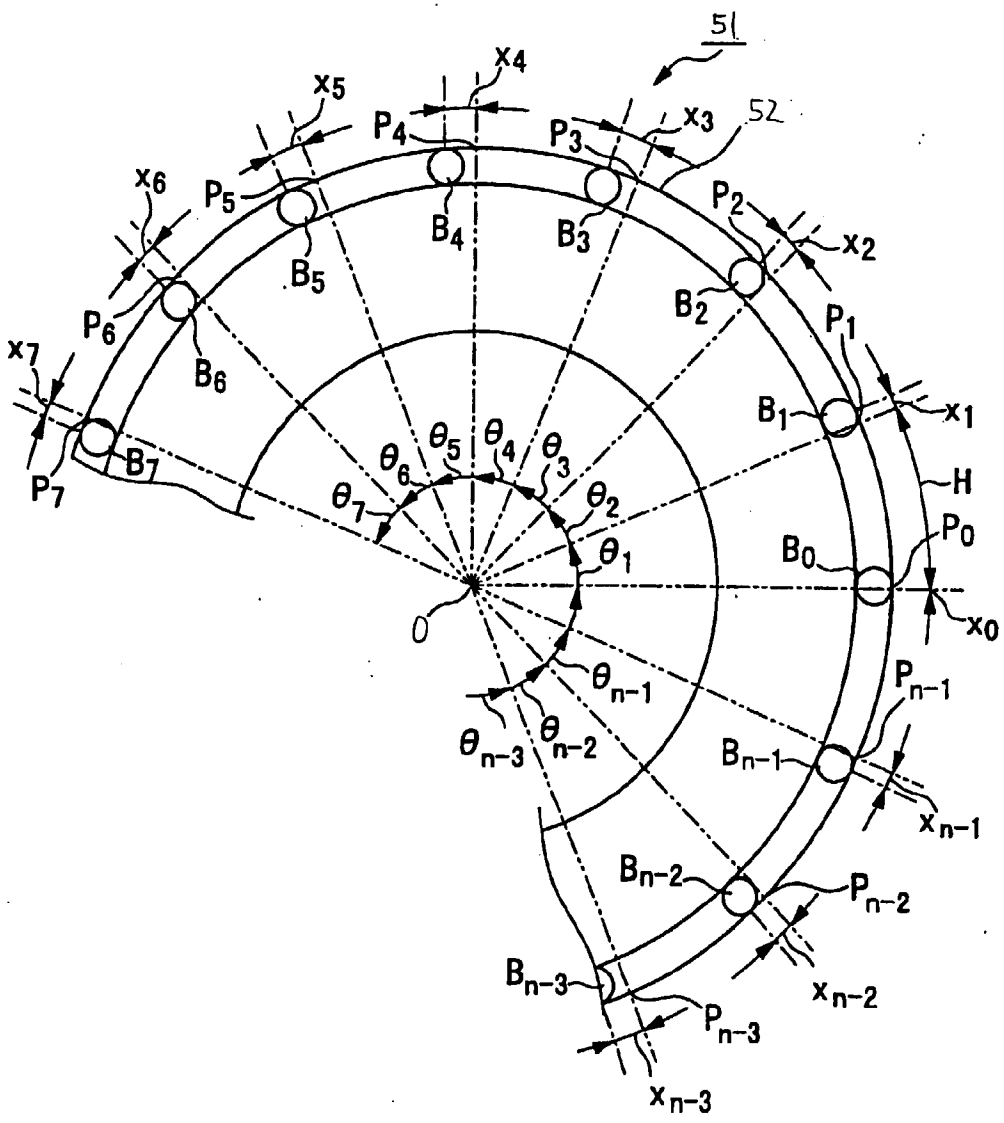

51
52
x_4
x_5
P_4
P_3
x_3
x_6
P_5
P_2
x_2
B_4
B_3
B_5
B_2
P_1
P_6
B_6
x_7
B_1
x_1
B_7
θ_5
θ_4
θ_3
θ_6
θ_2
H
P_7
θ_7
θ_1
B_0
P_0
x_0
0
θ_{n-1}
P_{n-1}
θ_{n-3}
θ_{n-2}
B_{n-1}
x_{n-1}
B_{n-2}
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x_{n-2}
P_{n-3}
x_{n-3}

FIG. 7

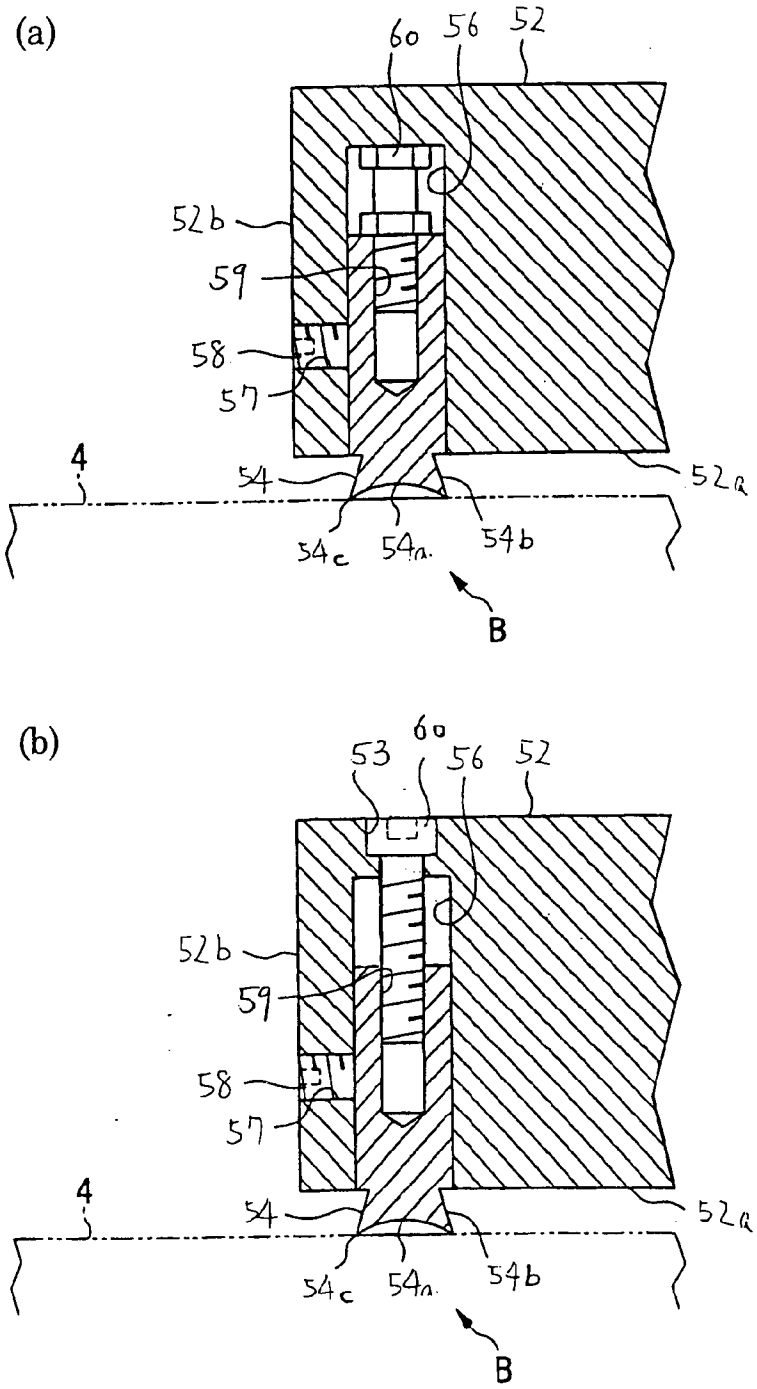

(a)
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B
(b)
53
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B

FIG. 8

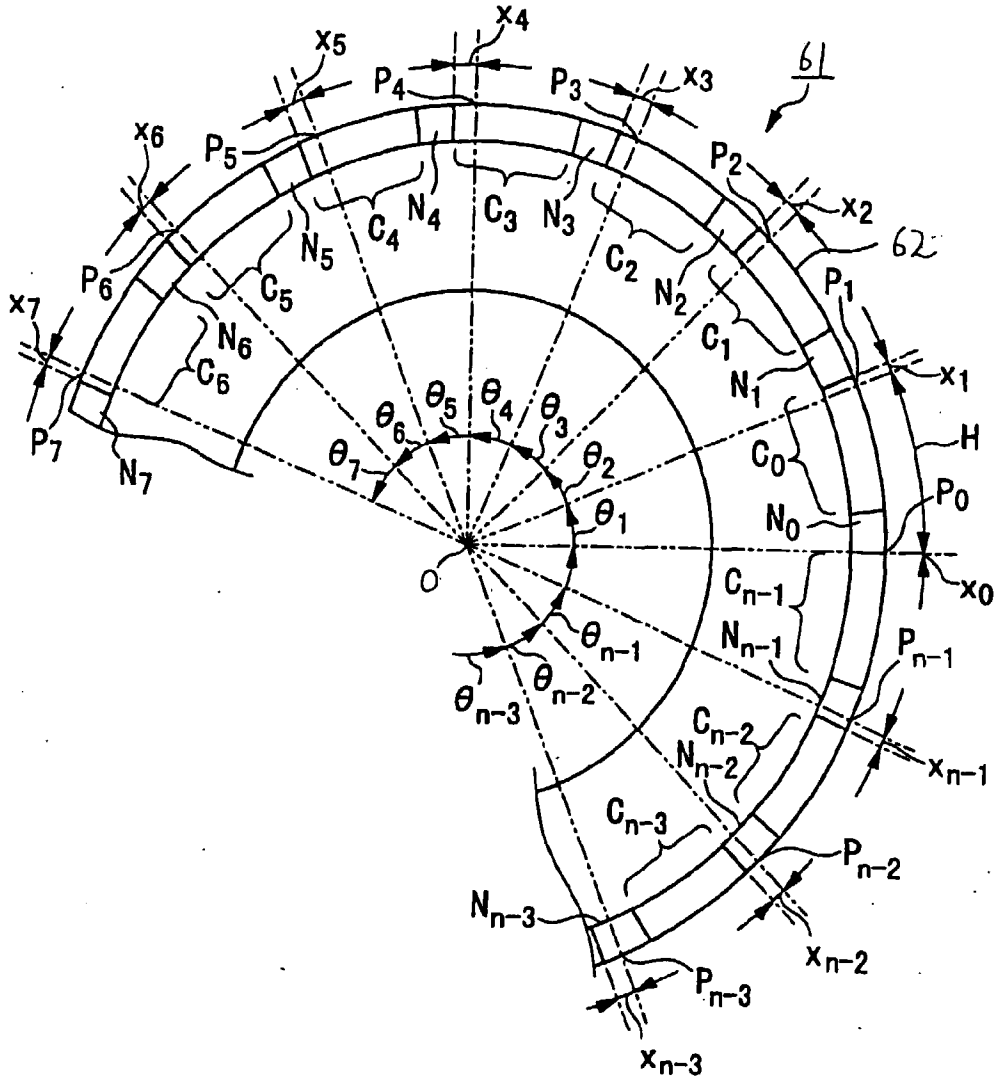

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P_5
P_2
x_2
P_6
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N_4
C_3
N_3
C_2
N_2
P_1
x_7
C_5
C_1
x_1
N_6
N_1
C_6
θ_5
θ_4
θ_3
θ_6
H
P_7
θ_2
C_0
θ_7
P_0
θ_1
N_7
N_0
O
x_0
C_{n-1}
θ_{n-1}
N_{n-1}
P_{n-1}
θ_{n-2}
θ_{n-3}
C_{n-2}
N_{n-2}
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x_{n-3}

FIG. 9

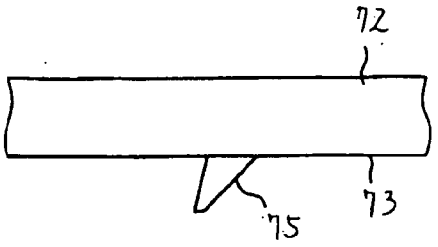


FIG. 10

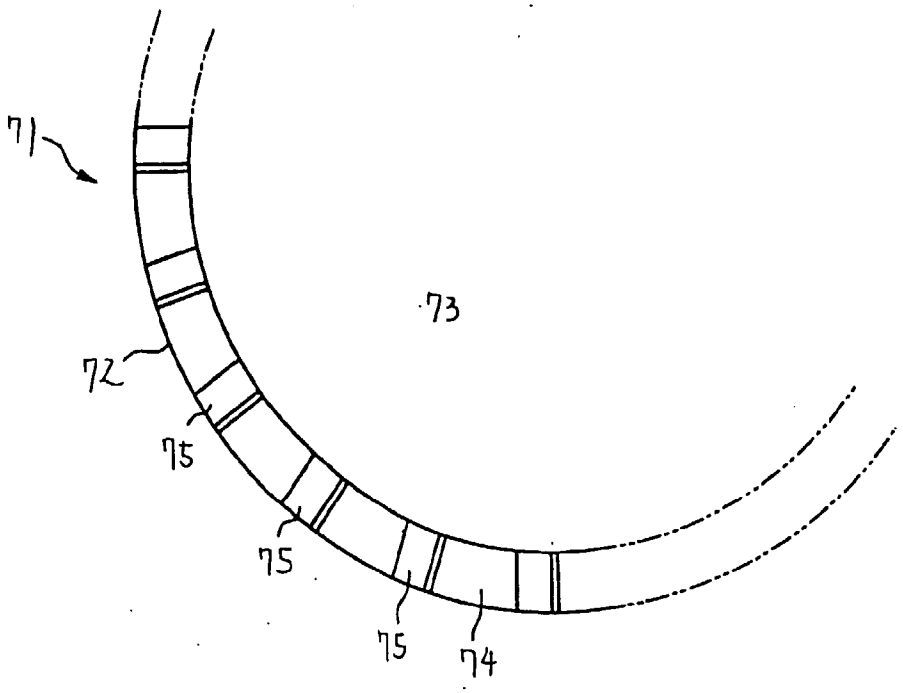


FIG. 11

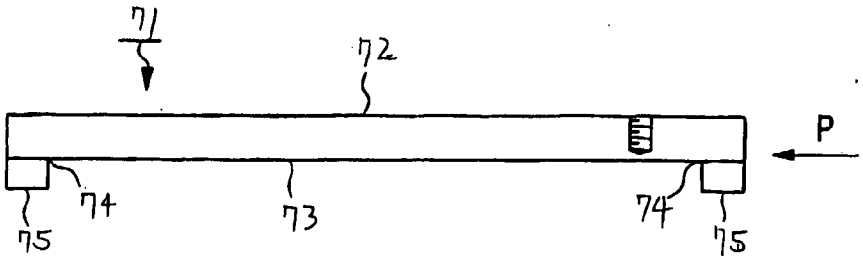


FIG. 12

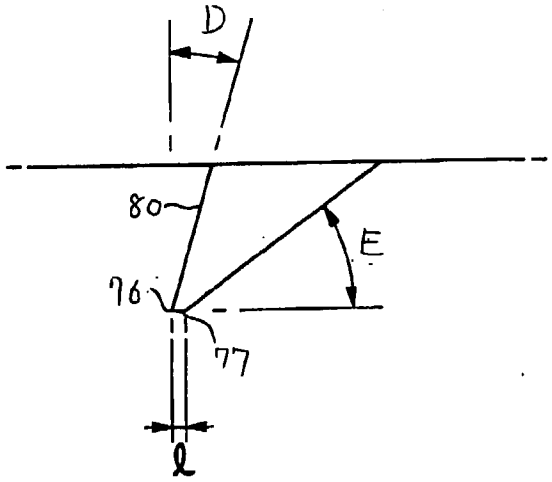


FIG. 13

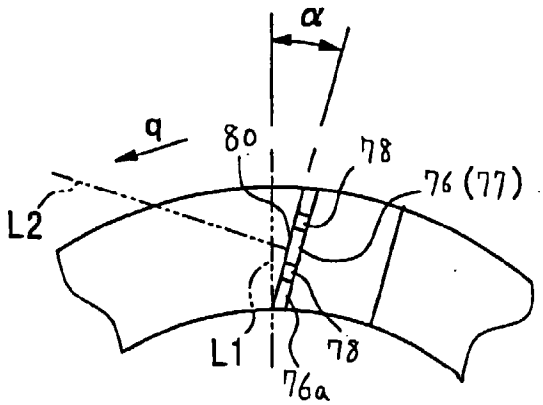


FIG. 14

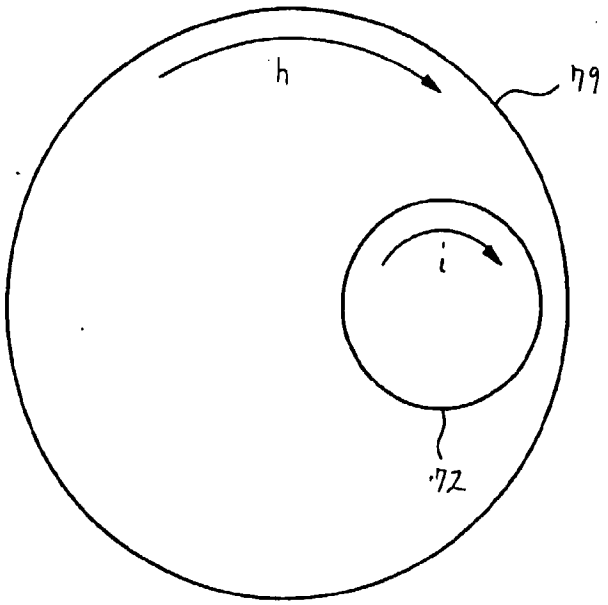


FIG. 15

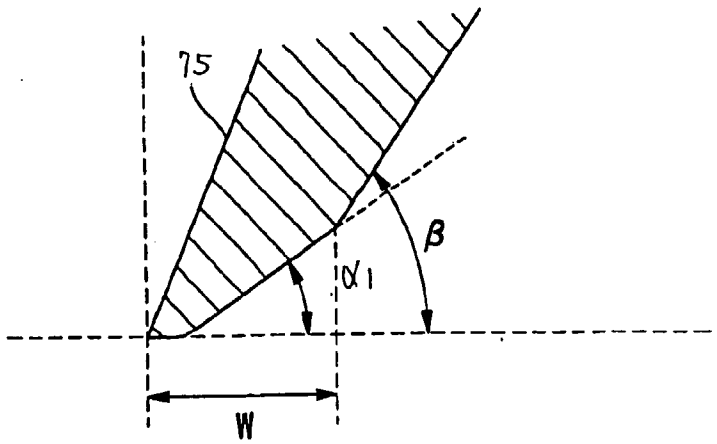


FIG. 16

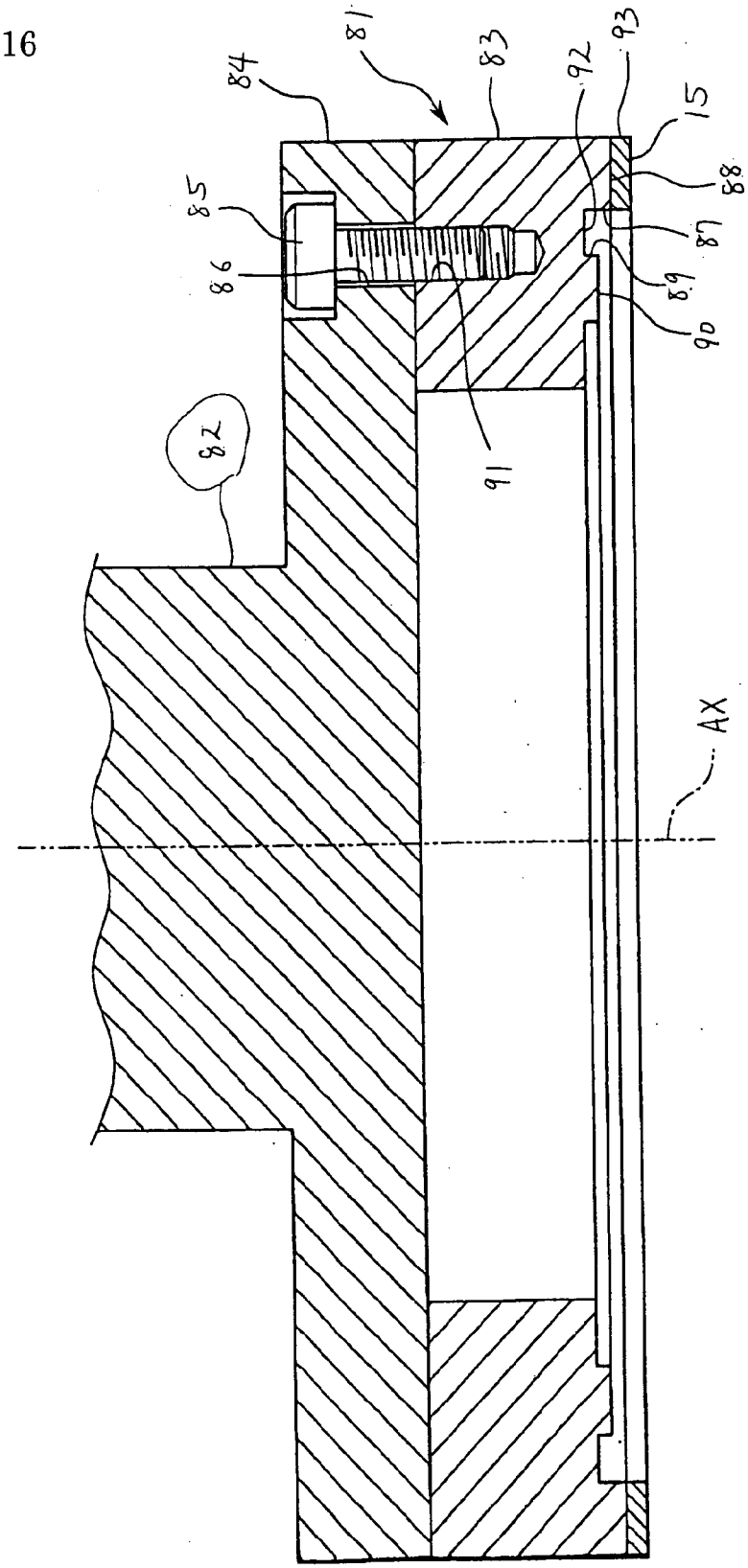


FIG. 17

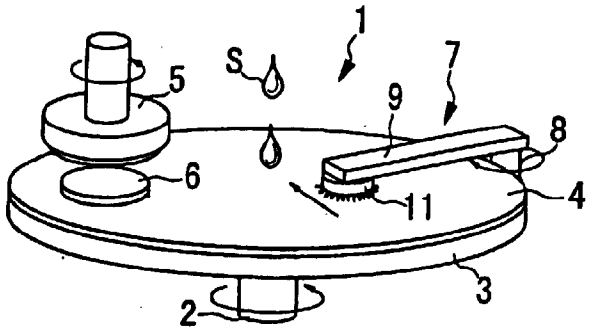


FIG. 18

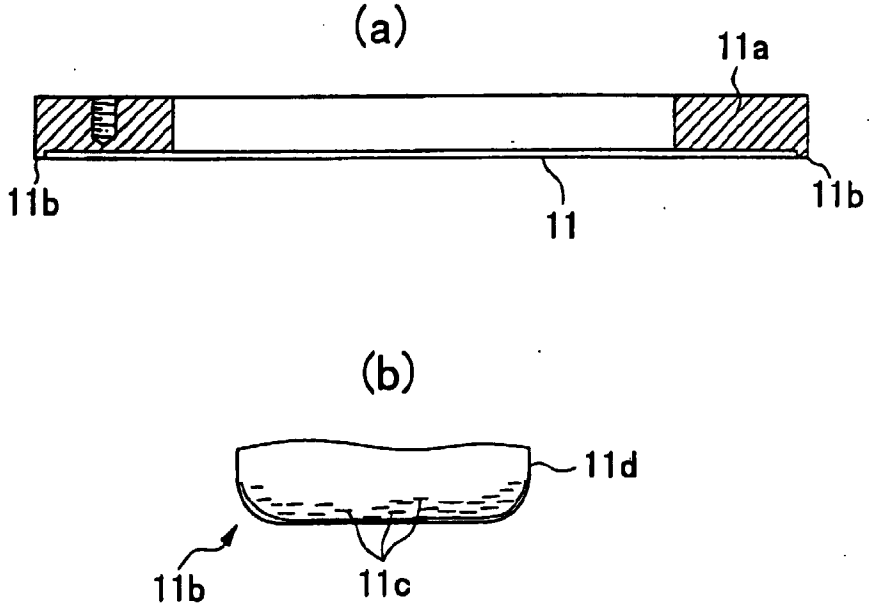


FIG. 19

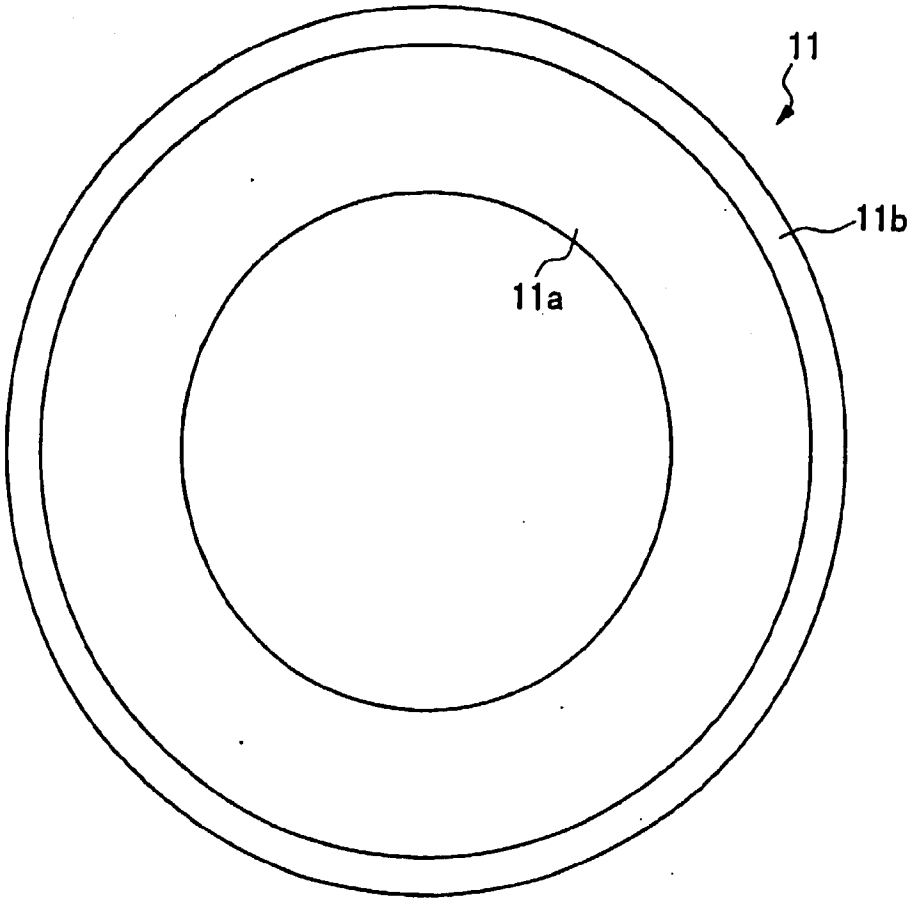


FIG. 20

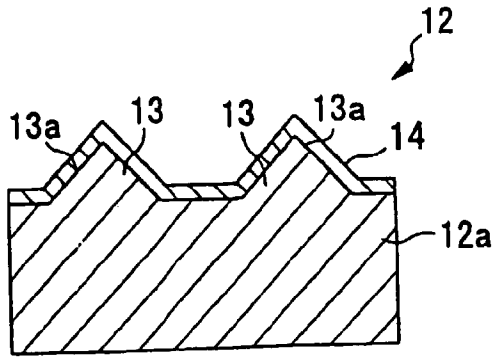
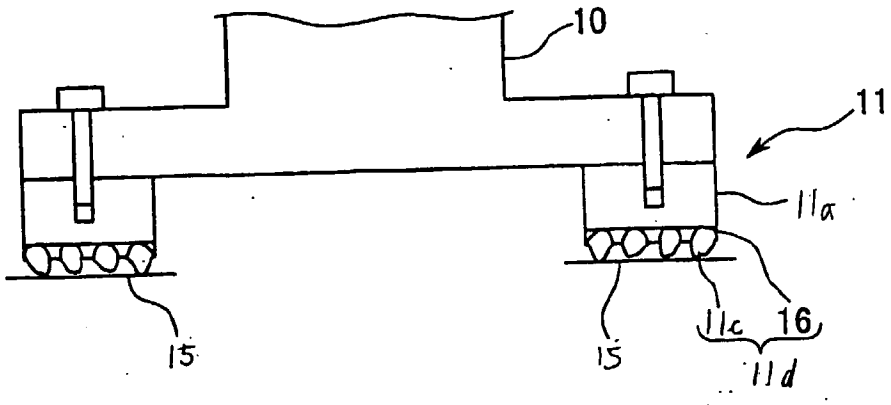


FIG. 21



PATENT ABSTRACTS OF JAPAN

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(43)Date of publication of application : 22.02.2007

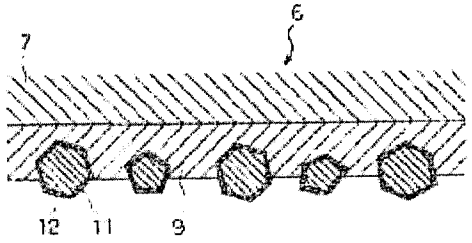
(51)Int.Cl. B24B 53/12 (2006.01)
H01L 21/304 (2006.01)
B24B 37/00 (2006.01)
B24D 3/00 (2006.01)

(21)Application number : 2005-232524
(22)Date of filing : 10.08.2005

(71)Applicant : SOKEN:KK
(72)Inventor : TANI KAZUNORI
IWASAKI HIDEKAZU

(54) CMP PAD CONDITIONER IN SEMICONDUCTOR PLANARIZATION CMP PROCESS (CHEMICAL-MECHANICAL POLISHING)

(57)Abstract:
PROBLEM TO BE SOLVED: To reduce the time and trouble for replacing a CMP pad conditioner, and the down time and loss time of a CMP device by preventing abrasion, wearing and alteration of abrasive grains and fallout and defective of the abrasive grains to achieve long-time conditioning of the polishing pad.
SOLUTION: This pad conditioner includes abrasive grains for pad polishing and grinding used in a semiconductor planarization CMP process, a bond layer holding the abrasive grains; and a bed to which the bond layer is fixed, wherein the abrasive grains or coating material coating the abrasive grains is a material having durability against CMP slurry. The material having durability is silicon carbide (SiC), diamond-like carbon, sapphire, alumina, TiO2, stabilized zirconia, ZrN, ZrC, WC, WC-Co, TiC, TiAlN, TiN-Ni, LiNbO3, NbC, LiTaO3, TaC or HfC.



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(43)公開日　平成19年2月22日(2007.2.22)

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H01L 21/304	(2006.01)	H01L	21/304	622M	3C058
B24B 37/00	(2006.01)	B24B	37/00	A	3C063
B24D 3/00	(2006.01)	B24D	3/00	320A	
		B24D	3/00	330D	

審査請求 未請求　請求項の数 8　OL　（全 9 頁）　最終頁に続く

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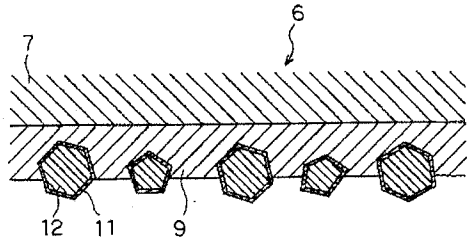
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(54)【発明の名称】半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー

(57)【要約】　（修正有）
【課題】砥粒の磨耗、磨滅、変質や砥粒の脱落、欠損を防止できるので、長時間研磨パッドのコンディショニングを行うことができ、ＣＭＰパッドコンディショナーの交換の手間やＣＭＰ装置のダウンタイムならびにロス時間を減らすこと。
【解決手段】パッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、砥粒あるいは砥粒を被覆する被膜物質がＣＭＰスラリーに対して耐久性を持つ物質である。耐久性を持つ物質は、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣである。
【選択図】　図２



【特許請求の範囲】
【請求項1】
半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒はダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質であることを特徴とする半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項2】
半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒の表面にＣＭＰスラリーに対して耐久性を持つ物質が被覆されていることを特徴とする半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項3】
半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、ＣＭＰスラリーに対して耐久性を持つ物質を上記砥粒表面及び上記ボンド層表面に被覆せしめたことを特徴とする半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項4】
上記被覆した物質の膜厚が１０ｎｍ～９００μｍであることを特徴とする請求項２又は３記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項5】
上記各砥粒は夫々離間しており、上記砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする請求項１、２、３又は４記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項6】
上記各砥粒は夫々離間しており、上記被覆した砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする請求項２、３又は４記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項7】
上記ダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質が、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアであることを特徴とする請求項１又は５記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。
【請求項8】
上記ＣＭＰスラリーに対して耐久性を持つ物質が、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣであることを特徴とする請求項２、３、４、５又は６記載の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー。

【発明の詳細な説明】
【技術分野】
【0001】
本発明は半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナー、特に、化学機械的研磨（ＣＭＰ）装置に用いるＣＭＰパッドのコンディショナーに関するものである。
【背景技術】
【0002】

コンピュータのＣＰＵ能力向上の為には回路の集積度を上げる必要があり、これを実現する為に配線の多層化が行なわれているが、この時、シリコン基板上の各層間絶縁膜を平坦化するＣＭＰ（Chemical Mechanical Polishing）加工技術がキーテクノロジーとなる。半導体デバイスの多層配線化プロセスにおいては、半導体ウェハ表面の凹凸を極力平坦化することが重要であり、この半導体ウェハ表面の平坦化装置として化学的エッチングと研磨剤による機械的研磨とを組み合わせた研磨加工を行うＣＭＰ装置がある。

【0003】

図４は従来のＣＭＰ装置のコンセプトの一例を示す。１は回転自在な直径３００ｍｍの円板状の定盤、２は上記定盤１の略全面に設けたＣＭＰ研磨パッド、３は上記定盤１の回転中心軸に対して偏心した位置に設けた円板状の半導体ウェハ、４は上記半導体ウェハ３を保持し、上記半導体ウェハ３を上記研磨パッド２に押圧せしめる回転自在の半導体ウェハ押圧具、５は上記研磨パッド２上にコロイダルシリカ系、ヒュームドシリカ系、セリア系またはアルミナ系などのＣＭＰスラリーを供給するＣＭＰスラリー供給部、６は上記研磨パッド２の表面を再研磨または再研削（コンディショニング）するため上記半導体ウェハ３とは異なる位置で上記研磨パッド２上に載置した回転自在のＣＭＰパッドコンディショナーを示す。

【0004】

上記研磨パッド２は一般に大別して発泡ウレタンを基材としたパッドと無発泡のウレタンを基材としたパッドが使用されている。前者の発泡ウレタンを基材とする研磨パッドは弾力性があり後者の無発泡のウレタンを基材とするものに比べ平坦性が劣るという報告もある。発泡性ウレタン研磨パッドのＣＭＰパッドコンディショナーにはブラシ状の繊維を埋めこんだもの、あるいはダイヤモンド砥粒をメタルボンドした砥石状のＣＭＰパッドコンディショナーが使用される。一方、無発泡のウレタンの基材を用いたＣＭＰパッドコンディショナーにはダイヤモンド砥粒をメタルボンドした砥石状のＣＭＰパッドコンディショナーが用いられる。

【0005】

上記砥石状のＣＭＰパッドコンディショナー６は図４及び図５に示すように、円板状の金属製台金７と、この台金７の下面に設けた粒径５０μｍ～２００μｍのダイヤモンド砥粒８と、上記ダイヤモンド砥粒８を保持するための上記金属製台金７の下面あるいは台金表面全体を被覆するＮｉメッキボンド層等のボンド層９とよりなる。

【0006】

上記のような従来のＣＭＰ装置においては、上記ＣＭＰ研磨パッド２上にＣＭＰスラリーを供給し、上記定盤１と上記半導体ウェハ押圧具４とを相対的に回転せしめて、上記半導体ウェハ押圧具４により上記半導体ウェハ３を上記ＣＭＰ研磨パッド２上に押圧せしめれば、上記半導体ウェハ３の表面が研磨される。また、上記ＣＭＰパッドコンディショナー６を常時又は定期的に回転せしめれば、上記研磨パッド２の平坦度を維持、修復し、また目詰まりを防止せしめ、また、ＣＭＰ研磨パッド表面の面粗さを維持することによりＣＭＰスラリーの研磨特性を維持、回復せしめることができる。

【0007】

また、上記ＣＭＰパッドコンディショナー６におけるボンド層９により上記台金７を被覆しているので、上記ＣＭＰスラリーにより台金が溶出することがなく、ダイヤモンド砥粒８の脱落を防止できる。このようなＣＭＰ装置は特許文献１に記載されている。

【特許文献1】特開２００１－２３９４４９号

【発明の開示】

【発明が解決しようとする課題】

【0008】

しかしながら、上記従来のＣＭＰ装置においては、ある程度ＣＭＰ研磨パッド２のコンディショニングを続ければ、ＣＭＰパッドコンディショナー上の砥粒の切刃が研磨、磨滅、平坦化され、切れ味が鈍ることにより上記ＣＭＰ研磨パッド２の平坦度の修復が遅くなる。またダイヤモンド砥粒８等がＣＭＰパッドコンディショナー６のボンド層９から脱落

、欠損し、脱落したダイヤモンド砥粒８等がＣＭＰ研磨パッド２の表面に落下、固定され、あるいは転動してウェハ表面に傷をつけてしまうという欠点があった。

【0009】

本発明者は種々実験研究の結果、ダイヤモンド砥粒はコロイダルシリカ系、ヒュームドシリカ系、セリア系またはアルミナ系などのＣＭＰスラリーにより磨耗、磨滅、変質すること、また、この磨耗等により砥粒にかかる力が増大しダイヤモンド砥粒が脱落、欠損することを見出した。また、ＣＭＰスラリーに対して耐久性のある物質、例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣで砥粒あるいはＣＭＰコンディショナーの加工部表面を被覆すれば砥粒の磨耗等を少なくでき、研磨パッドの平坦度ならびに面粗さを維持し、砥粒の脱落等を防止できることを見出した。また、安価な砥粒にＣＭＰスラリーに対して耐久性のある物質を被覆すれば、安価で高品質のＣＭＰコンディショナーを提供できることを見出した。本発明はかかる知見をもとになされたものである。

【課題を解決するための手段】

【0010】

本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒はダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質であることを特徴とする。

【0011】

本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、上記砥粒の表面にＣＭＰスラリーに対して耐久性を持つ物質が被覆されていることを特徴とする。

【0012】

本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーは、半導体平坦化ＣＭＰプロセスに用いるＣＭＰパッド研磨研削用の砥粒と、この砥粒を保持するボンド層と、このボンド層を固着した台とよりなり、ＣＭＰスラリーに対して耐久性を持つ物質を上記砥粒表面及び上記ボンド層表面に被覆せしめたことを特徴とする。

【0013】

上記被覆した物質の膜厚は１０ｎｍ～９００μｍであることを特徴とする。

【0014】

上記各砥粒は夫々離間しており、上記砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする。

【0015】

上記各砥粒は夫々離間しており、上記被覆した砥粒のうち上記台からの高さが一番低い砥粒の高さと、上記台からの高さが一番高い砥粒の高さとの差が１００μｍ以内であることを特徴とする。

【0016】

上記ダイヤモンドよりＣＭＰスラリーに対して耐久性を持つ物質は、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアであることを特徴とする。

【0017】

上記ＣＭＰスラリーに対して耐久性を持つ物質は、炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣであることを特徴とする。

【発明の効果】
【0018】
本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーによれば、砥粒の磨耗、磨滅、変質や砥粒の脱落、欠損を防止できるので、長時間研磨パッドのコンディショニングを行うことができ、ＣＭＰパッドコンディショナーの交換の手間やＣＭＰ装置のダウンタイムならびにロス時間を減らすことができ、また、半導体ウェハ表面に傷が付くのを防止することができるという大きな利益がある。また、安価で高品質のＣＭＰコンディショナーを提供できる。
【発明を実施するための最良の形態】
【0019】
以下図面によって本発明の実施例を説明する。
【実施例】
【0020】
本発明のＣＭＰ装置用のＣＭＰパッドコンディショナー６においては、図１に示すように、ＣＭＰ研磨パッドのＣＭＰコンディショニング用砥粒としてダイヤモンド砥粒８を用いる代わりに、例えば粒径１００μｍ±４０μｍの、ダイヤモンドよりＣＭＰスラリーに対して耐磨耗性、耐磨滅性、耐変質性等の耐久性を持つ化学的に安定した結晶構造を持った例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアなどの物質からなる砥粒などの物質からなる砥粒１０を用いる。パッドコンディショナー用の台金７に形成せしめたＮｉメッキボンド層等のボンド層９の厚さは、上記砥粒１０の粒径のおよそ三分の一を突出せしめて固着せしめることができる程度が好適である。なお、各砥粒間隔は例えば約１０μｍ～１０ｍｍとし、ＣＭＰコンディショナーにかかる加圧力と相関してひとつの砥粒にかかる加圧力でＣＭＰコンディショナー全体の砥粒の数を決定することが望ましい。
【0021】
本発明によれば、上記砥粒１０はＣＭＰスラリー対して耐久性がダイヤモンドより大きいので、磨耗、磨滅、変質しづらく、砥粒の脱落、欠損を防ぐ事ができ、長期間ＣＭＰ研磨パッドのコンディショニングを続けることができるという大きな利益がある。
【0022】
なお、ＣＭＰスラリーをポリシャーとしての被研磨特性を試行したところ、ダイヤモンドは１時間程度で磨滅したが、サファイアを同じ量削るには２～３時間かかり、また、ＳｉＣを同量研磨するには１０～２０時間かかった。従って、ＣＭＰスラリーに対して耐久性のある物質としては特にＳｉＣが好ましい。
【0023】
また、上記各砥粒を夫々離間せしめ、また、上記砥粒のうち、台金からの先端高さが一番低い砥石の先端高さと、台金からの先端高さが一番高い砥粒の先端高さとの差を１００μｍ以内、例えば３μｍ以内としたＣＭＰコンディショナーを用いた場合、ＣＭＰパッドの面粗さを均一化することができ、ＣＭＰ加工品質を向上させ、半導体ウェハの品質を高めることができる。
【0024】
また、上記台金７は金属系の他に樹脂系、粉末冶金系であってもよい。
【実施例】
【0025】
本発明の第２の実施例においては、図２に示すように研磨パッドのコンディショニング用の砥粒として、その表面にスパッタリング、イオンプレーティング、真空蒸着法又は化学蒸着（ＣＶＤ）法等により、ＣＭＰスラリーに対して耐久性のある、例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣなどの物質１１を例えば約１０ｎｍ～９００μｍ被覆したダイヤモンド砥粒、ＳｉＣ砥粒、アルミナ砥粒あるいは立方晶窒

化ホウ素（ＣＢＮ）砥粒などの砥粒１２を用い、パッドコンディショナー用の台金７に形成せしめたＮｉメッキボンド層等のボンド層９に、上記砥粒１２の全部あるいは一部を上記ボンド層９で固着せしめる。

【0026】

この第２の実施例においては、上記物質１１はＣＭＰスラリーに対して耐久性があるので、磨耗等しづらく、砥粒の脱落等を防ぐ事ができ、長期間ＣＭＰ研磨パッドのコンディショニングを続けることができる。また、安価な砥粒にＣＭＰスラリーに対して耐久性のある物質を被覆すれば、安価で高品質のＣＭＰコンディショナーを提供できる。

【0027】

なお、上記物質１１を被覆する部分は、上記砥粒１２の切刃となる部分の表面だけであってもよい。

【0028】

また、各砥粒を夫々離間せしめ、また、上記被覆した砥粒のうち、台金からの先端高さが一番低い砥石の先端高さと、台金からの先端高さが一番高い砥粒の先端高さとの差を１００μｍ以内、例えば３μｍ以内としたＣＭＰコンディショナーを用いた場合、ＣＭＰパッドの面粗さを均一化することができ、ＣＭＰ加工品質を向上させ、半導体ウェハの品質を高めることができる。

【0029】

また、上記台金は金属系の他に樹脂系、粉末冶金系であってもよい。

【0030】

また、上記ＣＭＰスラリーに対して耐久性のある物質は炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアなどのダイヤモンドよりＣＭＰスラリーに対して耐久性のある物質であることが好ましい。

【実施例】

【0031】

本発明の第３の実施例においては、図３に示すようにＣＭＰ研磨パッドのコンディショニング用の砥粒としてダイヤモンド砥粒、ＳｉＣ砥粒、アルミナ砥粒あるいは立方晶窒化ホウ素（ＣＢＮ）砥粒などの砥粒１２を用い、パッドコンディショナー用の台金７に形成せしめたＮｉメッキボンド層等のボンド層９に、上記砥粒１２の全部あるいは一部を上記ボンド層９の表面から突出せしめて固着せしめる。また加えて上記ボンド層９の表面から突出した砥粒１２の表面及び上記ボンド層９の表面にスパッタリング又はＣＶＤ法等により、ＣＭＰスラリーに対する耐久性のある、例えば炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、TiO_2、安定化ジルコニア、ＺｒＮ、ＺｒＣ、ＷＣ、ＷＣ－Ｃｏ、ＴｉＣ、ＴｉＡｌＮ、Ｔｉｎ－Ｎｉ、$LiNbO_3$、ＮｂＣ、$LiTaO_3$、ＴａＣあるいはＨｆＣなどの物質１１を例えば厚さ約１０ｎｍ～９００μｍで被覆せしめる。

【0032】

この第３の実施例においても、上記物質１１はＣＭＰスラリーに対して耐久性があるので、磨耗等しづらく、砥粒の脱落等を防ぐ事ができ、長期間ＣＭＰ研磨パッドのコンディショニングを続けることができる。また、安価な砥粒にＣＭＰスラリーに対して耐久性のある物質を被覆すれば、安価で高品質のＣＭＰコンディショナーを提供できる。

【0033】

なお、上記砥粒１２を被覆する部分は、上記砥粒１２の切刃となる部分の表面だけであってもよい。

【0034】

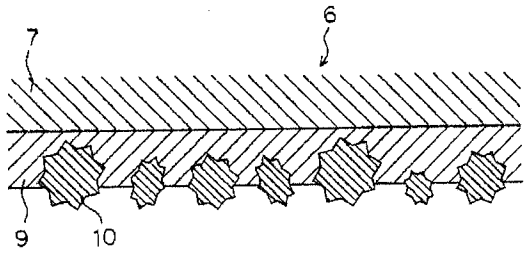
また、上記ＣＭＰスラリーに対して耐久性のある物質は炭化珪素（ＳｉＣ）、ダイヤモンドライクカーボン、サファイア、アルミナ、安定化ジルコニアなどのダイヤモンドよりＣＭＰスラリーに対して耐久性のある物質であることが好ましい。

【図面の簡単な説明】

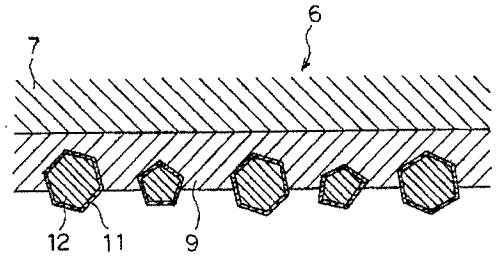
【0035】

【図1】本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの第１の実施例の要部を拡大した縦断側面図である。
【図2】本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの第２の実施例の要部を拡大した縦断側面図である。
【図3】本発明の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの第３の実施例の要部を拡大した縦断側面図である。
【図4】従来の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰ装置の斜視図である。
【図5】従来の半導体平坦化ＣＭＰプロセス（化学機械的研磨）におけるＣＭＰパッドコンディショナーの要部を拡大した縦断側面図である。
【符号の説明】
【0036】
１　定盤
２　ＣＭＰ研磨パッド
３　半導体ウェハ
４　半導体ウェハ押圧具
５　ＣＭＰスラリー供給部
６　ＣＭＰパッドコンディショナー
７　金属製台金
８　砥粒
９　ボンド層
１０　砥粒
１１　被覆物質
１２　砥粒

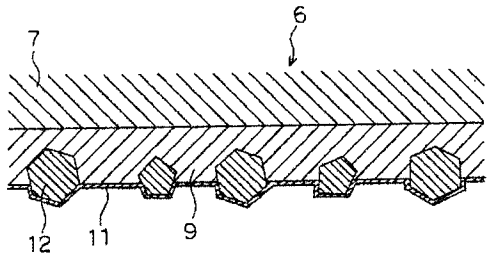
【図1】



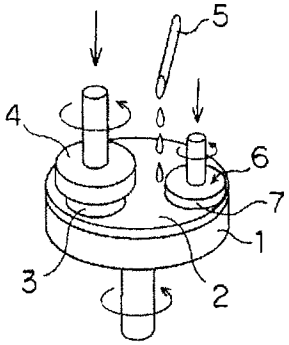
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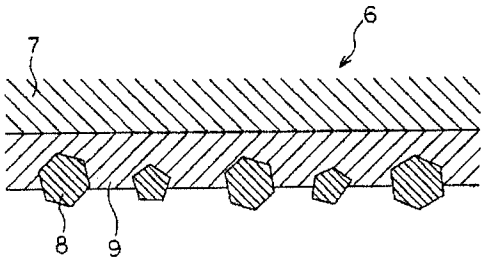
【図3】



【図4】



【図5】



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(54) Title: POLYCRYSTALLINE ABRASIVE GRIT

(57) Abstract: A method is provided for producing a plurality of polycrystalline ultra-hard abrasive grit. The method includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of crystalline abrasive grit. The ultra-hard abrasive is generally diamond or cubic boron nitride.

POLYCRYSTALLINE ABRASIVE GRIT

BACKGROUND OF THE INVENTION

This invention relates to polycrystalline abrasive grit.

Ultra-hard abrasive bodies in the form of either abrasive compacts or individual crystals are well known in the art. The abrasive compact will generally be a diamond compact, also known as polycrystalline diamond or PCD, or a cubic boron nitride compact, also known as polycrystalline cubic boron nitride or PCBN. These abrasive compacts have wide application in cutting, drilling, boring, milling and other abrasive applications.

Such ultra-hard abrasive bodies are produced under conditions of elevated temperature and pressure at which the ultra-hard abrasive is crystallographically stable. Polycrystalline diamond or polycrystalline boron nitride can be produced with or without a second phase or bonding matrix. The second phase, when provided, may be in the case of diamond a solvent/catalyst such as cobalt, or it may be a carbide-forming element such as silicon. Similar sintering mechanisms are utilised in PCBN synthesis with various carbides, nitrides and borides being common second phases.

Abrasive compacts are generally produced in the form of a disc, either free-standing or bonded to a support, which may be cut into smaller segments for use.

Single crystal ultra-hard abrasives in the form of either diamond or cubic boron nitride crystals, also referred to as "grit", are used in loose or bonded form for a variety of abrasive applications such as lapping, drilling, grinding and sawing.

Examples of abrasive tools which utilise single crystal ultra-hard abrasives are grinding wheels and saw segments. Bond types for such abrasives can be a metal, resin or a ceramic.

Diamond or CBN grits are typically produced through a high pressure/high temperature process where graphite or hexagonal boron nitride is converted in the presence of a suitable catalyst to, respectively, diamond or cubic boron nitride. In some cases natural diamond crystals are also employed.

The concepts of abrasive compacts and grits have been combined and have led to the development of polycrystalline grit. For instance United States Patent 4,776,861 describes a process for generating polycrystalline grit containing ultra-hard material. This is achieved by leaching non-diamond material from polycrystalline diamond or cubic boron nitride compacts obtained through a high pressure/high temperature process and subsequently crushing the leached product.

The process of high pressure/high temperature sintering followed by subsequent crushing is not ideal as a high amount of energy is consumed in crushing sintered PCD and control over the shape and size of the final product is limited. Hence yield and quality tend to be low.

SUMMARY OF THE INVENTION

According to the present invention, a method of producing a plurality of polycrystalline ultra-hard abrasive grit includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions at which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of polycrystalline abrasive grit.

The method of the invention involves, as a first step, the forming of the mass of ultra-hard abrasive particles or of combination of a precursor for such particles and solvent/catalyst into a plurality of green state granules. The term "green state granules" means a coherent mass of any suitable shape or size and which is produced, for example, by known granulation or pelletising techniques.

The green state granules will generally be produced in the presence of a second (or binder) phase. The second phase may be provided by a material which participates in or contributes to the formation of the polycrystalline ultra-hard abrasive grit, e.g. a solvent/catalyst for the ultra-hard abrasive. The second phase may also be a binder, organic or inorganic, which may be removed prior to subjecting the granules to the high temperature/high pressure sintering conditions. The second phase can also consist of a combination of these two second phases.

If a precursor for the ultra-hard abrasive is used, then a solvent/catalyst for that ultra-hard abrasive must also be present. Examples of suitable solvent/catalysts for such particles, particularly when the particles are diamond or cubic boron nitride, are well known in the art. The solvent/catalysts may be precursors which can be converted to the solvent/catalyst, e.g. metal oxides which on heating are converted to the metal. Such precursors are included in the term "solvent/catalyst".

Examples of combinations, generally in the form of mixtures, of ultra-hard abrasive particles or precursor particles and second phases which are useful in the practice of the invention are:

1. Diamond and a diamond solvent/catalyst which may be a transition metal such as cobalt, nickel, iron or manganese or non-metallic solvent/catalyst such as a carbonate or sulphate to produce a sintered, intergrown polycrystalline diamond grit material.

2. Graphite and a diamond solvent/catalyst which may be a transition metal such as cobalt, nickel, iron or manganese or a non-metallic solvent/catalyst such as a carbonate or sulphate to produce a sintered, intergrown polycrystalline diamond grit. In producing the grit, the graphite is converted to diamond.

3. A combination of 1 and 2.

4. Diamond and a carbide forming metal such as silicon or titanium to produce a grit which is a sintered polycrystalline diamond/ SiC or TiC composite.

5. A combination of 1 and 4 or 2 and 4.

6. Cubic boron nitride together with a boride or nitride forming metal such as aluminium, titanium, zirconium, hafnium, tantalum, molybdenum, niobium, chromium or tungsten or mixtures thereof introduced either in metallic form or as a substoichiometric or stoichiometric carbide, boride or nitride. The polycrystalline cubic boron nitride grit produced consists of cubic boron nitride and metal nitrides or borides.

7. A combination of 6 and cobalt, nickel, iron or manganese.

8. A combination of cubic boron nitride and alumina or a combination of diamond and alumina.

9. Hexagonal boron nitride and a suitable solvent/catalyst for cubic boron nitride such as magnesium, lithium or calcium in either metallic form, as a nitride or in the form of a boronitride to produce a sintered, intergrown polycrystalline cubic boron nitride grit. In producing the grit, the hexagonal boron nitride is converted to cubic boron nitride.

The green state granules are placed in the reaction zone of a standard high pressure/high temperature apparatus for the high pressure/high temperature sintering. Generally, the granules will be placed in a capsule which itself is placed in the reaction zone.

A separating medium separates individual granules in the reaction zone. The separating medium is preferably provided as a coating on individual granules. A particularly suitable method of coating individual granules is spray coating in a fluidised medium.

The separating medium, in one form of the invention, may be a metal or alloy which does not interfere with the high pressure/high temperature sintering of the green state granules. For example, molybdenum is a suitable coating

where the ultra-hard abrasive is diamond or a precursor for diamond, e.g. graphite.

The separating medium may also be an inert medium which adequately transmits pressure, e.g. a salt such as a chloride or a carbonate, graphite, hexagonal boron nitride or an oxide.

A chemical barrier layer may be applied to the green state granules , generally to coat the granules completely, prior to the separation medium being interposed between adjacent granules. Examples of suitable chemical barrier layers are niobium, molybdenum, tantalum, titanium or other transition metal. The chemical barrier layer may be left on the polycrystalline abrasive grit produced from the green state granules.

The separating medium and chemical barrier layers may be applied to the green state granules by spraying in the form of an aqueous or non-aqueous suspension. The granules will generally be in a fluidised state during spraying. Alternatively, the granules may be dipped into a suspension of the separation medium and/or chemical barrier layer, or these layers may be coated mechanically on to the granules.

In one particular form of the invention, the green state granules are placed in a container, the separating medium in powdered or liquid form poured into the container and the granules and the separating medium mixed. If necessary, good dispersion and mixing can be assisted by some mechanical agitation or vibration to ensure that there are no gaps and the green state granules are all embedded in or enclosed by the separating medium.

Before subjecting the green state granules to the elevated temperature and pressure sintering, any removable binder, e.g. an organic binder which is present is preferably removed, for example, by a pressureless heat treatment.

The heat treatment conditions will vary according to the nature of the granules and its content. Typical heat treatment or outgassing conditions are 500°C in an argon atmosphere or 400°C in air or 1100°C in a vacuum. A slow heating cycle is preferred.

The green state granules may optionally be densified. Densification can be achieved by uniaxial compaction or cold isostatic pressing. Some deformation of the granules will take place during this compaction. When the green state granules contain a binder which is removed, the densification may take place before or after the binder is removed.

The elevated temperature and pressure sintering conditions to which the green state granules are subjected are known in the art. Typical pressures are 3 to 9 GPa and typical temperatures are 1000 to 2500°C.

The sintered material is removed from the reaction zone of the high temperature/high pressure apparatus using known techniques. The material which is recovered is sintered and coherent and consists of a plurality of sintered granules separated by the separating medium and a chemical barrier layer, when provided. The individual sintered granules or polycrystalline ultra-hard abrasive grit can be released by removing the separating medium. For example, if the separating medium is a metal such as molybdenum, the material may be placed in a hot boiling acid such as 3 parts of boiling hydrofluoric acid and one part nitric acid. This will dissolve the molybdenum leaving a plurality of polycrystalline diamond grit. When the separating medium is hexagonal boron nitride, removal of the separating medium may be achieved by placing the sintered material in an ultrasonic bath filled with water. Hexagonal boron nitride is hydrolysed by the water and the sonification breaks up or disintegrates the hexagonal boron nitride.

The polycrystalline ultra-hard abrasive grit produced by the method of the invention will typically have a particle size less than 5 mm and typically less than 2 mm. This grit may be used in a variety of abrasive applications, depending on the content and composition of the grit. The polycrystalline nature of the grit provides for a better bond retention in the bonding matrix of an abrasive tool when compared with single crystal grit. Further, controlled fracture of the grit can occur resulting in sharp edges or points being continuously produced, in use. The invention provides a particularly effective and economic method of producing polycrystalline abrasive grit. Further, the method is versatile in that polycrystalline abrasive grit may be produced with or without a second (binder) phase and contain more than one type of ultra-abrasive. The method allows for the production of polycrystalline abrasive grit of controlled shape and size.

EXAMPLE 1

A solvent based suspension with a 80 weight percent diamond (average particle diameter approximately 10 microns) and 20 weight percent of submicron cobalt powder was prepared and approximately 1 volume percent of organic binder added. The suspension was processed using a combination of spray drying and fluidised bed technology to produce strong green state spherical granules of approximately 1mm diameter and a porosity of approximately 42%. A solvent based suspension was formulated using submicron molybdenum powder. The diamond/cobalt granules were fluidised and a thin layer of molybdenum of approximately 100 microns thickness was spray dried on to the granules, using the molybdenum suspension.

The coated green state granules were placed into a die set and uniaxially compacted to yield a green compact of approximately 60% density. Binder removal from the green state granules was achieved by heat treatment at 1100°C for 2 hours in vacuum. The outgassed green state granules were then

loaded into a metal canister. The canister was loaded into the reaction capsule of a standard high pressure/high temperature apparatus and the loaded capsule placed into the reaction centre of this apparatus. The contents of the canister were exposed to a temperature of approximately 1450°C and a pressure of 5 GPa. These conditions were maintained for 10 minutes. After completion of the treatment a densely sintered compact was recovered from the canister. A polished cross-section showed sintered polycrystalline diamond grit separated by a honeycomb structure of thin molybdenum veins. The compact was placed into a beaker with 3 parts of boiling hydrofluoric acid and 1 part nitric acid. After a few minutes of treatment the compact separated into a plurality of roundish particles of approximately 0,5 to 0,7 mm diameter. Closer examination showed these particles to consist of hard sintered polycrystalline diamond with the cobalt leached out of the surface region of the particles.

EXAMPLE 2

An organic suspension of hexagonal boron nitride containing a small amount of dissolved organic binder was prepared. The molybdenum clad green state granules described in Example 1 were fluidised and spray coated with a second approximately 100 micron thick coating of hexagonal boron nitride, using the hexagonal boron nitride suspension. Repeating the same compaction, outgassing and high temperature/high pressure treatment as described in Example 1 resulted in a coherent sintered compact recovered from the canister. The compact was placed into an ultrasonic bath filled with water. After a few minutes of sonification the compact separated into a plurality of roundish particles of approximately 0,6 to 0,8 mm diameter. Closer examination revealed the particles to consist of sintered polycrystalline diamond grit clad with a thin sintered molybdenum metal coating.

EXAMPLE 3

The procedure in Example 2 was repeated replacing the hexagonal boron nitride layer with a spray deposited sodium chloride layer. The binder removal temperature was lowered to 500°C in argon so as to prevent volatilisation of the chloride. Repeating the same compaction, outgassing and high temperature/high pressure treatment as described in Example 1 resulted in a coherent sintered compact recovered from the canister. The compact was placed into an ultrasonic bath filled with water. After a few minutes of sonification the compact separated into a plurality of roundish particles of approximately 0,6 to 0,8 mm diameter. Closer examination revealed the particles to consist of sintered polycrystalline diamond grit clad with a thin sintered molybdenum metal coating.

CLAIMS

1 A method of producing a plurality of polycrystalline ultra-hard abrasive grit includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions at which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of polycrystalline abrasive grit.

2 A method according to claim 1 wherein the green state granules are produced by granulation or pelletising.

3 A method according to claim 1 or claim 2 wherein the green state granules contain a second phase which is an organic or inorganic binder, such binder being removed prior to subjecting the granules to the high temperature/high pressure conditions.

4 A method according to claim 1 or claim 2 wherein the green state granules contain a second phase which participates in or contributes to the formation of the polycrystalline ultra-hard abrasive grit.

5 A method according to claim 4 wherein the second phase is a solvent/catalyst for the ultra-hard abrasive.

6 A method according to any one of the preceding claims wherein the green state granules contain diamond and a metal solvent/catalyst.

7 A method according to any one of claims 1 to 5 wherein the green state granules contain graphite and a diamond solvent/catalyst.

8 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond, graphite and a diamond solvent/catalyst.

9 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond and a carbide forming metal.

10 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond, a diamond solvent/catalyst and a carbide forming metal.

11 A method according to any one of claims 1 to 5 wherein the green state granules contain cubic boron nitride and a boride or nitride forming metal.

12 A method according to any one of claims 1 to 5 wherein the green state granules contain a combination of cubic boron nitride, a boride or nitride forming metal, and a metal selected from cobalt, nickel, iron and manganese.

13 A method according to any one of claims 1 to 5 wherein the green state granules contain cubic boron nitride and alumina.

14 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond and alumina.

15 A method according to any one of claims 1 to 5 wherein the green state granules contain hexagonal boron nitride and a solvent/catalyst for cubic boron nitride.

16 A method according to any one of the preceding claims wherein the separating medium is provided as a coating on individual granules.

17 A method according to any one of the preceding claims wherein the ultra-hard abrasive for the green state granules is diamond or a precursor for diamond, and the separating medium is molybdenum.

18 A method according to any one of the preceding claims wherein the separating medium is selected from a salt, graphite, hexagonal boron nitride and an oxide.

19 A method according to any one of the claims 1 to 16 wherein a chemical barrier layer is applied to the green state granules prior to the separation medium being interposed between adjacent granules.

20 A method according to claim 19 wherein the chemical barrier layer coats the granules completely.

21 A method according to 19 or claim 20 wherein the chemical barrier layer is selected from niobium, molybdenum, tantalum, titanium or other transition metal.

22 A method according to any one of claims 19 to 21 wherein the chemical barrier layer is left on the polycrystalline abrasive grit produced from the green state granules.

23 A method according to any one of the preceding claims wherein the elevated temperature conditions are a pressure in the range 3 to 9 GPa and a temperature in the range 1000 to 2500°C.

24 A method according to claim 1 substantially as herein described with reference to any one of the examples.

Electronic Patent Application Fee Transmittal

Application Number:	13479148
Filing Date:	23-May-2012
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Warren Archibald
Attorney Docket Number:	02074-24012.NP

Filed as Small Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Submission- Information Disclosure Stmt	2806	1	90	90
		Total in USD ($)		**90**

Electronic Acknowledgement Receipt

EFS ID:	20410277
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	14-OCT-2014
Filing Date:	23-MAY-2012
Time Stamp:	15:29:49
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$90
RAM confirmation Number	2039
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Transmittal Letter	transmittal.PDF	79609 11713683f1cfd0094127ebab08eb7caf955dfbc2	no	4
Warnings:					
Information:					
2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	108570 dd70d9c2dd2a262c4a69e16e10d3f8833022d46a	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	91849 7e1dbdfbdf173b1805ae521444a93f6a42f87756	no	2
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	Foreign Reference	EP1075898A2.pdf	1325035 27f542ba9757d200653606b2a360d36dc2f64ca2	no	28
Warnings:					
Information:					
5	Foreign Reference	JP20078044823.pdf	422036 d9da2eabf4fcd098e3d1969cbcb634540ee24a2c	no	10
Warnings:					
Information:					
6	Foreign Reference	WO0231078A2.pdf	536253 18f5843123686ad39652d694adfe371b32147ae5	no	15
Warnings:					
Information:					
7	Fee Worksheet (SB06)	fee-info.pdf	30344 11a29eff763274b1617f5e6d51932724e6a465fe	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	2593696		

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New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: George Nguyen FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: October 14, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☐ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☒ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☒ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☒ Credit card payment in the amount of $ 90 (amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 14th day of October, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
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P.O. Box 1219
Sandy, Utah 84091-1219
Telephone: (801) 566-6633

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

ART UNIT:	3723
EXAMINER:	George Nguyen
FIRST NAMED INVENTOR:	Chien-Min Sung
SERIAL NO.:	13/479,148
FILED:	5/23/2012
CONF. NO.:	7248
FOR:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
DOCKET NO.:	02074-24012.NP

CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8

DATE OF DEPOSIT: **November 17, 2014**

I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via:

- ☒ EFS Web
- ☐ facsimile to _____
- ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.

/Nicole Solomon/
Nicole Solomon

THORPE NORTH & WESTERN, LLP
8180 South 700 East, Suite 350
Sandy, Utah 84070

RESPONSE UNDER 37 C.F.R. § 1.111

Mailstop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Sir:

In response to the Office Action of May 15, 2014, please enter this amendment and reconsider this application in view of the remarks provided below. A petition for a 3-month extension of time and the associated fee are enclosed herewith.

AMENDMENTS TO THE CLAIMS

1-6. (canceled)

7. (currently amended) The dresser of claim 10, wherein the plurality of superabrasive particles are arranged in at least one annular configuration having a central region devoid of superabrasive particles.

8. (currently amended) The dresser claim 10, wherein the plurality of superabrasive particles are configured in an attitude having a sharp portion oriented towards a pad to be dressed.

9. (currently amended) The dresser of claim 10, wherein the plurality of superabrasive particles are substantially all configured in an attitude having either an apex or an edge portion oriented toward a pad to be dressed.

10. (currently amended) A CMP pad dresser, comprising:

a first monolayer of superabrasive particles disposed on and protruding from one side of a metal support layer, wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 50 microns;

a second monolayer of superabrasive particles disposed on the metal support layer on an opposite side from the first monolayer, wherein the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer; and

a rigid support coupled to the second monolayer of superabrasive particles opposite the first monolayer.

11. (original) The dresser of claim 10, wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip of the first monolayer of

superabrasive particles is less than or equal to about 10 microns.

12. (original) The dresser of claim 11, wherein the difference in protrusion distance between the highest protruding tip and the 10th highest protruding tip of the first monolayer of superabrasive particles is less than or equal to about 20 microns.

13. (original) The dresser of claim 12, wherein the difference in protrusion distance between the highest protruding tip and the 100th highest protruding tip of the first monolayer of superabrasive particles is less than or equal to about 40 microns.

14-27. (canceled)

28. (new) The dresser of claim 10, wherein the difference in protrusion distance between the highest protruding tip and the second highest protruding tip of the first monolayer of superabrasive particles is less than or equal to about 20 microns.

REMARKS

In the Office Action of May 15, 2014, claims 1-27 were pending for consideration. All of the claims were rejected on various statutory grounds, each of which is addressed in turn below. By the present amendment, claims 7-10 have been amended. New claim 28 has been added. Support for these amendments can be found on page 11, lines 16-17 of the specification as filed. As such, Applicant submits that no new matter is added thereby. Additionally, claims 1-6 and 14-27 have been canceled. Accordingly, claims 7-13 and 28 remain pending in the present application. The Applicant respectfully submits that the present claims are allowable over the cited references.

It is noted that the amendments made should not be seen as being in agreement with Examiner, and Applicant reserves the right to pursue any relinquished matter at a later time.

Nonstatory Obviousness-Type Double Patenting:

The Examiner has provisionally rejected claims 10, 14-23, 25, and 26 under the judicially created doctrine of obviousness-type double patenting as being allegedly unpatentable over claims 1, 12-18, 20 and 21 of U.S. Patent Application No. 13/239,198. A terminal disclaimer is filed herewith in order to expedite the present prosecution, without agreeing to the Examiner's assertions.

35 U.S.C. 112, Second Paragraph Rejections:

Claims 1-9 and 24 were rejected under 35 U.S.C. 112, second paragraph, as being allegedly indefinite. Specifically, the Examiner has rejected the claims over the determination of

the protrusion distance between the highest 1% of the protruding tips being within 80 microns or less. As claim 1 has been canceled, and this limitation is no longer in the claim set, the present rejection is now moot.

35 U.S.C. § 102 Rejections:

The Examiner has rejected claims 14-15, 20, 25, and 26 under 35 U.S.C. § 102(b) as being allegedly anticipated by Dinh-Ngoc (2010/0248595). As these claims have been canceled, the present rejections have been rendered moot.

35 U.S.C. § 103 Rejections:

The Examiner has rejected claims 1-9 and 27 under 35 U.S.C. § 103(a) as being allegedly unpatentable over Dinh-Ngoc. Independent claims 1 and 27 have been canceled, along with dependent claims 2-6. Remaining claims 7-9 have been amended to depend from claim 10, which has not been rejected under 35 USC 103(a). As such, no claims remain from the present rejection, which is now moot.

CONCLUSION

In view of the foregoing, Applicants assert that claims 7-13 and 28 of the present application present allowable subject matter and the allowance thereof is requested. If any impediment to the allowance of these claims remains after consideration of the present amendment and above remarks, and such impediment could be removed during a telephone interview, the Examiner is invited to telephone the undersigned attorney so that such issues may be resolved as expeditiously as possible.

It is believed that no fee is due herewith: however, the Commissioner is hereby authorized to charge any required fee (except for Issue Fees) or credit any overpayment to Deposit Account No. 20-0100.

Dated this 17th day of November, 2014.

Respectfully submitted,

THORPE, NORTH & WESTERN, LLP

/David W. Osborne/

David W. Osborne
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DWO/TBA/ns

Electronic Patent Application Fee Transmittal

Application Number:	13479148
Filing Date:	23-May-2012
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Nicole Solomon
Attorney Docket Number:	02074-24012.NP

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Extension - 3 months with $0 paid	1253	1	1400	1400

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Statutory or Terminal Disclaimer	1814	1	160	160
		Total in USD ($)		**1560**

Electronic Acknowledgement Receipt

EFS ID:	20722390
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Nicole Solomon
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	17-NOV-2014
Filing Date:	23-MAY-2012
Time Stamp:	20:36:11
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$1560
RAM confirmation Number	7788
Deposit Account	
Authorized User	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)

1	Extension of Time	02074-24012-NP-Extension.pdf	59061 34f3f59bd910fe9c329e36b1c86d3f9220218c39	no	1
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Information:					
2	Terminal Disclaimer Filed	02074-24012-NP-TD.pdf	110238 6e094b1789162af1786b1df8260f38e18ffbec1d	no	1
Warnings:					
Information:					
3		02074-24012-NP-Response.PDF	84581 ce5d5c46e416073b1ff4390ee2739e7492fafeef	yes	6

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Amendment/Req. Reconsideration-After Non-Final Reject	1	1
	Claims	2	3
	Applicant Arguments/Remarks Made in an Amendment	4	6

Warnings:					
Information:					
4	Fee Worksheet (SB06)	fee-info.pdf	32357 66c18b3f5595b001bba9b1f89ce9d302e5a344f5	no	2
Warnings:					
Information:					
		Total Files Size (in bytes):	286237		

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/22 (03-13)
Approved for use through 3/31/2013. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PETITION FOR EXTENSION OF TIME UNDER 37 CFR 1.136(a)

Docket Number (Optional): 02074-24012.NP

Application Number	Filed
13/479,148	5/23/2012

For: CMP Pad Dresser Having Leveled Tips and Associated Methods

Art Unit	Examiner
3723	George Nguyen

This is a request under the provisions of 37 CFR 1.136(a) to extend the period for filing a reply in the above-identified application.

The requested extension and fee are as follows (check time period desired and enter the appropriate fee below):

	Fee	Small Entity Fee	Micro Entity Fee	
☐ One month (37 CFR 1.17(a)(1))	$200	$100	$50	$
☐ Two months (37 CFR 1.17(a)(2))	$600	$300	$150	$
☑ Three months (37 CFR 1.17(a)(3))	$1,400	$700	$350	$ 1400
☐ Four months (37 CFR 1.17(a)(4))	$2,200	$1,100	$550	$
☐ Five months (37 CFR 1.17(a)(5))	$3,000	$1,500	$750	$

☐ Applicant asserts small entity status. See 37 CFR 1.27.

☐ Applicant certifies micro entity status. See 37 CFR 1.29.
Form PTO/SB/15A or B or equivalent must either be enclosed or have been submitted previously.

☐ A check in the amount of the fee is enclosed.

☑ Payment by credit card. Form PTO-2038 is attached.

☐ The Director has already been authorized to charge fees in this application to a Deposit Account.

☑ The Director is hereby authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account Number 20-0100.

☑ Payment made via EFS-Web.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

I am the

☐ applicant/inventor.

☐ assignee of record of the entire interest. See 37 CFR 3.71. 37 CFR 3.73(b) statement is enclosed (Form PTO/SB/96).

☑ attorney or agent of record. Registration number 44989.

☐ attorney or agent acting under 37 CFR 1.34. Registration number _____.

/David W. Osborne/	November 17, 2014
Signature	Date
David W. Osborne	801-566-6633
Typed or printed name	Telephone Number

NOTE: This form must be signed in accordance with 37 CFR 1.33. See 37 CFR 1.4 for signature requirements and certifications. Submit multiple forms if more than one signature is required, see below*.

☐ * Total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.136(a). The information is required to obtain or retain a benefit by the public, which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 6 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/26 (02-09)
Approved for use through 03/31/2009. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TERMINAL DISCLAIMER TO OBVIATE A DOUBLE PATENTING REJECTION OVER A "PRIOR" PATENT	Docket Number (Optional) 02074-24012.NP

In re Application of: Chien-Min Sung

Application No.: 13/479,148

Filed: 5/23/2012

For: CMP Pad Dresser Having Leveled Tips and Associated Methods

The owner*, Chien-Min Sung, of 100 percent interest in the instant application hereby disclaims, except as provided below, the terminal part of the statutory term of any patent granted on the instant application which would extend beyond the expiration date of the full statutory term **prior patent** No. 8,777,699 as the term of said prior patent is defined in 35 U.S.C. 154 and 173, and as the term of said **prior patent** is presently shortened by any terminal disclaimer. The owner hereby agrees that any patent so granted on the instant application shall be enforceable only for and during such period that it and the **prior patent** are commonly owned. This agreement runs with any patent granted on the instant application and is binding upon the grantee, its successors or assigns.

In making the above disclaimer, the owner does not disclaim the terminal part of the term of any patent granted on the instant application that would extend to the expiration date of the full statutory term as defined in 35 U.S.C. 154 and 173 of the **prior patent**, "as the term of said **prior patent** is presently shortened by any terminal disclaimer," in the event that said **prior patent** later:

expires for failure to pay a maintenance fee;
is held unenforceable;
is found invalid by a court of competent jurisdiction;
is statutorily disclaimed in whole or terminally disclaimed under 37 CFR 1.321;
has all claims canceled by a reexamination certificate;
is reissued; or
is in any manner terminated prior to the expiration of its full statutory term as presently shortened by any terminal disclaimer.

Check either box 1 or 2 below, if appropriate.

1. ☐ For submissions on behalf of a business/organization (e.g., corporation, partnership, university, government agency, etc.), the undersigned is empowered to act on behalf of the business/organization.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

2. ☑ The undersigned is an attorney or agent of record. Reg. No. 44989

/David W. Osborne/ — November 17, 2014
Signature — Date

David W. Osborne
Typed or printed name

801-566-6633
Telephone Number

☑ Terminal disclaimer fee under 37 CFR 1.20(d) included.

WARNING: Information on this form may become public. Credit card information should not be included on this form. Provide credit card information and authorization on PTO-2038.

*Statement under 37 CFR 3.73(b) is required if terminal disclaimer is signed by the assignee (owner).
Form PTO/SB/96 may be used for making this certification. See MPEP § 324.

This collection of information is required by 37 CFR 1.321. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/SB/06 (09-11)
Approved for use through 1/31/2014. OMB 0651-0032
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

PATENT APPLICATION FEE DETERMINATION RECORD Substitute for Form PTO-875	Application or Docket Number 13/479,148	Filing Date 05/23/2012	☐ To be Mailed

ENTITY: ☐ LARGE ☒ SMALL ☐ MICRO

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	RATE ($)	FEE ($)
☐ BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A	
☐ SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A	
☐ EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A	
TOTAL CLAIMS (37 CFR 1.16(i))	minus 20 =	*	X $ =	
INDEPENDENT CLAIMS (37 CFR 1.16(h))	minus 3 =	*	X $ =	
☐ APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $310 ($155 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR 1.16(s).			
☐ MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))				
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL	

APPLICATION AS AMENDED – PART II

AMENDMENT **11/17/2014**

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	* 8	Minus	** 27	= 0	X $40 =	0
Independent (37 CFR 1.16(h))	* 1	Minus	***5	= 0	X $210 =	0
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	0

AMENDMENT

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	RATE ($)	ADDITIONAL FEE ($)
Total (37 CFR 1.16(i))	*	Minus	**	=	X $ =	
Independent (37 CFR 1.16(h))	*	Minus	***	=	X $ =	
☐ Application Size Fee (37 CFR 1.16(s))						
☐ FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))						
					TOTAL ADD'L FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20".
*** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3".
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

LIE
/Kelley Dantzler/

This collection of information is required by 37 CFR 1.16. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**
If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Application Number	Application/Control No.	Applicant(s)/Patent under Reexamination	
	13/479,148	SUNG, CHIEN-MIN	

Document Code - DISQ	Internal Document – DO NOT MAIL

TERMINAL DISCLAIMER	☒ APPROVED	☐ DISAPPROVED
Date Filed : 17 NOV 2014	This patent is subject to a Terminal Disclaimer	

Approved/Disapproved by:

JAB

U.S. Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

20551 7590 12/09/2014

THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

EXAMINER	
NGUYEN, GEORGE BINH MINH	
ART UNIT	PAPER NUMBER
3723	

DATE MAILED: 12/09/2014

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

TITLE OF INVENTION: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	03/09/2015

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20551 7590 12/09/2014
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

TITLE OF INVENTION: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	03/09/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, GEORGE BINH MINH	3723	451-443000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
- ❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:
- ❑ Issue Fee
- ❑ Publication Fee (No small entity discount permitted)
- ❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ❑ A check is enclosed.
- ❑ Payment by credit card. Form PTO-2038 is attached.
- ❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ❑ Applicant certifying micro entity status. See 37 CFR 1.29
  NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ❑ Applicant asserting small entity status. See 37 CFR 1.27
  NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ❑ Applicant changing to regular undiscounted fee status.
  NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Ex. 1003, Page 1043

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

20551 7590 12/09/2014

THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

EXAMINER	
NGUYEN, GEORGE BINH MINH	
ART UNIT	PAPER NUMBER
3723	

DATE MAILED: 12/09/2014

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 13/479,148	Applicant(s) SUNG, CHIEN-MIN	
	Examiner GEORGE NGUYEN	Art Unit 3723	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *November 17, 2014*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on_____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *7-13 and 28*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☒ Notice of References Cited (PTO-892)
2. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 10/14/2014;08/16/2014;07/11/2014
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/GEORGE NGUYEN/
Primary Examiner, Art Unit 3723

Notice of References Cited	Application/Control No. 13/479,148	Applicant(s)/Patent Under Reexamination SUNG, CHIEN-MIN	
	Examiner GEORGE NGUYEN	Art Unit 3723	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-8,777,699 B2	07-2014	Sung, Chien-Min	451/443
	B	US-			
	C	US-			
	D	US-			
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 13/407,634; filing date 02/28/2012; Chien-Min Sung; office action dated 06/13/2014	

Examiner Signature	/George Nguyen/ (12/02/2014)	Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		U.S. Application 13/239, 189; filed 09/21/2011; Chien-Min Sung; office action dated 12/21/2012	
		U.S. Application 12/059,422; filed 03/31/2008; Chien-Min Sung; office action dated 01/24/2013	
		U.S. Application 13/153,176; filed 06/03/2011; Chien-Min Sung; office action dated 12/06/2013	

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Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2002/0182401 A1	12/2002	Lawing	
		2008/0153398	06/2008	Sung	
		2009/0215363	08/27/2009	Sung	
		2011/0252710 A1	10/2011	Hall et al.	
		4155721	05/1979	Fletcher	
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		8398466	03/19/2013	Sung et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		EP1075898	02/2001	Tanaka et al.		
		JP 2007/044823	02/22/2007	Soken		
		WO02/31078	04/2002	Fries		

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		US Application 12/715,583; filed 03/02/2010; Chien-Min Sung; notice of allowance dated 12/07/2012	
		US Application 13/113,779; filed 05/23/2011; Chien-Min Sung; office action dated 11/12/2013	
		US Application 13/021,350; filed 02/04/2011; Chien-Min Sung; office action dated 03/20/2013	
		US Application 13/239,189; filed 09/21/2011; Chien-Min Sung; notice of allowance dated 05/03/2013	
		US Application 12/267,172; filed 11/07/2008; Chien-Min Sung; notice of allowance dated 01/07/2013	
		US Application 13/239, 189; filed 09/21/2011; Chien-Min Sung; notice of allowance dated 03/04/2014	
		US Application 13/644,790; filing date 10/04/2012; Chien-Min Sung; office action dated 06/17/2014	
		US Application 13/416,201; filing date -3/09/2012; Chien-Min Sung; office action dated 06/18/2014	
		US Application 13/153, 176; filing date 06/03/2011; Chien-Min Sung; office action dated 07/01/2014	
		US Application 13/113,779; filing date 05/23/2011; Chien-Min Sung office action dated 07/02.2014	
		US Application 13/794,164; filing date 03/11/2013; Chien-Min Sung; office action dated 07/16/2014	

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				First Named Inventor	Chien-Min Sung
				Art Unit	3723
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		US 2008/0014845 A1	01/17/2008	Yimaz et al.	
		US 2009/0094902 A1	04/16/2009	Hou	
		US 2011/0104989 A1	05/05/2011	Boutaghou et al.	
		US 2013/0225052 A1	08/29/2013	Song et al.	

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		US 6159286	12/2000	Sung	
		US 5919084	07/1999	Powell, et al.	
		US 2004/0238946	12/2004	Tachibana, et al.	
		US 2008/0296756	12/2008	Koch, et al.	
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FOREIGN PATENT DOCUMENTS

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		CN 1351922	06/05/2002	China Emerg Wheel Entpr. Co. Ltd.		
		CN 1494984	05/12/2004	Read Co. Ltd		
		EP 0238434	03/1987	United Tech. Corp.		
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		EP 0712941	05/22/1996	Agency of Ind. Sci. & Tec		
		GB 2239011	06/1991	Anthony et al.		
		JP 06182184	07/1994	Sumitomo Electric Industires		
		JP 10128654	05/1998	Toshiba Corp.		
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		JP 11048122	02/1999	Hitachi Ltd.		
		JP 11077536	03/1999	Asahi Diamond Ind.		
		JP 2000343436	12/12/2000	Noritake Diamond Ind. Co. Ltd.		
		JP 2000167774	06/20/2000	Toho Titanium Co. Ltd.		

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		JP 2003/071718	03/12/2003	Nippon Steel Corp.		
		JP 2004/025401	01/29/2009	Airtec Japan KK		
		KR 200339181	01/31/2004	Jang		
		WO 95/27596	10/1995	Ultimate Abrasive System		
		WO 94/27883	12/08/1994	Zeller Plastik Keehan Graebner DE		
		WO 96/06732	03/07/1996	Roberts		
		WO 98/10897	03/1998	Norton Company		
		WO 98/45091	10/15/1998	Sung		
		WO 98/45092	10/15/1998	Sung		
		WO 98/51448	03/1998	Norton Company		
		WO 02/31078	04/2002	Fries		
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		WO 2007/032946	03/22/2007	Sung		
		WO2008/063599	05/29/20078	Sung		

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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	9	("20040238946" | "5919084" | "6159286" | "7791188").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/12/02 14:03
L2	4	("20040238946" | "5919084" | "6159286" | "7791188").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/12/02 14:04
L3	9	("20040238946" | "5919084" | "6159286" | "7791188").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/12/02 14:05
L7	4	("20080014845" | "20090094902" | "20110104989" | "20130225052").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/12/02 14:09
L8	10	("20020182401" | "20080153398" | "20090215363" | "20110252710" | "4155732" | "6899592" | "7507267" | "7954483" | "8377158" | "8398466").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/12/02 14:10
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L15	632	451/443.ccls.	USPAT	OR	OFF	2014/12/02 14:27
L16	339	451/444.ccls.	USPAT	OR	OFF	2014/12/02 14:29
L17	918	451/548.ccls.	USPAT	OR	OFF	2014/12/02 14:29
L18	451	b24b53/12.cpc.	USPAT	OR	OFF	2014/12/02 14:31
L19	860	b24b53/017.cpc.	USPAT	OR	OFF	2014/12/02 14:32
L20	1466	51/295.ccls.	USPAT	OR	OFF	2014/12/02 14:33
L21	3044	51/309.ccls.	USPAT	OR	OFF	2014/12/02 14:34
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		20070051355-$ or US-20090283089-$ or US-20110296766-$ or US-20120192499-$ or US-20120220208-$ or US-20120260582-$ or US-20020173234-$ or US-20050095959-$ or US-20060068691-$ or US-20060073774-$).did. or (US-6517424-$ or US-7300338-$ or US-5492771-$ or US-5511718-$ or US-5976205-$ or US-7124753-$ or US-7771498-$ or US-8104464-$ or US-6884155-$ or US-7201645-$ or US-7241206-$ or US-7258708-$ or US-7285039-$ or US-7393264-$ or US-7473162-$ or US-7491116-$ or US-7494404-$ or US-7544117-$ or US-7651386-$ or US-7690971-$ or US-7749050-$ or US-7901272-$ or US-8043145-$ or US-8142261-$ or US-8298043-$ or US-8298048-$).did. or (US-8414362-$ or US-8449357-$).did.				
S2	6	("20070232074" | "20080271384" | "20090073774" | "7067903" | "7198553" | "7651386").PN.	US-PGPUB; USPAT	OR	OFF	2013/07/09 08:42
S3	10	("20040180617" | "20080076338" | "20100015898" | "6899592" | "7150677").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 08:42
S4	6	("0238946" | "0296756" | "7791188").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 08:43
S5	843	451/443.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 09:39
S6	462	451/444.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 10:02
S7	84	("20070049185" | "6136043" | "3990124" | "4818515" | "6402603" | "6626747" | "7641538" | "20020068518" | "20040198206" | "4925457" | "6022266" | "6416878" | "6511713" | "RE26879" | "20080248734" | "20100022174" | "7467989" | "20060010780" | "5919084" | "6099603" | "7217172" | "7124753" | "5049165" | "5304223" | "5511718" | "5833724" |	US-PGPUB; USPAT; USOCR	OR	OFF	2013/07/09 10:14

		"6096107" | "6575353" | "20050214201" | "5921856" | "20060254154" | "5791975" | "5863306" | "6159087" | "6347982" | "20050260922" | "20040037948" | "5219462" | "6136143" | "20060010780" | "5152917" | "5669943" | "5842912" | "6679243" | "6769975" | "6234883" | "6309433" | "20020072302" | "20060213128" | "20050215188" | "20060073774" | "2175073" | "5645474" | "5683289" | "20050276979" | "20020197947" | "5492771" | "6358133" | "6368198" | "6537140" | "6572446" | "7258708" | "20080132153" | "20020173234" | "4968326" | "20020173234" | "4222204" | "4951423" | "5851138" | "7575503" | "6123612" | "6286498" | "20080004743" | "20070060026" | "5382189" | "6261167" | "6887138" | "20030036341" | "5014468" | "5980678" | "6293980" | "6818029" | "6039641" | "20050118820" | "20100022174").PN.				
S8	1658	451/548.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 10:21
S9	4663	51/309.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 10:46
S10	180	S9 and (flatness warping)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 10:47
S11	2468	51/295.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 12:31
S12	86	S11 and (flatness warping)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 12:32
S13	1378	451/56.ccls.	US-PGPUB; USPAT; USOCR; FPRS;	OR	OFF	2013/07/09 12:37

			EPO; JPO; DERWENT; IBM_TDB			
S14	204	S13 and (flatness warping)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 12:37
S15	180	("1854071" | "1988065" | "0187593" | "2027087" | "2027307" | "2033991" | "2035521" | "2075354" | "2184348" | "2187624" | "2194253" | "2268663" | "2281558" | "2318570" | "2334572" | "2612348" | "2652951" | "2725693" | "2811960" | "2867086" | "2876086" | "2947608" | "2952951" | "20010003884" | "20010009844" | "20020042200" | "20020127962" | "20020173234" | "20030054746" | "20030084894" | "20030114094" | "20030207659" | "20040009742" | "20040060243" | "20040079033" | "20040107648" | "20050032462" | "20050060941" | "20050118939" | "20050215188" | "20050260939" | "20060073774" | "20060079160" | "20060079162" | "20060128288" | "20060135050" | "20060143991" | "20060254154" | "20060258276" | "20070051354" | "20070051355" | "20070060026" | "20070066194" | "20070093181" | "20070128994" | "20070155298" | "20070249270" | "20070254566" | "20070264918" | "20070295267" | "20080096479" | "20080171503" | "20080292869" | "20090068937" | "20090093195" | "20090145045" | "20090283089" | "20100139174" | "20100186479" | "20100221990" | "20100248596" | "20110212670" | "20110275288" | "20110296766" | "3067551" | "3121981" | "3127715" | "3146560" | "3276852" | "3293012" | "3372010" | "3377411" | "3416560" | "3440774" | "3608134" | "3625666" | "3630699" | "3631638" | "3743489" | "3767371" | "3802130" | "3819814" | "3852078" | "3894673" | "3905571" | "3982358" | "4028576" | "4078906" | "4149881" | "4182628" | "4188194" | "4211294" | "4211924" | "4224380" | "4228214" | "4229186" | "4273561" | "4287168" | "4289503" | "4341532" | "4355489" | "4481016" | "4525179" | "4547257" | "4551195" | "4565034" | "4610699" | "4617181" | "4629373" | "4632817" | "4662896" | "4669522" | "4680199" | "4712552" | "4749514" | "4770907" | "4776861" | "4780274" | "4797241" | "4828582" | "4849602" | "4866888" | "4883500" | "4908046" | "4916869" | "4923490" | "4925457"	US-PGPUB; USPAT; USOCR	OR	OFF	2013/07/09 12:47

		"4927619" | "4943488" | "4945686" | "4949511" | "4954139" | "4968326").pn.				
S16	159	("5000273" | "5011513" | "5022895" | "5024680" | "5030276" | "5037451" | "5043120" | "5049165" | "5092082" | "5092910" | "5116568" | "5131924" | "5133782" | "5137543" | "5151107" | "5164247" | "5176155" | "5190568" | "5194070" | "5194071" | "5195403" | "5195404" | "5197249" | "5203881" | "5232320" | "5243790" | "5246884" | "5247765" | "5248317" | "5264011" | "5266236" | "5271547" | "5273730" | "5295402" | "5314513" | "5328548" | "5364423" | "5374293" | "5380390" | "5443032" | "5453106" | "5454343" | "5458754" | "5486131" | "5492774" | "5505272" | "5518443" | "5527424" | "5536202" | "5547417" | "5551959" | "5560745" | "5560754" | "5609286" | "5620489" | "5660894" | "5674572" | "5725421" | "5746931" | "5772756" | "5779743" | "5791975" | "5801073" | "5815891" | "5820450" | "5833519" | "5851138" | "5855314" | "5885137" | "5902173" | "5916011" | "5921856" | "5924917" | "5961373" | "5975988" | "5976205" | "5980852" | "5980982" | "5985228" | "6001008" | "6001174" | "6024824" | "6027659" | "6030595" | "6039641" | "6054183" | "6093280" | "6106382" | "6123612" | "6159286" | "6179886" | "6190240" | "6206942" | "6213856" | "6217413" | "6224469" | "6258138" | "6258201" | "6258237" | "6281129" | "6284556" | "6286498" | "6293854" | "6299508" | "6319108" | "6325709" | "6346202" | "6354918" | "6368198" | "6371838" | "6371842" | "6394886" | "6409580" | "6439986" | "6446740" | "6478831" | "6497853" | "6544599" | "6551176" | "6605798" | "6607423" | "6616725" | "6616752" | "6626167" | "6627168" | "6646725" | "6672943" | "6679243" | "6694847" | "6749485" | "6755720" | "6790126" | "6818029" | "6824455" | "6835365" | "6884155" | "6935365" | "6945857" | "6979357" | "7021995" | "7033408" | "7044990" | "7066795" | "7124753" | "7201645" | "7258708" | "7261621" | "7323049" | "7368013" | "7384436" | "7404857" | "7465217" | "7585366" | "7651386" | "7658666" | "7690971" | "RE20660" | "RE35812").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2013/07/09 12:49
S17	672	first near2 monolayer near2 second	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:42

S18	81761	rigid near2 support	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:43
S19	0	S17 with S18	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:43
S20	341	sung-chien-min.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:47
S24	655	b24b53/07.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:04
S25	3143	b24b53/017.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:07
S26	608	451/443.ccls.	USPAT	OR	OFF	2014/02/24 11:31
S27	331	451/444.ccls.	USPAT	OR	OFF	2014/02/24 11:34
S28	912	451/548.ccls.	USPAT	OR	OFF	2014/02/24 11:37
S29	1838	b24b53/12.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:40
S34	6	("20040203325" | "20070266639" | "20100203811" | "20100248595" | "20120241943" | "6196911").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/02/25 09:10
S35	204	("2027087" | "2027307" | "2184348" | "20010003884" | "20010009844" | "20020042200" | "20040091627" | "20050032462" | "20080096479" | "20080171503" | "20080292869" | "20100139174" | "20110296766" | "3146560" | "3802130" | "3982358" | "4018576" | "4610699" | "4632817" | "4780274" | "4828582" | "4923490" |	USPAT	OR	OFF	2014/04/01 13:58

		"5295402" | "5328548" | "5536202" | "5674572" | "5924917" | "5975988" | "6106382" | "6217413" | "6346202" | "6497853" | "6626167" | "6712552" | "6790126" | "7021995" | "7150677" | "7368013" | "7641538" | "7840305" | "20070266639" | "1988065" | "0187593" | "2652951" | "2725693" | "2811960" | "2876086" | "2952951" | "20030054746" | "20030114094" | "20040060243" | "20040107648" | "20050060941" | "20070295267" | "20080076338" | "20090283089" | "20100186479" | "3416560" | "3625666" | "3631638" | "4525179" | "4797241" | "4916869" | "4954139" | "5024680" | "5092082" | "5151107" | "5194071" | "5247765" | "5314513" | "5496386" | "5560754" | "5620489" | "5669943" | "5885137" | "5902173" | "6001008" | "6001174" | "6027659" | "6054183" | "6258138" | "6371842" | "6616752" | "6899592" | "6905571" | "7124753" | "7465217" | "7585366" | "8104464" | "20100261419" | "2307461" | "2268663" | "20060128288" | "20110212670" | "3127715" | "3440774" | "3894673" | "4201601" | "4551195" | "4908046" | "5022895" | "5133782" | "5195404" | "5243790" | "5248317" | "5443032" | "5486131" | "5500248" | "5518443" | "5609286" | "5772756" | "5820450" | "5916011" | "5921856" | "5961373" | "5976205" | "5985228" | "6190240" | "6224469" | "6258237" | "6286498" | "6325709" | "6354918" | "6409580" | "6544599" | "6749485" | "6884155" | "7033408" | "7258708" | "7658666" | "6722952" | "20040203325" | "6692547" | "7494404" | "20060143991" | "20070051354" | "20070249270" | "20110293905" | "20120192499" | "3067551" | "3276852" | "3372010" | "3608134" | "4155721" | "4188194" | "4229186" | "4481016" | "4547257" | "4617181" | "4669522" | "4680199" | "4849602" | "4866888" | "4925457" | "4949511" | "5049165" | "5116568" | "5195403" | "5266236" | "5374293" | "5492771" | "5527424" | "5660894" | "5855314" | "6024824" | "6206942" | "6478831" | "6629884" | "6672943" | "6679243" | "6694847" | "6818029" | "6935365" | "7651386" | "6458018" | "20100203811" | "2318570" | "20030084894" | "20050215188" | "20050260939" | "20060073774" | "20060254154" | "20070051355" | "20070066194" | "20070155298" | "20090093195" | "3121981" | "3630699" | "3664662" | "3852078" | "4149881" | "4355489" | "4629373" | "4749514" | "5037451" | "5137543" | "5232320" | "5246884" | "5273730" | "5364423" |			

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S39	1	"7198553".pn.	US-PGPUB; USPAT	OR	OFF	2014/04/01 15:41
S40	1203	tip adj (level leveling)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:42
S41	113033	"451"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:43
S42	8	S40 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	OFF	2014/05/07 11:43

			DERWENT; IBM_TDB			
S43	14761	"51"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:52
S44	3	S40 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:53
S45	1212	tip adj (level leveling leveled)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:54
S46	8	S45 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:54
S47	59	protrusion adj difference	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 13:42
S48	4102	heat near2 pressure near2 bonding	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 13:59
S49	9	S48 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:00
S50	263	sintering adj compound	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:05
S51	3	S50 and S43	US-PGPUB; USPAT; USOCR;	OR	OFF	2014/05/07 14:06

			FPRS; EPO; JPO; DERWENT; IBM_TDB			
S52	4	S50 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:06
S53	1160	adhesive near2 transfer near2 sheet	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 15:46
S54	12	S53 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 15:46
S55	971	aperture near2 template	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:09
S56	0	S53 with S55	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:10
S57	0	S53 same S55	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:10
S58	44	("2223063" | "2642654" | "3817719" | "3894673" | "4018576" | "4042559" | "4311489" | "4378975" | "4621031" | "4652275" | "4799939" | "4925457" | "5000273" | "5049165" | "5131924" | "5203880" | "5203881" | "5251802" | "5264011" | "5304342" | "5380390" | "5486131" | "5492188" | "5511718" | "5569062" | "5605499" | "5707276" | "5782679" | "5832360" | "5833021" | "5871060" | "6039641" | "6123612" | "6361423" | "6434946" | "6679243").PN. OR ("7198553").URPN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/05/08 22:41
S59	53542	hot adj pressing	US-PGPUB; USPAT;	OR	OFF	2014/05/09 08:18

			USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			
S60	14766	"51"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:18
S61	581	S59 and S60	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:18
S62	126	warping adj (reducing reduction minimizing mininized)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:51
S63	0	S62 and S60	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:51
S64	113048	"451"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:51
S65	0	S62 and S64	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:52

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S21	608	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S22	53464	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S23	1	S21 same S22	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S30	635	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38

S31	55259	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38
S32	19881	(superabrasive abrasive) adj particles	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:39
S33	1	S30 same S31 same S32	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:39

12/ 2/ 2014 2:36:46 PM
C:\ Users\ gnguyen\ Documents\ EAST\ Workspaces\ 13479148.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	Art Unit
	GEORGE NGUYEN	3723

CPC- SEARCHED		
Symbol	Date	Examiner
B24b53/12;53/017	5/9/2014	GN
Updated search above	12/2/2014	GN

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
451	443,444,548,56,	5/9/2014	GN
51	295,309	5/9/2014	GN
	updated search above	12/2/2014	GN

SEARCH NOTES		
Search Notes	Date	Examiner
Inventor search	5/9/2014	GN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
	Please see East search history	12/2/2014	GN

	/GEORGE NGUYEN/ Primary Examiner.Art Unit 3723

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	**Art Unit**
	GEORGE NGUYEN	3723

CPC						
Symbol					**Type**	**Version**
H01L		21	/	304	F	2013-01-01
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CPC Combination Sets							
Symbol					**Type**	**Set**	**Ranking**	**Version**
			/					
			/					

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	8	
/GEORGE NGUYEN/ Primary Examiner.Art Unit 3723	12/02/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	**Art Unit**
	GEORGE NGUYEN	3723

US ORIGINAL CLASSIFICATION		INTERNATIONAL CLASSIFICATION										
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED					
451	443	B	2	4	B	53 / 12 (2006.01.01)						

CROSS REFERENCE(S)					
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)				
451	444	548			

NONE		Total Claims Allowed:	
(Assistant Examiner)	(Date)	8	
/GEORGE NGUYEN/ Primary Examiner.Art Unit 3723	12/02/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	**Art Unit**
	GEORGE NGUYEN	3723

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
-	1	-	17												
-	2	-	18												
-	3	-	19												
-	4	-	20												
-	5	-	21												
-	6	-	22												
2	7	-	23												
3	8	-	24												
4	9	-	25												
1	10	-	26												
5	11	-	27												
6	12	8	28												
7	13														
-	14														
-	15														
-	16														

NONE (Assistant Examiner)	(Date)	**Total Claims Allowed:** 8	
/GEORGE NGUYEN/ Primary Examiner.Art Unit 3723 (Primary Examiner)	12/02/2014 (Date)	O.G. Print Claim(s) 1	O.G. Print Figure 5

PTO/SB/30EFS (03-09)
Approved for use through 04/30/2009. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

REQUEST FOR CONTINUED EXAMINATION(RCE)TRANSMITTAL
(Submitted Only via EFS-Web)

Application Number	13/479,148	Filing Date	2012-05-23	Docket Number (if applicable)	02074-24012.NP	Art Unit	3723
First Named Inventor	Chien-Min Sung			Examiner Name	George Binh Minh Nguyen		

This is a Request for Continued Examination (RCE) under 37 CFR 1.114 of the above-identified application.
Request for Continued Examination (RCE) practice under 37 CFR 1.114 does not apply to any utility or plant application filed prior to June 8, 1995, or to any design application. The Instruction Sheet for this form is located at WWW.USPTO.GOV

SUBMISSION REQUIRED UNDER 37 CFR 1.114

Note: If the RCE is proper, any previously filed unentered amendments and amendments enclosed with the RCE will be entered in the order in which they were filed unless applicant instructs otherwise. If applicant does not wish to have any previously filed unentered amendment(s) entered, applicant must request non-entry of such amendment(s).

☐ Previously submitted. If a final Office action is outstanding, any amendments filed after the final Office action may be considered as a submission even if this box is not checked.

- ☐ Consider the arguments in the Appeal Brief or Reply Brief previously filed on _____
- ☐ Other _____

☒ Enclosed

- ☐ Amendment/Reply
- ☒ Information Disclosure Statement (IDS)
- ☐ Affidavit(s)/ Declaration(s)
- ☐ Other _____

MISCELLANEOUS

☐ Suspension of action on the above-identified application is requested under 37 CFR 1.103(c) for a period of months _____
(Period of suspension shall not exceed 3 months; Fee under 37 CFR 1.17(i) required)

☐ Other _____

FEES

☒ **The RCE fee under 37 CFR 1.17(e) is required by 37 CFR 1.114 when the RCE is filed.**
The Director is hereby authorized to charge any underpayment of fees, or credit any overpayments, to Deposit Account No 200100

SIGNATURE OF APPLICANT, ATTORNEY, OR AGENT REQUIRED

☒ Patent Practitioner Signature

☐ Applicant Signature

PTO/SB/30EFS (03-09)
Approved for use through 04/30/2009. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Signature of Registered U.S. Patent Practitioner			
Signature	/David W. Osborne/	Date (YYYY-MM-DD)	2014-12-16
Name	David W. Osborne	Registration Number	44989

This collection of information is required by 37 CFR 1.114. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450.

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C. 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether the Freedom of Information Act requires disclosure of these record s.

2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.

3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.

4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).

5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.

6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).

7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.

8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspections or an issued patent.

9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: George Nguyen FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: December 16, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☒ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Credit card payment in the amount of $ (amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 16th day of December, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
Customer No. 20,551
P.O. Box 1219
Sandy, Utah 84091-1219
Telephone: (801) 566-6633

PTO/SB/08B (08-03)
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U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		PCT Application PCT/US2007/024165; filed 11/16/2007; Chien-Min Sung; Internaitonal Search Report mailed 05/23/2011	
		PCT Application PCT/US2011/052626; filing date 09/21/2011; Chien-Min Sung; International Search Report mailed 05/02/2012	
		US Application 12/255,823; filing date 10/22/2005; Chien-Min Sung; office action issued 03/07/2012	
		US Application 12/267,172; filing date 11/07/2008; Chien-Min Sung; office action issued 01/03/2012	
		US Application 12/267,172; filing date 01/31/2012; Chien-Min Sung; office action issued 07/09/2012	
		US Application 12/715,583; filing date 03/02/2010; Chien-Min Sung; office action issued 03/21/2012	
		US Application 12/715,583;; filling date 03/02/2010; Chien-Min Sung; office action issued 08/09/2012	
		US Application 12/715,583; filing date 03/02/2010; Chien-Min Sung; office action issued 10/25/2011	
		US Application 12/328,338; filed 12/04/2008; Chien-Min Sung; office action issued 05/10/2011	
		US Application 13/021,350; filing date 02/04/2011; Chien-Min Sung; office action issued 08/31/2011	
		US Application 13/021,350; filed 02/04/2011; Chien-Min Sung; office action issued 02/07/2012	
		US Application 13/113/779; filing date 05/23/2011; Chien-Min Sung; office action dated 10/09/2014	
		US Application 13/153,176; filing date 06/03/2011; Chien-Min Sung; office action dated 10/10/2014	
		US Application 13/407,634; filing date 02/28/2012; Chien-Min Sung; office action dated 10/29/2014	

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Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

Sheet | | of | |

		US Application 13/802,112; filing date 03/13/2013; Chien-Min Sung; office action dated 11/06/2014	

Examiner Signature		Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 075 898 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
14.02.2001 Bulletin 2001/07

(51) Int. Cl.[7]: **B24B 37/04**, B24B 53/007, B24B 53/12

(21) Application number: **00116133.0**

(22) Date of filing: **31.07.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **13.08.1999 JP 22949599**
24.09.1999 JP 27117699
28.04.2000 JP 2000131784
28.04.2000 JP 2000131785

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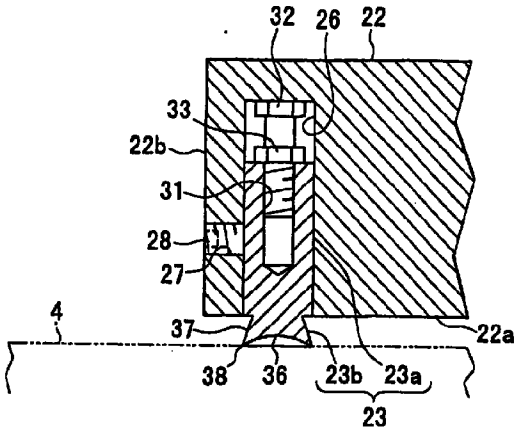
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(54) Dresser and dressing apparatus

(57) A dresser for dressing a polishing pad used for polishing a material to be polished is disclosed, the dresser comprising: a dresser principal and a dressing-working part which is provided as a body other than the dresser principal; and a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

FIG. 2



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Description

BACKGROUND OF THE INVENTION

Field of the invention:

[0001] The present invention relates to a dresser and a dressing apparatus for dressing the surface of a polishing pad which is used for polishing materials to be polished, for example, semiconductor wafer or the like.

[0002] The present specification is based on Japanese patent applications (N0. HEI 11-229495, N0. HEI 11-271176, N0. 2000-131784 and N0. 2000-131785) and the contents of these applications are incorporated herein as a part of the present specification.

Description of the Related Art:

[0003] A chemical and mechanical polishing method (CMP method) which provides a high flatness is used for polishing the surface of materials to be polished for which excellent polishing accuracy is required, for example, for polishing semiconductor wafers or the like.

[0004] The CMP method is a method where the surface of wafer is polished chemically and mechanically to obtain a flatness of the surface, using an alkali slurry containing SiO_2, a neutral slurry containing CeO_2, an acid slurry containing Al_2O_3 or a slurry containing abrasive grains. For example, the following polishing apparatus is known as an apparatus for polishing the surfaces of wafers.

[0005] As schematically shown in Fig 17 of an enlarged perspective view of an important part, a polishing pad 4 comprising, for example, hard urethane, is provided on a disc-shaped platen 3 attached to a center shaft 2 in a polishing apparatus 1 and a wafer-polishing head 5 which holds a wafer 6 is disposed facing the polishing pad 4 and in a position eccentric from the center shaft 2 of the platen 3 to the polishing pad such that the head can be rotated on its own axis.

[0006] In the polishing apparatus 1, the polishing pad 4 and the wafer 6 are moved relatively each other while the wafer 6 is held in the state of being pressed against the polishing pad 4 by the wafer-polishing head 5 and the above-mentioned slurry S is interposed between the wafer 6 and the polishing pad 4, thereby to polish one surface of the wafer 6.

[0007] A lot of fine pores, channels or the like are provided on the polishing pad 4 for holding the slurry S, whereby the wafer 6 is polished by the slurry S hold on the polishing pad 4.

[0008] However, repeating the polishing causes the decrease of the surface flatness of the polishing pad 4 and causes clogging and dulling thereof with the result of bringing about a problem to decrease the polishing accuracy and efficiency of the wafer 6.

[0009] Accordingly, a dressing apparatus 7 has conventionally been arranged in a CPM apparatus as shown in Fig 17, thereby to dress the surface of the polishing pad 4.

[0010] In the above-mentioned dressing apparatus, a dresser 11 is, through an arm 9, attached to a rotary shaft 8 which is disposed outside a platen 3, while the dresser 11 is moved to perform a reciprocating and oscillatory motion on the rotating polishing pad 4 by rotating the arm 9 with the rotary shaft 8 to shave a slight amount of the surface of the polishing pad 4, whereby the surface flatness and the like of the polishing pad are recovered and maintained, and the clogging, dulling and the like are dissolved. The surface of the polishing pad is shaved off little by little in such a manner that while pressed against the surface of the polishing pad 4, the dresser 11 is rotated by a friction force between the dresser and the polishing pad or is rotated by being driven by a drive unit which is not shown in the drawing.

[0011] The conventional dresser 11 has a nearly circular shape having an opening in the center, for example, as shown in Fig.18 (a) of a side cross-sectional view and Fig.19 of a plane view and is provided with a dresser principal 11a wherein a projection 11b is formed in the outer peripheral portion of one end face. As shown in Fig.18 (b) of a partially enlarged side sectional view, the conventional dresser having a dressing-working part is used which comprises a diamond electrodeposited part 11d formed by electrodepositing on the projection 11b abrasive grains 11c (super abrasive grain) such as diamond or cBN. The dressing-working part shaves little by little the polishing pad 4 (such a dresser is called electrodeposited grindstone). Fig.19 is a plane view illustrating the under surface of the dresser 11. A dressing apparatus using this type of dresser is disclosed in, for example, JP-A 9-168961.

[0012] In the conventional dresser 11, there has been encountered the dropping off of the abrasive grains 11 such as diamond grain during dressing. In this case, a trouble is brought about due to scratching the surface of the wafer 6, when the wafer is polished while the dropped grains are filled up in the surface of the polishing pad.

[0013] In order to dissolve the above-mentioned problem, there was a proposal in JP-A 10-217103 as in Fig.20. A dresser 12 shown in Fig.20 has the following construction as a dressing-working part: a lot of projections 13 having a shape of pyramid are formed in the surface of a metal base 12a by machining and a surface 13a of the metal base 12a having the formed projections 13 was coated by a hard film. Dressing is carried out by pressing the projections 13 against a polishing cloth (polishing pad). There is no fear in the dressing apparatus having the dresser 12 for dropping of abrasive grains such as diamond grain with the result that there is little anxiety for suffering from a damage in the surface of materials to be polished.

[0014] However, in the dressers 11 and 12 as men-

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tioned above, a cutting quality degreases due to reasons such as wear of the dressing-working part in proportion to repeated dressings. In this case, changing a dresser unit is required, which takes a high cost.

[0015] In addition, as shown in Fig.19, the dressing of the polishing pad 4 is carried out by the whole surface of the dressing-working part which is projected in a shape of ring in the under surface of the outer peripheral portion of a dresser principal 11a. Chatter is apt to be caused due to a force acting all over the whole surface of the dressing-working part. Further, if once the chatter is caused, the vibration of the dressing 11 continues due to reasons such as the resonance of the vibration, which causes cases leading to a failure to polish uniformly the surface of the polishing pad.

[0016] Further, chips generate from the polishing pad 4 shaved little by little during dressing with dresser 12. In the above-mentioned construction having a lot of projections 13, the chips clog the spaces between each projection, thereby to bring about a problem of degreasing the dressing performance.

[0017] Furthermore, it is difficult to maintain always a stable dressing performance, as it is difficult to estimate how much the wear of the hard film 14 proceeds with the passage of time and a criterion for use becomes unclear.

[0018] The Constitution of the dresser 11 is shown in a side sectional view illustrated in Fig.21 (a schematically illustrated view). A dresser 11 is attached to an arm 9 by the aid of a setting shaft 10 and on a dresser principal 11a connected to the setting shaft 10, there is formed a diamond-electrodepositing part 11d (an abrasive grain layer) including abrasive grains 11c, thereby to form a dressing-working face 15. The diamond-electro-depositing part 11d has the following construction: electroplating is carried out on a ground face positioned on the dresser principal 11a, whereby the abrasive grains 11c such as diamond, cBN or the like are fastened dispersedly on the ground face.

[0019] In the dresser 11, the dressing-working face 15 comprises the under surface of the diamond-electro-depositing part 11d (an abrasive grain layer). In Fig.21, the thickness of the diamond-electro-depositing part 11d and the size of abrasive grains are illustrated larger than actual ones so as to understand easily the shape of the dressing-working face 15.

[0020] If the dresser 11 contacts partially the polishing pad 4 during dressing the pad 4 with the dresser 11, the contact area of the dressing-working face 15 to the polishing pad 4 becomes small with the result that the dressing efficiency becomes lower and it takes a longer time to dress the pad than in unpartial contact cases, though the pad 4 can be dressed at any rate. Every time after polishing a wafer 6 has finished, the polishing pad 4 is dressed and it is carried out at every two and half to three minutes. Therefore, the working efficiency of polishing the wafer 6 becomes low when it takes a long time to dress the polishing pad 4.

[0021] Still further, when the dressing condition is unstable as mentioned above, the surface condition of the polishing pad varies widely and the polishing condition of the wafer 6 with the polishing pad 4 scatters. As the result, it becomes difficult to keep the rate of operation of CMP apparatus and the flatness of the wafer 6.

[0022] Because of the above-mentioned reasons, in order to stabilize the dressing condition, an arrangement is carried out such that the dressing-working face 15 is flat and the dressing-working face cross orthogonally the rotary axis of the dresser 11.

[0023] In a dresser having a prescribed shape formed by fixing abrasive grains by a binder, the above-mentioned arrangement is available by shaving the dressing-working face in the state that the dresser is attached to the setting shaft of a dressing apparatus 7 (this treatment is called "tooling"). However, the tooling can not be carried out in the case of an electrodeposited grindstone due to its own property.

[0024] Accordingly, in the case of using an electrodeposited grindstone for the dresser 11, it is necessary to increase the shape accuracy of the dresser principal 11a where the abrasive grain layer is formed and to increase the accuracy of attaching the dresser principal 11a to the setting shaft.

[0025] However, there are cases in the electrodeposited grindstone that the shape of the dresser principal 11a changes during the process of making thereof and the flatness of the dressing-working face 15 becomes inferior. The flatness of the dresser 11 is measured while contacing directly a dial gauge to the dressing-working face 15, and in the case of the electrodeposited grindstone, as the surface roughness of the dresser-working face is coarse which is a degree of #100, the measurement error is large and it is difficult to measure the flatness thereof accurately.

[0026] Further, there are cases during attaching the dresser 11 to the setting shaft that the dressing-working face 15 of the dresser 11 inclines against the rotary axis due to troubles such as an attaching error caused by a worker, dust interposed between the dresser 11 and the setting shaft, and so on. In order to detect the inclination, there is no way except measuring the deviation of the dressing-working face 15 while contacting directly the dial gauge to the dressing-working face, which has a problem in having a large measurement error. Therefore, it is difficult to obtain the attaching accuracy within a prescribed criterion.

[0027] In addition, as the polishing pad has a softness, it is difficult to detect the partial contact of the dresser 11 to the polishing pad 4 by observing the dressed state of the polishing pad 4, which is different from polishing materials having rigidity such as metal.

[0028] As mentioned above, it has been difficult to stabilize the dressing condition of the polishing pad 4 with the dresser 11.

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SUMMARY OF THE INVENTION

[0029] An object of the present invention is to provide a dresser which can be used economically and a dressing apparatus having the same.

[0030] In order to attain the above-mentioned object, the dresser of the present invention is one used for dressing a polishing pad for polishing materials to be polished and comprises a dresser principal, a dressing-working part which is provided as a body other than the dresser principal and a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

[0031] According to the dresser of the present invention, the dressing-working part can be attached and detached, and when a dressing performance thereof degreases due to reasons such as the wear of the dressing-working part, the dressing-working part is exchanged for a new one to recover the dressing performance. In this way, the dressing performance can be recovered only by exchanging a dressing-working part, thereby to degrease a cost for a dresser.

[0032] Another object of the present invention is to provide a dresser which enables a vibration hardly to take place, and which enables to suppress the vibration within a short time if the vibration takes place, and is to provide a dressing apparatus having the same.

[0033] In order to attain the above-mentioned object, the dresser of the present invention is one used for dressing a polishing pad for polishing materials to be polished and comprises a plurality of dressing-working parts which are disposed at unequal spaces in the circular direction of a dresser principal.

[0034] According to the dresser of the present invention, the dressing-working parts are disposed at unequal spaces in the circular direction of the dresser principal, whereby forces which cause the vibration of the dresser are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser.

[0035] As the result, a vibration hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0036] The interval between each dressing-working part can be decided by any way and for example, can be decided by using random numbers.

[0037] As another way, the interval can be unequal by arranging positions in such a manner that positions are designated as a standard position in the case of disposing dressing-working parts at an equal space each other, and each position is deviated from each standard position to the circular direction. In this case, the deviation of each dressing-working part from the corresponding standard position can be decided by using the random numbers or, for example, can be decided by designating as a starting point any position among each standard position, designating as θ an angle between the starting point and each standard position when looked from the center of axis, and specifying $x=\sin\theta$ as the deviation x of each dressing-working part from each standard position (or $x=\cos\theta$).

[0038] In the above-mentioned ways, when the deviation is too large, dressing-working parts having the too large deviation have a life shorter than the other dressing-working parts as a result of dressing more amount of a polishing pad. In contrast, when the deviation is too small, an effect on suppressing a resonance is lowered. Therefore, the deviation value is preferably by the absolute value within 10 to 30% of an interval between the corresponding standard positions.

[0039] The dresser is rotated in a position having an eccentric relation with the polishing pad, and the speed of the dresser relative to the polishing pad is lower in half a range of the circular direction (an inward peripheral side or an outward peripheral side of the polishing pad when looked from the center of axis of the dresser) than in the other half range and a load imposed on the dressing-working part is small. Therefore, it is estimated that the vibration of the dresser is hardly caused by a force imposed on a side which has a lower speed relative to the polishing pad. That is, dressing-working parts can be provided which are disposed in a same pattern every half a round.

[0040] A further object of the present invention is to provide a dresser which enables to always maintain an excellent dressing performance and can be used economically.

[0041] In order to attain the above-mentioned object, the dresser of the present invention is applied to an equipment which is used for polishing materials to be polished having a flat surface such as semiconductor wafer with a dressing pad, and is a dresser used for dressing the surface of the polishing pad, and is characterized by the following construction: the cutters are arranged in such a manner that the cutters are projected from the under surface of a dresser principal; the polishing pad surface is shaved by moving the edge of cutter which is a movement relative to and parallel to the polishing pad surface while the edge of the cutter is pressed against the polishing pad surface.

[0042] As the dressing pad is shaved with a cutter in the dresser of the present invention, the dresser is protected from the lowering of the dressing performance which is caused by clogging of the polishing pad with the shaved chips of the dressing pad in between abrasive grains, as compared with the conventional one, whereby a stable dressing performance is available. In addition, as an amount of wear can be decided from the flank of the cutter, a criterion for use is clear as compared with the conventional one, thereby to enable to maintain easily the dressing performance. Further, as a cutter is used, reusing the cutter is possible, which is different from the conventional one, with result of providing excellence in a cost for the dresser.

[0043] Still further object of the present invention is

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to provide a dresser wherein the polishing condition of the polishing pad can be stabilized.

[0044] In order to attain the above-mentioned object, the dresser of the present invention comprises: a dressing-working face formed by providing an abrasive grain layer including abrasive grains on the surface of a dresser principal, wherein the dresser principal comprises a ground face on which the abrasive grain layer is provided and a basic face which is disposed in a portion of the dresser principal more inward than the ground face and is formed in parallel to the ground face.

[0045] In the dresser of the present invention, as the basic face of the dresser principal is a plane parallel to the ground face, it is possible to predict the flatness of the ground face having the abrasive-grain layer formed thereon, that is, the flatness of the dressing-working face, by measuring the flatness of the basic face, whereby dressers can be selected which have a good flatness with regard to a dressing-working face.

[0046] In addition, when the dresser is attached to the dressing apparatus, the attaching situation can be confirmed according to the basic face as a basis, as the basic face is a plane parallel to the ground face.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047]

Fig.1 is a plan view illustrating the under surface of the dresser of Example 1 of the present invention.

Fig.2 is a sectional view looking in the direction of the arrows A-A in the Fig.1.

Fig.3 (a) is a side sectional view showing another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.3 (b) is an end surface view showing another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.4 (a) is a side sectional view showing a further embodiment of the dresser-working part used in the dresser of Example 1.

Fig.4 (b) is a side sectional view showing still another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.5 is a side sectional view illustrating another construction of the dresser in Example 1 of the present invention.

Fig.6 is an under surface view illustrating the shape of the dresser in Example 2 of the present invention.

Fig.7 (a) is a side sectional view illustrating the shape of the dresser in Example 2 of the present invention.

Fig.7 (b) is a side sectional view illustrating another shape of the dresser in Example 2 of the present invention.

Fig.8 is an under surface view illustrating the shape of the dresser in Example 3 of the present invention.

Fig.9 is a schematic view illustrating the dresser of Example 4 of the present invention, which is an enlarged side view of the important part of the dresser principal.

Fig.10 is a schematic view illustrating the dresser of Example 4 of the present invention, which is an under surface view of the dresser principal.

Fig.11 is a schematic view illustrating the dresser of Example 4 of the present invention, which is a side sectional view of the dresser principal.

Fig. 12 is an enlarged side view of a cutter used in the dresser shown in Figs.9 to 11.

Fig.13 is an enlarged under surface view of the cutter used in the dresser shown in Figs.9 to 11.

Fig.14 is a plan view showing a positional relationship between the dresser principal shown in Fig.9 to 13 and a platen to which a polishing pad is attached, when dressing is carried out.

Fig.15 is an enlarged side sectional view showing another embodiment of the cutter used in the dresser of Example 4.

Fig. 16 is a side sectional view illustrating the constitution and construction of the dresser in Example 5 of the present invention.

Fig.17 is an enlarged perspective view of the important part of the conventional polishing equipment and dressing apparatus, which is illustrating the schematic constitutions thereof.

Fig.18 (a) is a side sectional view illustrating the shape of the conventional dresser.

Fig. 18 (b) is a partially enlarged side sectional view of Fig. 18 (a).

Fig.19 is a plan view showing the under surface of the conventional dresser.

Fig.20 is an enlarged side sectional view of an important part illustrating the shape of the conventional dresser.

Fig.21 is a side sectional view illustrating the constitution and construction of the conventional dresser.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0048] The dresser of the present invention and the dressing apparatus having the same are described in detail hereunder.

[0049] Fig.1 is a plan view illustrating the under surface of the dresser of Example 1 of the present invention. Fig.2 is a sectional view looking in the direction of the arrows A-A in the Fig.1.

[0050] The dressing apparatus of the present invention comprises a constitution almost similar to that of, for example, a dressing apparatus 7 shown Fig.17, and a dresser 21 of the present invention is used as a dresser in place of a dresser 11.

[0051] The dresser 21 of the present invention comprises a dresser principal 22 having an approximately circular shape and a plurality of dressing-working parts

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23 disposed in the circular direction in the under surface of the outer peripheral portion of the dresser principal 22. The dresser-working parts 23 which are provided as bodies other than the dresser principal 22 are arranged and are held to the dresser 22 by a means mentioned after in such a manner that the dresser-working parts 23 can be attached to and detached from the dresser principal 22. The number and disposition of the dressing-working parts 23 shown in Fig.1 is only an example. The dressing-working parts 23 can be disposed at equal spaces in the circular direction of the dresser principal or at irregular spaces in the circular direction. The dressing-working parts 23 can be arranged in a plurality of lines in the circular direction of the dresser principal 22, which is similar to that of the conventional dresser.

[0052] In the present example, the dresser principal 22 is composed of an approximately circular shape having an opening in the center thereof.

[0053] As shown in Fig.2, the dressing-working part 23 is composed of a member having an approximately pin-like shape. A receiving hole 26 for receiving a part of the dressing-working part 23 is formed from the under surface 22a to a predetermined depth in the dresser principal 22. In the dresser principal 22, a tapped hole 27 is formed which leads to the intermediate position of the receiving hole 26 from the outer periphery 22b thereof. In the tapped hole 27, a clamp screw 28 is screwed such that the end of the clamp screw can be advanced and retreated in the receiving hole 26.

[0054] The dressing-working part 23 is fixed in the receiving hole 26 by pressing the side of dressing-working part 23 received in the receiving hole 26 to the inner wall of the receiving hole with the end of the clamp screw 28 and is released from being fixed by releasing the pressing of dressing-working part 23 with the end of the clamp screw.

[0055] The present example comprises a holding means which hold dressing-working part 23 to the dresser principal 22 in such a manner that the dressing-working part 23 can be attached to and detached from the dresser principal 22 by the receiving hole 26, the tapped hole 27 and the clamp screw 28.

[0056] Here, in the present example, the receiving hole 26 is approximately parallel to the axis of the dresser principal 22 and the bottom surface thereof is a plane which approximately crosses orthogonally the axis of the dresser principal 22.

[0057] As shown in Fig.2, the dressing-working part 23 is a cutter having approximately a pin-like shape, and comprises a base 23a having an approximately columnar shape and a cutting edge 23b formed in the end of the base 23a.

[0058] The base 23a is received in the receiving hole 26 of the dresser 22 and the side of the base is subjected to the pressure given by the clamp screw 28. A position-adjusting screw hole 31 is formed in the base 23a, which has a prescribed depth along the axis from the end face of the base.

[0059] A position-adjusting screw 32 is screw-clamped to the position-adjusting screw hole 31 and an amount of projection of the position-adjusting screw 32 from the base 23a can be adjusted by controlling a screwed length to the position-adjusting screw hole 31.

[0060] The upper surface of the head of the position-adjusting screw 32 is pressed against the bottom surface of the receiving hole 26 when the dressing-working part 23 is received in the receiving hole 26. An amount of projection of the dressing-working part 23 from the receiving hole 26, that is, an amount of projection of the dressing-working part 23 from the dresser principal 22 can be adjusted by controlling an amount of projection of the position-adjusting screw 32 from the base 23a. In the present example, the upper surface of the head of the position-adjusting screw 32 is a plane crossing approximately orthogonally to the axis thereof.

[0061] Further, a fixing nut 33 is screw-clamped to the position-adjusting screw 32 which is positioned on the position-adjusting screw hole 31. The position-adjusting screw 32 is fixed in a state projected at any distance from the base 23a by screwing the fixing nut toward the edge of the position-adjusting screw 32 while pressed against the base 23a.

[0062] The present example comprises a projection adjusting means having the position-adjusting screw hole 31, the position-adjusting screw 32 and the fixing nut 33 for controlling an amount of projection of the dresser-working part 23 from the dresser principal 22.

[0063] The cutting edge portion 23b of the dressing-working part 23 comprises: a flank 36 which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face 37 comprising a cicumferential surface in the end portion of the cutter; and a cutting edge 38 which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion of the cutter. Namely, the cutting edge portion 23b has a nearly Japanese soup cup-like shape.

[0064] Here, ceramics, diamond, cBN and the like can be used for the cutting edge 38, and the surface of the cutting edge portion 23b can be covered by a hard film comprising hard materials such as diamond or the like.

[0065] Almost in the same manner as in the dressing apparatus shown in Fig. 17, the surface of a polishing pad 4 is dressed by the dressing apparatus of the present invention, which comprises the steps of: oscillating a dresser 21 while the dresser 21 is pressed against the surface of the polishing pad 4; rotating of the dresser owing to a friction force caused by friction with the polishing pad 4 or rotating the dresser by driving by a drive unit which is not shown in Figs while the dresser 21 is pressed against the surface of the polishing pad.

[0066] In the dresser 21, the surface of the polishing pad 4 is shaved little by little by the dresser 21 by providing to the dresser a relative movement to a direction parallel to the polishing pad 4, while the cutting edge 38 of the dressing-working part 23 is pressed

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against the surface of the polishing pad 4.

[0067] As an amount of projection of the dressing-working part 23 from the dresser principal 22 can be adjusted, the dressing performance of the dresser 21 is controlled by adjusting the depth of cut of the dressing-working part 23 into the dressing pad 4 according to the material and hardness of the dressing pad.

[0068] The dressing apparatus of the present invention can be composed of a constitution other than the above-mentioned one, in which the dresser 21 is connected to an arm 9 through a ball bearing, and the dresser can freely be inclined according to the surface of the polishing pad 4. In this case, in the dressing apparatus, the dresser is pressed against the dressing pad 4 by the dead weight thereof or by a force obtained by pressing the arm 9, and a depth of cut of the dressing-working part 23 into the polishing pad 4 is adjusted by controlling an amount of force of the pressing.

[0069] Adjusting an amount of projection of the dressing-working part 23 is carried out as follows: first, an amount of the position-adjusting screw 32 from the base 23a is adjusted by turning round the position-adjusting screw 32 which is screw-clamped to the base 23a to any of two directions in the state of detaching the dressing-working part 23 from the dresser principal 22 and the position-adjusting screw 32 is fixed to the base 23a by the fixing nut 33; then, the dressing-working part 23 is inserted into the receiving hole 26 of the dresser principal 22 and the clamp screw 28 is driven and tightened which is screw-clamped to the tapped hole 27, whereby the dressing-working part 23 is fixed in such a state that the cutting edge 38 of the dressing-working part 23 is projected from the under surface 22a of the dresser principal 22 by a prescribed amount.

[0070] In addition, as the dressing-working part 23 has the cutting edge 38 in the whole round thereof, the shaving of the polishing pad 4 can be carried out for any direction thereto, thereby to enable to increase a dressing performance.

[0071] And, as the dressing-working part 23 is a cutter, the dressing performance can be recovered by repolishing the cutter edge 38 when the dressing performance degreases, thereby to enable to lower a cost for the dresser.

[0072] Furthermore, though shaved chips generate due to shaving a little the polishing pad 4, the polishing pad 4 is hardly clogged with the shaved chips, which is different from a dresser having a dressing-working part comprising an abrasive grain layer and projections, thereby to obtain a stable dressing performance.

[0073] Still further, as the dressing performance can be judged from an amount of wear of the cutting edge 38 to clear a criterion for use, the stable dressing performance can always be obtained.

[0074] Yet further, there is no fear to scratch the surfaces of materials to be polished due the dropping of abrasive grains, as the abrasive grains are not used in the dressing-working part 23.

[0075] Still furthermore, if a dressing performance lowers due to reasons such as the wear of the dressing-working part 23, the dressing performance can be recovered by exchanging only the dressing-working part 23, thereby to enable to decrease a cost for a dresser.

[0076] The example is exemplified by a case wherein the dressing-working part 23 is used which comprises a cutting edge portion 23b having a Japanese soup cup-like shape and the example is not limited to the case. For another example, a dressing-working part 39 can be used which has a plurality of projections in the end thereof as shown in Fig.3 (a) of a side sectional view and Fig.3 (b) of an end surface view. The projection 40 of a dressing-working part 39 has a cross section approximately equal to an end face 40a from one end of the projection to near another end of the projection from which the projection is started and a cutting edge 40b is provided by a ridgeline formed by crossing of the end face 40a and the side surface of the projection. The projections are disposed in any way, regularly or irregularly. In addition, any shape can be provided to the end face 40a of the projection 40, for examples, the end face 40a can be nearly circular (the projection 40 is approximately columnar) or can be a polygon (the projection 40 is a square pillar having a polygonal section).

[0077] Further, ceramics, diamond, cBN and the like can be used for the cutting edge 40b, and the surface of the cutting edge 40b can be covered by a hard film comprising hard materials such as diamond.

[0078] In the dressing-working part 39 formed as mentioned above, the surface of the polishing pad 4 is dressed by the cutting edge 40b of each projection 40. Here, as the cutting edge 40b is formed in the wholly around of each projection 40, the polishing pad 4 can be dressed from any direction. The projection 40 has a cross section approximately equal to an end face 40a from one end of the projection to near another end of the projection from which the projection is started and the change of shape and area of the end face 40a is small when the projection 40 wears with the result that the dressing performance hardly changes and the stable dressing performance can be obtained.

[0079] Further, for example, as shown in Fig.4 (a) of a side sectional view, a dressing-working part 41 can be used which has a cutting edge 42 having a cutting edge portion 41b directed to one direction of the circular direction of dressing-working part. Here, ceramics, diamond, cBN and the like can be used for the cutting edge 42 and the surface of the cutting edge portion 41b can be covered by a hard film comprising hard materials such as diamond.

[0080] In addition, the polishing pad can be shaved from any direction, as a whole dresser, by providing to the dressing-working part 41 the cutting edges 42 which are directed in various directions each other.

[0081] Further, a dressing-working part 43 can be used as a dressing-working part, which comprises a grindstone 44 in the end of the base 43a which is

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approximately columnar as shown in Fig.4 (b). In this case, the grindstone 44 can be a grindstone which is conventionally used for dressing the polishing pad 4, for examples, can be a grindstone formed by an abrasive grain layer prepared by electrodepositing abrasive grains such as diamond or can be a metal bonded grindstone.

[0082] Further, a means for controlling an amount of projection can be composed of a constitution other than the above-mentioned one, in which a bolt inserting hole 29 leading to the upper surface of the dresser principal 22 is formed in the bottom face of a receiving hole 26 as shown in Fig.5 of a side sectional view and a position-adjusting screw 32 is inserted into the bolt inserting hole 29 from the upper surface of the dresser principal 22 and screw-clamped to a position-adjusting screw hole 31 (a fixing nut becomes unnecessary). Here, the position adjusting screw 32 is attached to the dresser principal 22 in such a manner that the screw is possible to turn around an axis while the head of the screw is received in the bolt inserting hole 29. When a means for controlling an amount of projection is provided as mentioned above, as the dressing-working part 23 can be moved along the position adjusting screw 32 by handling the position adjusting screw 32 in the state of attaching the dresser-working part 23 to the dresser principal 22, an amount of projection of the dressing-working part 23 can be controlled without detaching the dressing-working part 23 from the dresser principal 22.

Example 2:

[0083] The dresser of Example 2 of the present invention and the dressing apparatus having the same are described in detail hereunder, referring to Figs.

[0084] Fig.6 is an under surface view illustrating the shape of the dresser of Example 2. Fig.7 is a side sectional view illustrating the dresser.

[0085] The dressing apparatus of the present invention comprises a constitution almost similar to that of a dressing apparatus 7 shown Fig. 17, and the dresser 51 of the present invention is used as a dresser in place of a dresser 11.

[0086] A dresser 51 of the present invention comprises a dresser principal 52 having an approximately circular shape and a plurality of dressing-working parts B disposed in the circular direction in the under surface of the outer peripheral portion of the dresser principal 52. The dresser principal 22 of the present invention is composed of a shape having an opening in the center thereof in the same manner as in the conventional dresser. The dresser-working parts B are provided as bodies other than the dresser principal 52 and are fixed to the dresser principal 52 by, for examples, brazing, a clamp method, a blade method and so on.

[0087] In the present example, the dressing-working parts are members having a approximately pin-like shape.

[0088] The dressing-working parts B are disposed at unequal spaces in the circular direction of the dresser principal 52. A space between each dressing-working part B is decided by any way. In the present example, the positions in the case of disposing dressing-working parts B at equal spaces are designated as a standard position P and any one among the standard positions is designated as a starting point P_0 and an angle between each standard position P and the starting point P_0 when looked from the center of axis O of the dresser 52 is designated as θ , and $x=\sin\theta$ is specified as a deviation x of each dressing-working part B from each standard position P. Here, in Fig.6, accompanied characters are provided to standard positions P (and a dressing-working part B, angle θ and an amount of deviation x corresponding to each standard position P), in a counterclockwise order starting from the starting point P_0.

[0089] In the above-mentioned way, when the deviation x of a dressing-working part B from the corresponding standard position P is too large, a distance becomes large which is between one dressing-working part B and another dressing-working part B next to the former dressing-working part. In this case, the life of the dressing-working parts B become shorter as an amount of dressing of the polishing pad 4 carried out by the dressing-parts B becomes always too much as compared with the other dressing-working parts B. In contrast, when the deviation is too small, an effect on suppressing a resonance is lowered. Therefore, a deviation value of each dressing working part B from the corresponding standard position P is preferable by the absolute value within 10 to 30% of a space H between standard positions P.

[0090] The dressing-working part is approximately pin-like and can comprise any construction such as a dressing-working part having a diamond-electro-deposited part formed by electrodepositing abrasive grains such as diamond in the end which is directed to the under surface side of the dresser principal 52 or a dressing-working part having a cutter having a cutting edge formed in the end which is directed to the under surface side of the dresser principal 52 if dressing the polishing pad 4 is possible.

[0091] In the present example, as shown in Fig.7 (a), there is provided to the dresser principal 52 a receiving hole 56 having a prescribed depth from an under surface 52a and there is provided thereto a tapped hole 57 which leads to the intermediate position of the receiving hole 56 from the outer periphery 52b of the dresser principal 52 and to which a clamp screw 58 is clamped. The dressing-working part B is fixed to the receiving hole 56 by the following mechanism: the side thereof is pressed by the clamp screw 58 which is screw-clamped to the tapped hole 57, whereby the dressing-working part B is fixed to the receiving hole 56. And, as shown in Fig.7 (a), in the dressing-working part B, a position-adjusting screw hole 59 having a prescribed depth is formed along an axis from the end face

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of the base end thereof and a position-adjusting screw 60 is screw-clamped to the position-adjusting screw hole 59. An amount of projection of the dressing-working part B from the base end can be controlled by controlling a screw-clamping length of the position-adjusting screw 60 to the position-adjusting screw hole 59, and the upper face of head of the position adjusting screw 60 can be contacted to the bottom face of the receiving hole 56 when the dressing-working B is received in the receiving hole 56. Here, an amount of projection of the dressing-working part B from the receiving hole 56, that is, an amount of projection of the dressing working part B from the under surface 52a of the dresser principal 52a can be controlled by adjusting an amount of projection of the position-adjusting screw 60 from of the base end of the dressing-working part B.

[0092] In the present example, the dressing-working part B is a cutter having approximately a pin-like shape. A cutting edge portion 54 formed in one end of the cutter comprises: a flank 54a which is formed by concaving the end face of the cutting edge portion toward the base end of the cutter; a rake face 54b comprising a circumferential surface in the end portion of the cutting edge portion; and a cutting edge 54c which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion. Namely, the cutting edge 54 has a nearly Japanese soup cup-like shape and whole the round of the edge makes it possible to shave the polishing pad 4.

[0093] For example, as shown in Fig.7 (b) of a side sectional view, the dresser 51 can be composed of a constitution other than the above-mentioned one, in which a bolt inserting hole 53 is formed in the dresser principal 52 from the bottom face of a receiving hole 56 to the upper surface of the dresser principal 52 and a position-adjusting screw 60 is inserted into the bolt inserting hole 53 from the upper side of the dresser principal 52, thereby to screw-clamped the screw to a position adjusting screw hole 59. In this case, the position-adjusting screw 60 is attached to the dresser principal 52 in such a manner that the screw is possible to turn around an axis while the head of the screw is received in the bolt inserting hole 53. When the dresser 51 is constituted as mentioned above, as the dressing-working part B can be moved along the position adjusting screw 60 by handling the position-adjusting screw 60 in the state of attaching the dresser-working part B to the dresser principal 52, an amount of projection of the dressing-working part B can be controlled without detaching the dressing-working part B from the dresser principal 52.

[0094] Dressing the polishing pad 4 by using a dressing apparatus having the dresser 51 constructed as mentioned above is carried out in the same manner as in the conventional dressing apparatus.

[0095] In the present example, as the dressing-working parts B are disposed at unequal spaces in the circular direction of the dresser principal 52, forces which cause the vibration of the dresser 51 are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser 51.

[0096] Thus, according to the dresser 51 of the present invention and the dressing apparatus having the same, the vibration of the dresser 51 hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0097] The number and disposition of arranged dressing-parts B are not limited to the example shown in Fig.6 and any embodiment is available as long as the dressing-working parts B are disposed at unequal spaces in the circular direction of a dresser principal 52.

Example 3:

[0098] The dresser of Example 3 of the present invention and the dressing apparatus having the same are described in detail hereunder, referring to Fig.8 showing an under surface view.

[0099] A dresser 61 of the present example comprises a dresser principal 62 having an approximately circular shape and a dressing-working part C comprising a grindstone disposed along the circular direction in the under surface of the outer peripheral portion of the dresser principal 62.

[0100] Nicks N are provided to the dressing-working part C by forming a plurality of notches at unequal spaces in the circular direction of the dresser principal 62.

[0101] The arrangement of the nicks N can be decided in the same manner as in the dressing-working parts of Example 2. In the present example, the positions in the case of disposing dressing-working parts C at equal spaces are designated as a standard position P, and any one among the standard positions P is designated as a starting point P_0, and an angle between each standard position and the starting point when looked from the center of axis of the dresser principal 62 is designated as θ , and $x=\sin\theta$ is specified as a deviation x of each dressing-working part C from each standard position P. Here, in Fig.8, accompanied characters are provided to standard positions P (and a dressing-working part C, nick N, angle θ and an amount of deviation x corresponding to each standard position P), in a counterclockwise order starting from the starting point P_0.

[0102] Dressing a polishing pad 4 is carried out in the thus-constituted dresser 61 and a dressing apparatus having the same, in the same manner as in the dresser 51 of Example 2 and the dressing apparatus having the same.

[0103] In this example, as the nicks N are disposed at unequal spaces in the circular direction of the dresser principal 62, forces which cause the vibration of the dresser 61 are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser 61.

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[0104] Thus, according to the dresser 61 of the present invention and the dressing apparatus having the same, the vibration of the dresser 61 hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0105] The number and disposition of arranged nicks N are not limited to the example shown in Fig.8 and any embodiment is available as long as the nicks are disposed at unequal spaces in the circular direction of a dresser principal 62.

Example 4:

[0106] Example 4 of the present invention is described in detail hereunder, referring to Figs.

[0107] Fig.10 and 11 are schematically illustrating the present example. In the Figs., symbol 71 shows a dresser.

[0108] As shown in the Figs., the dresser 71 comprises a plurality f cutters 75 disposed at a prescribed spaces in the circular direction of a dresser principal 72, in a peripheral edge portion 74 of an under surface 73 of the dresser principal 72 having a circular shape.

[0109] The cutters 75 are arranged in the state that the cutter is projected from the under surface73 of the dresser principal 72 as shown in Fig.9 of an enlarged view (a view illustrating the vicinity of the cutter 75 when looked from a p direction in Fig.11). As further enlarged in Fig.12, the cutter 75 comprises an edge of cutter 76 having a flat surface 77 parallel to a polishing pad surface to be dressed (not show in Figs.). The width of the flat surface (a land width:1) is 0.001 to 0.5mm.

[0110] The rake angle D of the cutter 75 is 10° and the clearance angle E thereof is also 10°. The edge of cutter 76 of the cutter 75 is arranged in such a manner having a -15° of an inclined angle α, wherein, as shown in Fig.13, the inclined angle is defined as an angle of the edge of the cutter 76 inclined from a straight line L1 passing through an edge of end 76a in the edge of cutter 76 at the center side of the dresser principal 72 (not shown in the Fig.) and the center of the dresser principal 72 (not shown in the Fig.), and a movement direction of the cutter 75 relative to the polishing pad, that is, a rotational direction of the dresser principal 72 (mentioned after) is defined as positive (a q direction in Fig.13). In addition, nicks 78 are provide to the edge of cutter 76 of the cutter 75 as shown in Fig.13.

[0111] Hard materials such as diamond having a single crystal, cBN, sintered compact produced under a high pressure such as polycrystalline diamond, and materials coated by hard materials as mentioned above are used for the edge of cutter 76.

[0112] When a polishing pad is dressed by using the dresser 71, the polishing pad is shaved by the cutter 75 by rotating a platen 79 having the polishing pad attached thereto to an h direction in the Fig.14 and rotating the dresser principal 72 to an i direction in the Fig.14 while pressing the under surface of the dresser principal 72 in such a manner that the flat surface 77 of the cutter 75 is pressed against the under surface of the dresser principal 72, thereby to dress the upper surface of the polishing pad. Here, the i direction is a movement direction of the cutter 75 mentioned above relative to the polishing pad (a q direction in Fig.13).

[0113] In the above-mentioned dresser 71, as the shaving of the polishing pad surface is carried out by providing to the edge of cutter 76 of the cutter 75 a movement relative to the polishing pad in a direction parallel to the polishing pad surface while the edge of cutter 76 is pressed against the polishing pad surface, the dresser is protected from the lowering of the dressing performance thereof which is caused by clogging of the polishing pad surface with the shaved chips in between abrasive grains, as compared with the conventional one, whereby a stable dressing performance is available. Further, as the polishing pad is shaved by using the cutter 75 as mentioned above, an amount of wear can be decided from the flank of the cutter 75 with result that the criterion for use is clear as compared with the conventional one, thereby to enable always to maintain easily a stable dressing performance. Furthermore, as the cutter 75 is used, reusing a cutter 75 which has worn is possible, which is different from the conventional one, with the result of providing excellence in a cost for the dresser.

[0114] In the dresser 71, as the flat surface 77 is formed in the edge of cutter 76 of the cutter 75, the edge of cutter 76 of the cutter 75 is disposed always at a settled position to the polishing pad without causing the vibration of the edge of cutter 76 of the cutter 75 when the dresser principal 72 is pressed against the polishing pad surface, whereby the flatness of the polishing pad can be obtained and in its turn, the polished performance of materials to polished such as semiconductor wafer can be increased.

[0115] Still further, in the dresser 71, the shaved chips of the polishing pad and the residues of slurries left in the polishing pad which have generated in polishing materials to be polished by methods such as a CMP method can be scooped up by the cutter 75 owing to providing a positive angle to a rake angle D of the cutter 75, whereby the dressing performance can be increased and the polishing pad can be easily cleaned.

[0116] In addition, in the dresser 71, the edge of cutter 76 of the cutter 75 is arranged in such a manner having a negative angle wherein a rotational direction of the dresser principal 72 (a q direction in Fig.13) is defined as positive to a straight line L1 passing through an edge of end 76a at the center side of the dresser principal 72 (not shown in the Fig.) and the center of the dresser principal 72. In such a construction, as a normal line L2 (refer to Fig.13) of the rank face 80 of the cutter 75 (refer to Figs.12 and 13) is always directed to the outward of the dresser principal, the shaved chips of the polishing pad scraped away and the residues left in the polishing pad of slurries which have generated in polish-

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ing materials to be polished by the CMP are scraped out by the edge of cutter 76 from the center side of the dresser 72 to the outward thereof. As mentioned above, as the shaved chips of the polishing pad and the residues of slurries left in the polishing pad which have generated in polishing materials to be polished by the CMP are scraped out to the outside by the cutter 75, the polishing pad can easily be cleaned.

[0117] It is to be understood that, within the spirit of the present invention, designs may be practiced otherwise than as specifically described in the present example.

[0118] For example, the rake angle D can be from -20 to 30°. Specifically, in case where channels having a embossed pattern or a latticed pattern are provide to the polishing pad, the rake angle D is preferably a negative angle such that the side wall of the channel can not be shaved off. In case where the polishing pad is too soft, a negative rake angle is also effective as the rake angle D in order to protect the polishing pad from an excessive shaving.

[0119] Further, in case where the rake angle D is from -5° to -15° , the mechanical strength of the cutter 75 can be ensured and it is useful for cases which require the strength of an edge of cutter.

[0120] Further, a width of land 1 can be within the range of 0.005 to 0.5mm and is preferably from 0.05 to 0.1mm. Further, the clearance angle can be from 3° to 15°. An amount of biting depth of the cutter to the polishing pad can be controlled by adjusting an amount of clearance angle E and a width of flank, as mentioned above. Thereby, an optimum shape can be adopted according to the materials and hardness of the polishing pads. Further, the angle α of inclination of the edge of cutter 76 of the cutter 75 can be within the rage of -10 to -30°. In addition, a construction is possible which has no nick 78.

[0121] Further, the edge of cutter 76 can be selected according to the materials of polishing pads to be dressed and slurry materials used in polishing materials to polished by a CMP method. With regard to a method for attaching the edge of cutter 75, brazing, a clamp method, a blade method and so on can be used.

[0122] Further, the clearance angle of the cutter 75 can comprise two steps as in shown in Fig.15 (for example, α 1=5° , β=15° ,in Fig.15). In this case, an amount of biting depth of the cutter 75 to the polishing pad is controlled by adjusting the clearance angle and the width of the first flank W, thereby to enable to obtain a pertinent dressing rate.

Example 5:

[0123] The dresser 81 of Example 5 of the present invention is described in detail hereunder, referring to Fig.16. The same symbols are provided to the same parts as those of the conventional dresser 11 described in the related art and the description thereon is omitted.

[0124] A dresser 81 is attached to an arm 9 of a dressing apparatus 7 by the aid of a setting shaft 82 in a CPM apparatus 1 shown in Fig.17, in the same manner as in the dresser 11.

[0125] Here, with regard to the setting shaft 82, one end of the setting shaft directed to a rotary shaft is connected to a drive unit (not shown in Figs.) by the aid of the arm and the setting shaft 82 is rotated around the rotary shaft. In the other end thereof, a flange 84 is formed for fixing the dresser 81 (refer to Fig.16 illustrating a side sectional view). In the flange 84, a plurality of bolt inserting holes 86 for bolts 85 for screw-clamping the dresser 81 to the flange 84 are disposed at appropriate spaces in the circular direction thereof (only one portion is illustrated in Fig. 16). Hereunder, in the present specification, the side of the dresser 81 contacting to the setting shaft 82 is defined as the upper side thereof and another side of the dresser 81 where a dressing-working part 15 is formed is defined as the lower side thereof.

[0126] The dresser 81 is an electrodeposited grindstone having a dressing-working face 15 formed by providing an abrasive grain layer 93 including abrasive grains 93 on the surface of a dresser principal 83 having a approximately annular shape, as shown in Fig.16, and the dresser is fixed to the setting shaft 82 while, the center of the dresser is matched with the center of the setting shaft 82.

[0127] The material of the dresser principal 83 comprises aluminum, stainless steel, steel or a combination of aluminum and steel and the section thereof is approximately a rectangle. A convex 87 of the outer peripheral side which is projected at the outer peripheral side of the under surface of the dresser principal 83 toward the lower side is formed all around the periphery, and the under surface of the convex 87 comprises a ground face 88 having an abrasive grain layer 93 formed thereon. The ground face is formed in such a manner that the face thereof is orthogonally crossed to a rotary axis AX of the dresser principal 83. In Fig.16, the thickness of the abrasive grain layer 93 is illustrated larger than the actual one so as to easily understand the shape of the dressing-working face 15.

[0128] A convex 89 of the inward peripheral side having an amount of projection to the lower side smaller than that of the convex 87 of the outer peripheral side is formed in a position closer to the center of rotation than the convex 87 of the outer peripheral side in such a manner that the convex 89 is concentric with the convex 87 and the under surface of the convex 89 comprises a basic face 90 which is parallel to the ground face 88. A recess 92 is formed between the convex 87 and the convex 89 so as to obtain the working accuracy thereof. A plurality of holes for bolt 91 for screw-clamping the bolts 85 are formed at appropriate spaces in the upper face of the dresser principal 83 all around the periphery (only one portion is illustrated in Fig.16).

[0129] Here, the dresser principal 83 is screw-

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clamped to the under surface of the flange 84 of the setting shaft 82 by screw-clamping the bolts 85 to the holes for bolt 91.

[0130] When the dressing of a polishing pad 4 is carried out with the dresser 81 constructed as mentioned above, the following operations are carried out so as to stabilize conditions for dressing the polishing pad 4.

[0131] First, dressers 81 are checked on whether or not a dresser 81 has a flatness of the dressing-working face 15 within a range which is proper to a use for the dressing apparatus 7, and dressers 81 are selected which have the proper flatness.

[0132] The flatness of a dressing-working face 15 can be predicted by inspecting the flatness of the ground face 88 for forming the dressing-working face 15, and the flatness of the ground face 88 can be predicted by inspecting the flatness of the basic face 90 parallel to the ground face 88.

[0133] Namely, if the flatness of a basic face 90 is within the range proper for a use in the dressing apparatus 7, the flatness of the corresponding ground face 88 and dressing-working face 15 can be predicted to be also within the range proper for the use, thereby to select dressers 81 which have the flatness of a basic face which is within the range proper for the use and to use the selected dressers.

[0134] Next, a dresser 81 which has been confirmed to have a flatness within the proper range is attached to the under surface of the flange 84 of the setting shaft 82 by the bolts 85.

[0135] Then, the deflection of the basic face 90 of the dresser 81 is measured with dial gauge, while rotating the setting shaft 82 together with the dresser 81 by a drive unit which is not shown in Figs., and the setting condition of the dresser is adjusted so as to attain a deflection having a proper range.

[0136] When the deflection is not within the proper range, it is considered as a reason that dust is contained in between the setting shaft 82 and the dresser 81, together with another reason due to an error in attaching the setting shaft 82. If the dust problem is considered, the dresser 81 is detached from the setting shaft 82 to confirm whether or not the dust is interposed in between. When the dust is interposed, the dust is removed, followed by attaching again the dresser 81 to the setting shaft 82.

[0137] According to the thus constructed dresser 81, as a ground face 88 having a dressing-working face 15 formed thereon can be predicted whether to be flat or not, dressers having a good flatness of the dressing-working face can be selected and used.

[0138] Further, the condition of attaching a dresser 81 to the setting shaft 82 of the dressing apparatus 7 is confirmed whether to be proper or not, the accuracy of attaching to the dressing apparatus 7 can be increased.

[0139] Thereby, the condition of dressing a polishing pad 4 with the dresser 81 can be stabilized.

[0140] Furthermore, as the basic face 90 is disposed in a position closer to the center of rotation as mentioned above than the ground face 88, that is, at the inward peripheral side of the dresser principal 83, a possibility of damaging the basic face 90 due to hitting the basic face 90 against something is decreased during delivering the dresser 81 or attaching the dresser 81 to the dressing apparatus 7, thereby to ensure an accuracy for predicting the flatness of the dressing-working face 15.

[0141] Still further, as the basic face 90 is disposed in a position close to the center of rotation, the outside diameter of the dresser 81 can be minimized and the dresser 81 can be easily handled.

[0142] In the above-mentioned example, a metal plating layer comprising the abrasive grain layer 93 can be formed by a metal which is not limited to Ni, and other metals can used. A method for forming the metal layer is not limited to electroplating, and the metal layer can be formed on the dresser principal 83 by PVD or CVD.

[0143] The present invention is not limited to the examples as mentioned above and various modified examples are included which contain the combinations of the examples (for examples, a combination of Example 1 and Example 2, and the combinations of any of Examples 1 to 4 and Example 5).

Claims

1. A dresser for dressing a polishing pad used for polishing a material to be polished, the dresser comprising:

   a dresser principal and a dressing-working part which is provided as a body other than the dresser principal; and
   a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

2. The dresser as claimed in claim 1, wherein a projection adjusting means is provided for controlling an amount of projection of said dressing-working part from said dresser principal.

3. The dresser as claimed in claim 2, wherein said dressing-working part is a cutter.

4. The dresser as claimed in claim 3, wherein said cutter has an approximately columnar shape and comprises: a flank which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face comprising a circumferential surface in the end portion of the cutter; and a cutting edge which is a ridgeline formed by crossing of the end face and the circumferential surface in the end

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portion.

5. The dresser as claimed in claim 3, wherein said cutter comprises:

a plurality of projections formed in one end of the cutter;
said projection having a cross section approximately equal to an end face of the projection from one end of the projection to near another end of the projection from which the projection is started; and
a cutting edge which is a ridgeline formed by crossing of the end face of the projection and the side surface of the projection.

6. The dresser as claimed in claim 1, wherein said dressing-working part is a cutter.

7. The dresser as claimed in claim 6, wherein said cutter has an approximately columnar shape and comprises: a flank which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face comprising a circumferential surface in the end portion of the cutter; and a cutting edge which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion.

8. The dresser as claimed in claim 6, wherein said cutter comprises:

a plurality of projections formed in one end of the cutter;
said projection having a cross section approximately equal to an end face of the projection from one end of the projection to near another end of the projection from which the projection is started; and
a cutting edge which is a ridgeline formed by crossing of the end face of the projection and the side surface of the projection.

9. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 1.

10. A dresser for dressing a polishing pad used for polishing a material to be polished, said dresser comprising a plurality of dressing-working parts for dressing the polishing pad which are disposed at unequal spaces in the circular direction of a dresser principal.

11. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 10.

12. A dresser for dressing a polishing pad used for polishing a material to be polished, said dresser comprising: a dressing-working part for dressing the polishing pad along the circular direction of a dresser principal; and a plurality of nicks formed in the dressing-working part at unequal spaces in the circular direction of the dresser principal.

13. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 12.

14. A dresser for dressing a polishing pad surface which is used for an apparatus for polishing, with the polishing pad, materials to be polished such as a semiconductor wafer having a flat surface, said dresser comprising at least one cutter projected from the under surface of a dresser principal,
wherein shaving the polishing pad surface is carried out by providing to the edge of cutter of the cutter a movement relative to the polishing pad surface in a direction parallel to the polishing pad surface, while the edge of cutter is pressed against the polishing pad surface.

15. The dresser as claimed in claim 14, wherein said edge of cutter comprises a flat surface which is parallel to the polishing pad surface and is pressed against the polishing pad surface.

16. The dresser as claimed in claim 14, wherein said cutter comprises a positive rake angle.

17. The dresser as claimed in claim 14, wherein said cutter comprises a rake angle having from -5° to -15°.

18. The dresser as claimed in claim 14, wherein said dresser principal has a circular shape and is constructed in such a manner that the dresser principal is rotated around a rotary shaft formed in the center thereof; and the edge of cutter of the cutter is arranged in such a manner that the edge of cutter has a negative angle wherein a rotational direction of the dresser principal is defined as positive to a straight line passing through the edge of end of the edge of cutter at the center side of the dresser principal and the center of the dresser principal.

19. A dresser which comprises a dresser principal and a dresser-working part having an abrasive grains layer including abrasive grains formed on the dresser principal,
wherein the dresser principal comprises a ground face on which the abrasive-grain layer is provided

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and a basic face which is disposed in a portion of the dresser principal more inward than the ground face and is formed in parallel to the ground face.

20. The dresser as claimed in claim 19, wherein said ground face comprises an approximately annular shape having a center which is the same as the center of rotation of said dresser principal; and the basic face is disposed in a position closer to the center of rotation than the ground face and is concentric with the ground face.

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FIG. 1

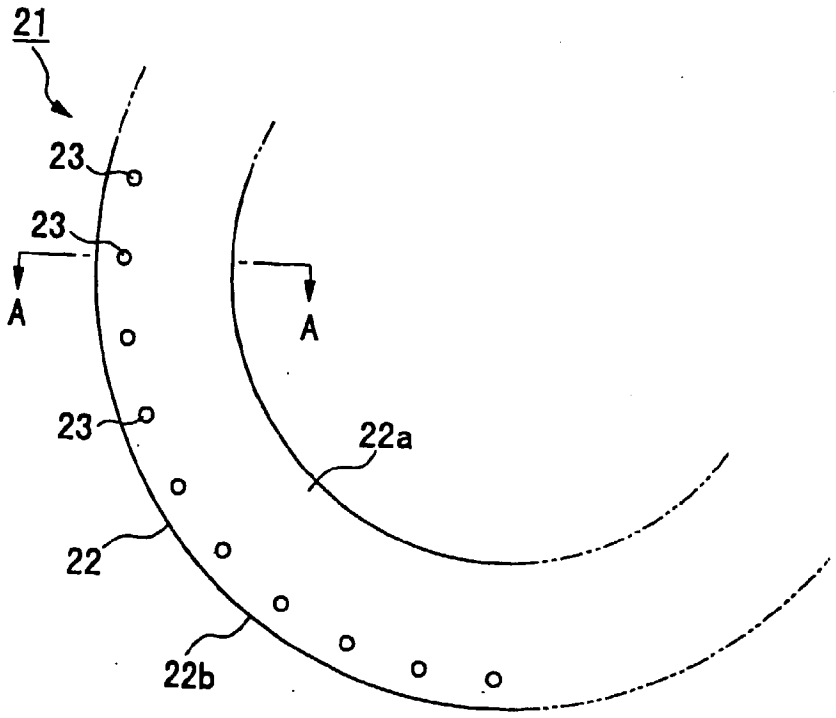


FIG. 2

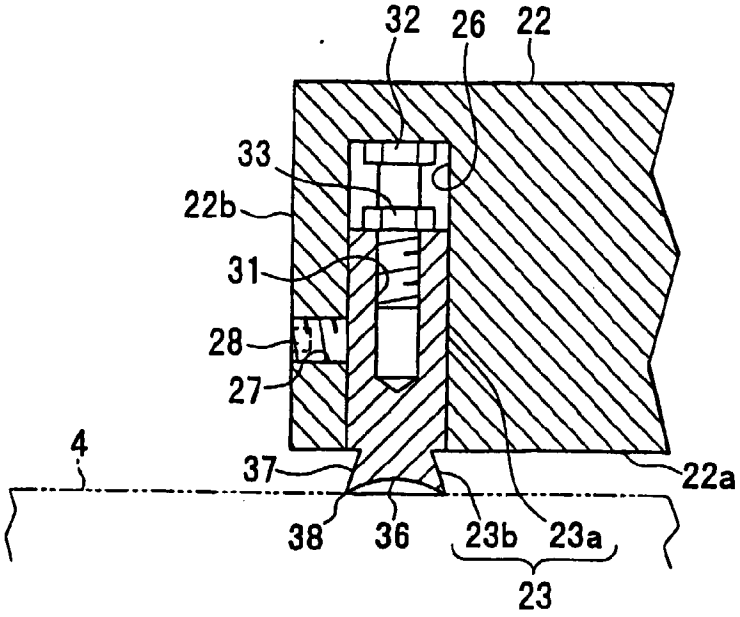

32
26
22
33
22b
31
28
27
4
37
22a
38
36
23b
23a
23

FIG. 3

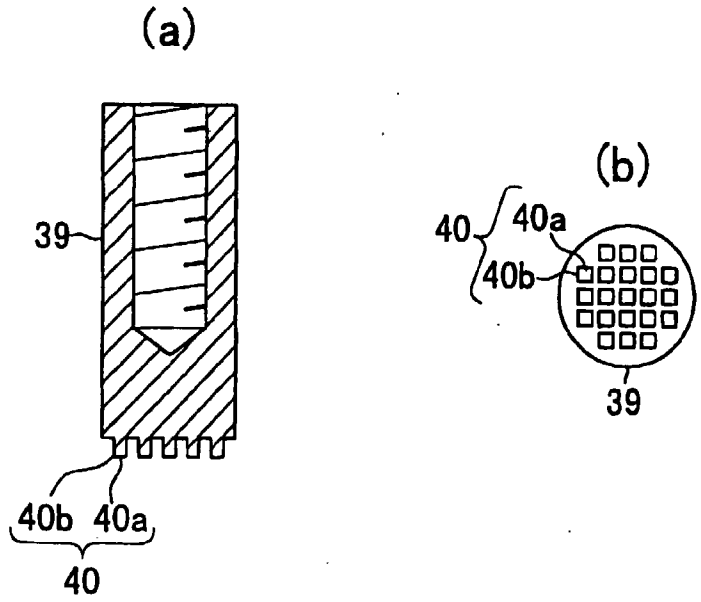

(a)
39
40b
40a
40
(b)
40
40a
40b
39

FIG. 4

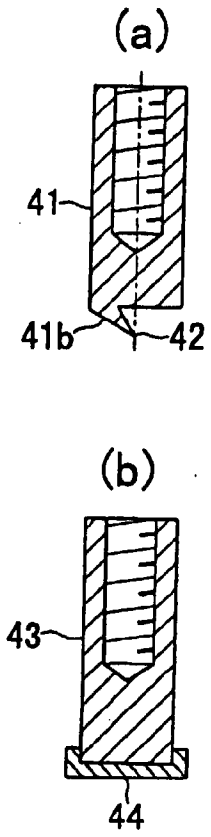


FIG. 5

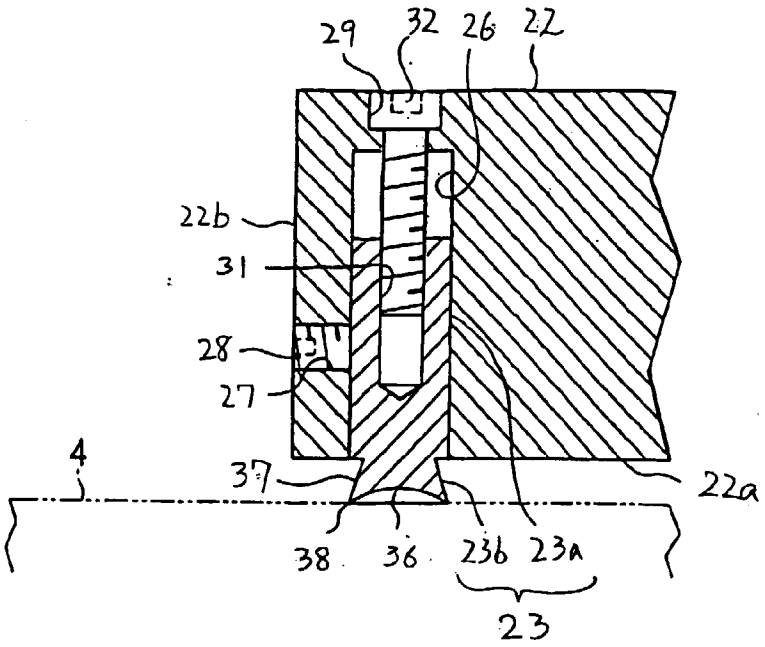


FIG. 6

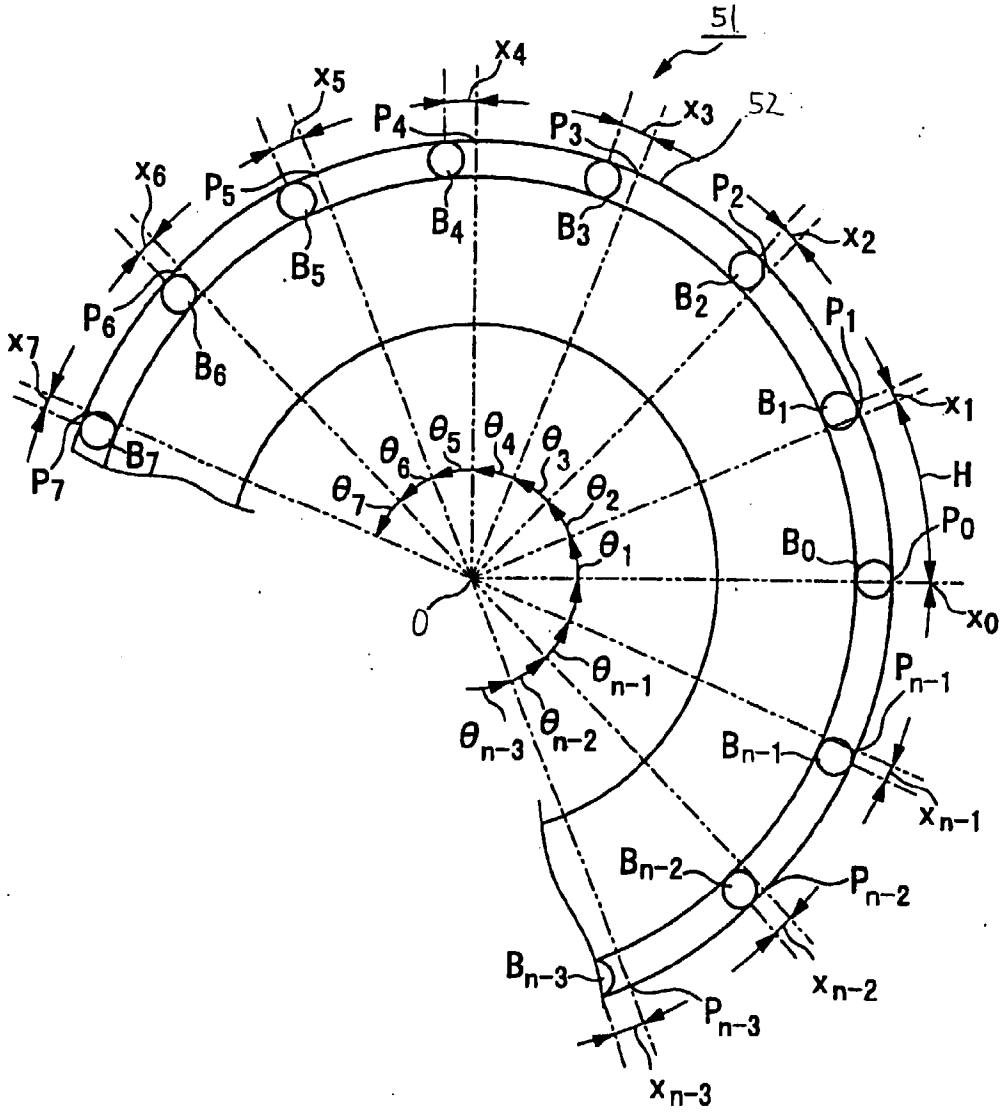

51
52
x_4
x_5
P_4
P_3
x_3
x_6
P_5
P_2
x_2
B_4
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B_5
B_2
P_1
P_6
x_7
B_6
B_1
x_1
B_7
θ_5
θ_4
θ_3
θ_6
θ_2
H
P_7
θ_7
θ_1
B_0
P_0
x_0
0
θ_{n-1}
P_{n-1}
θ_{n-3}
θ_{n-2}
B_{n-1}
x_{n-1}
B_{n-2}
P_{n-2}
B_{n-3}
x_{n-2}
P_{n-3}
x_{n-3}

FIG. 7

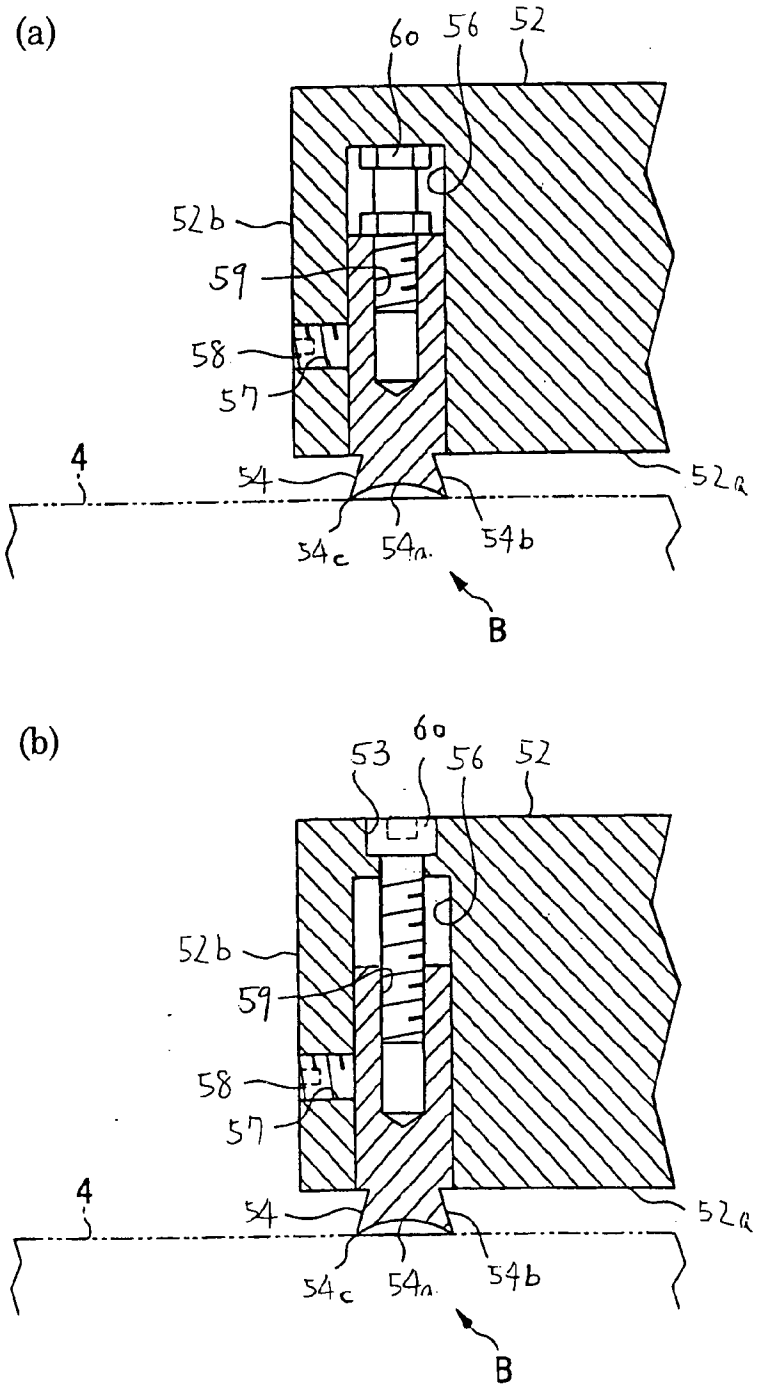

(a)
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B
(b)
53
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B

FIG. 8

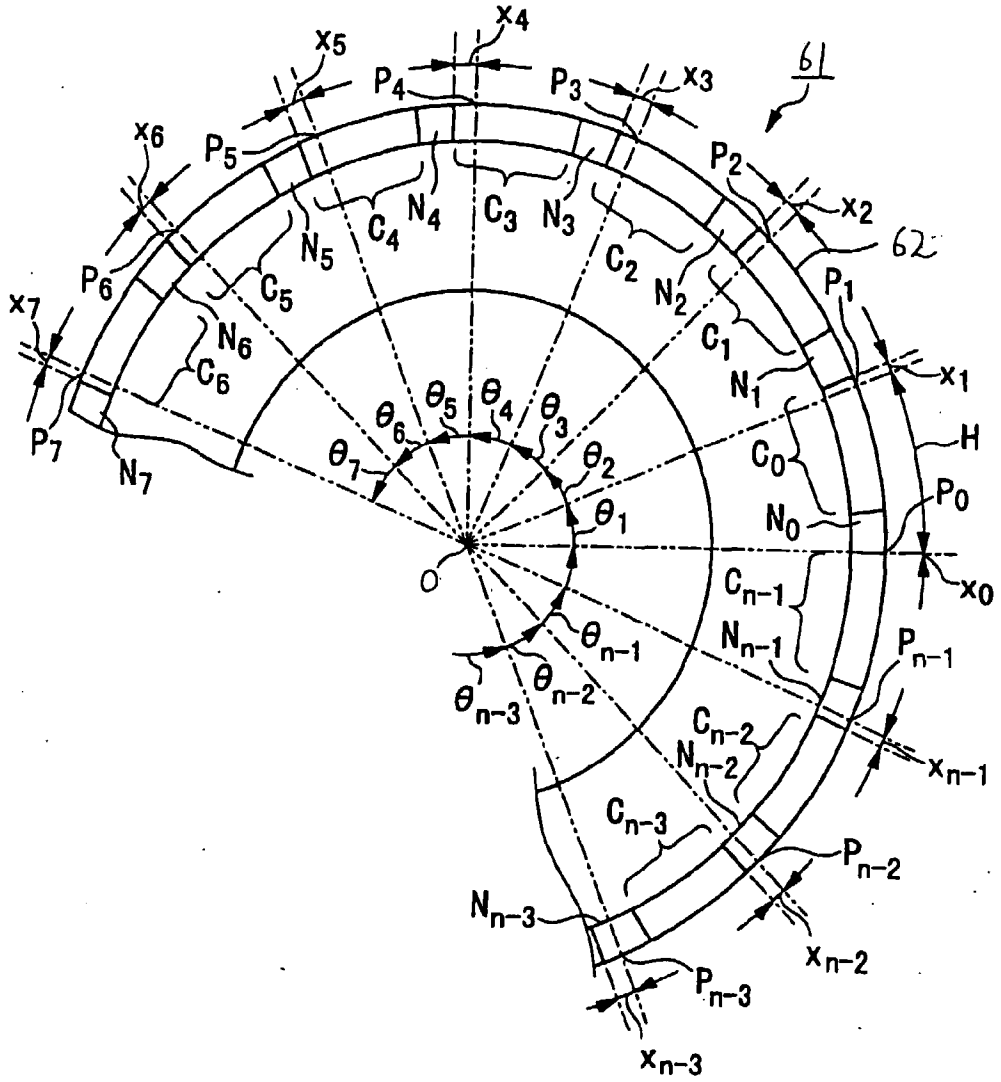

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62
x4
x5
x6
x7
x3
x2
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x0
xn-1
xn-2
xn-3
P4
P3
P5
P2
P6
P1
P7
P0
Pn-1
Pn-2
Pn-3
N5
C4
N4
C3
N3
C2
N2
C1
N1
C0
N0
N6
C5
N7
C6
Cn-1
Nn-1
Cn-2
Nn-2
Cn-3
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θ7
θ1
θn-1
θn-2
θn-3
O
H

FIG. 9

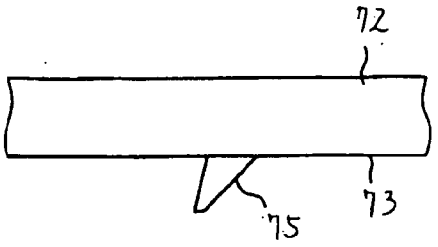


FIG. 10

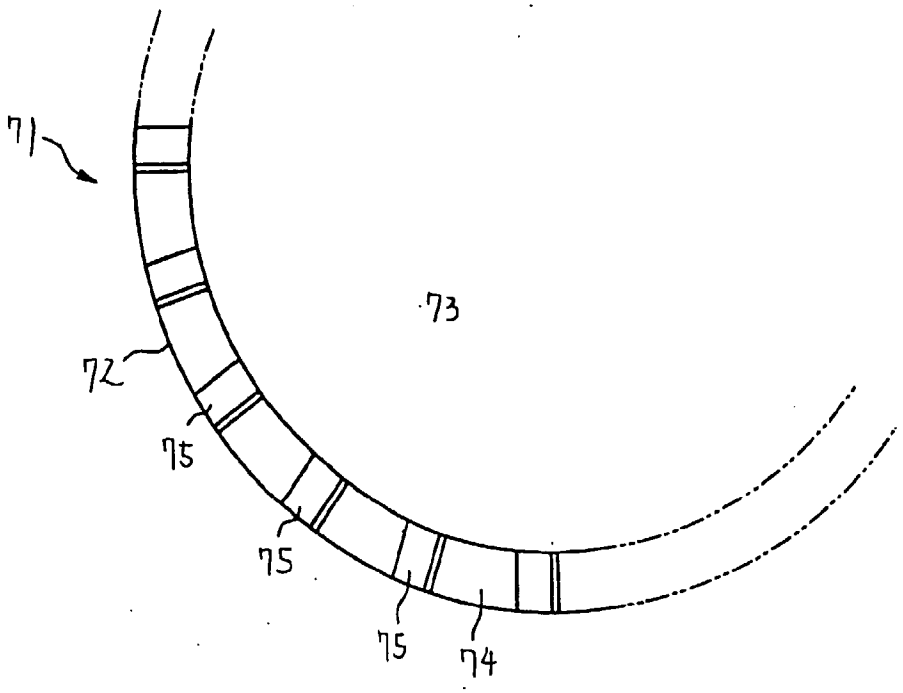


FIG. 11

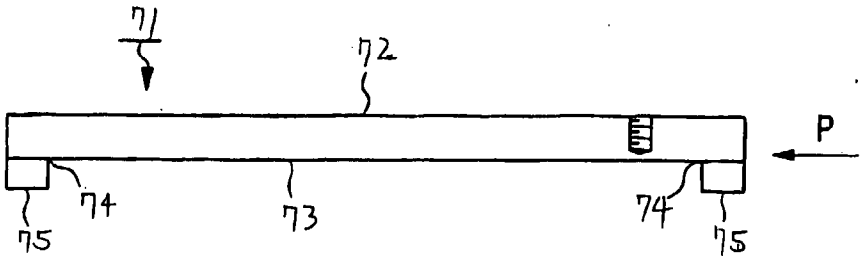


FIG. 12

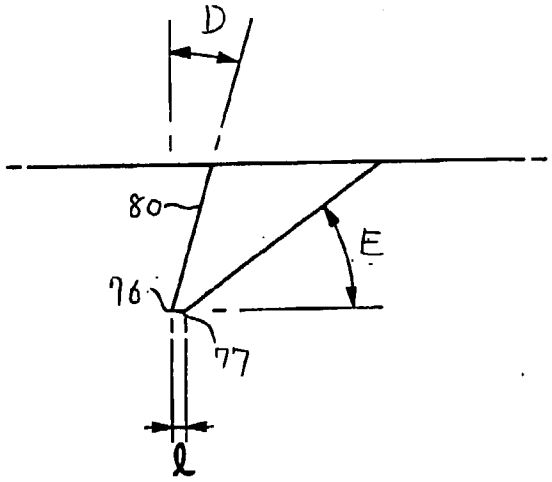


FIG. 13

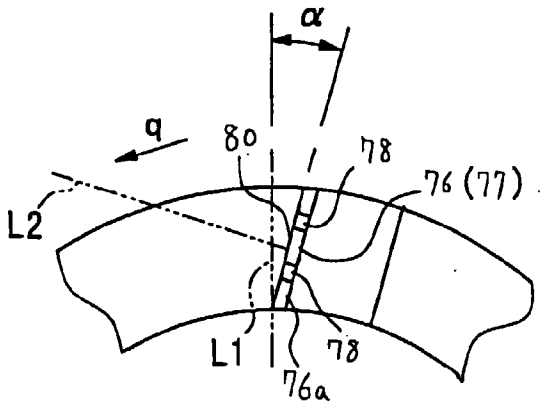


FIG. 14

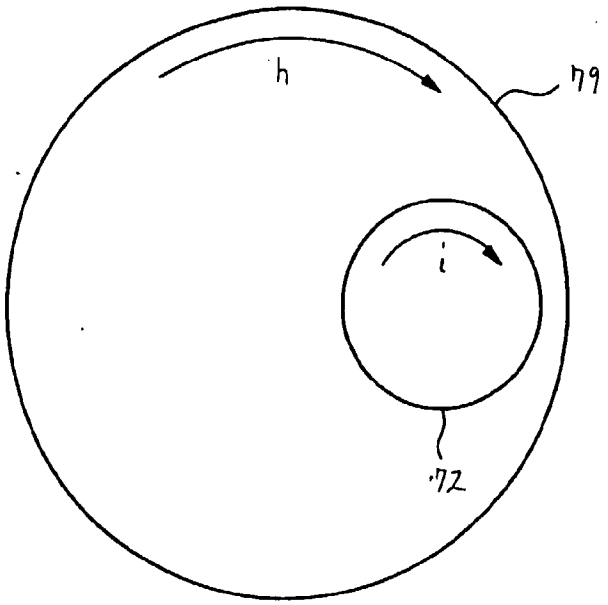


FIG. 15

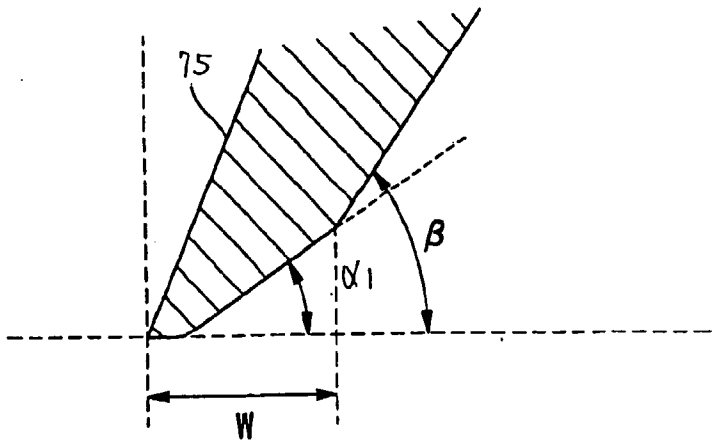


FIG. 16

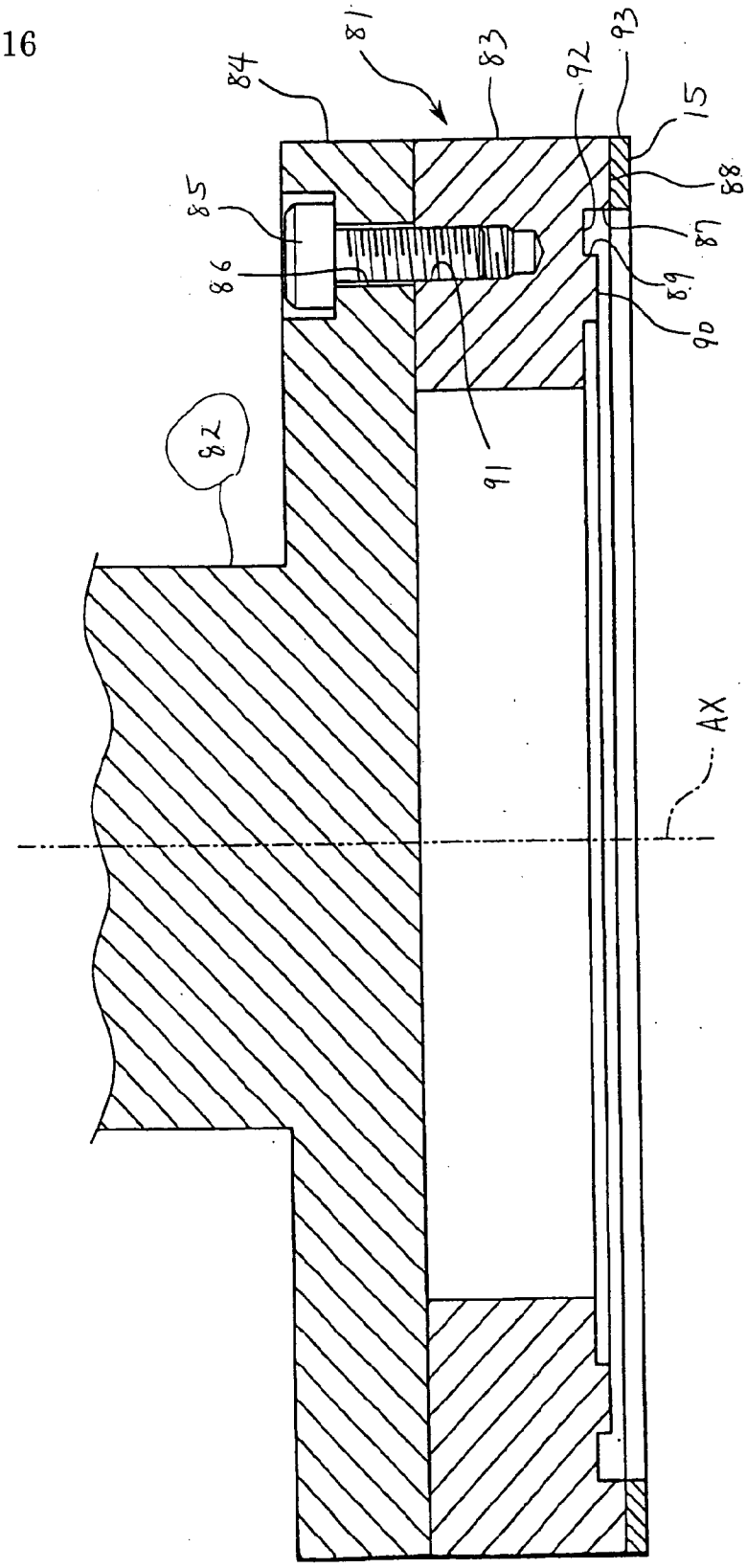


FIG. 17

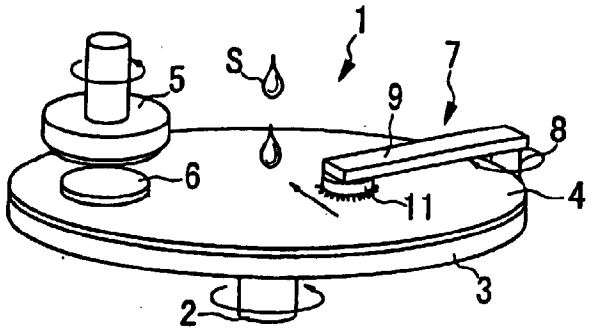


FIG. 18

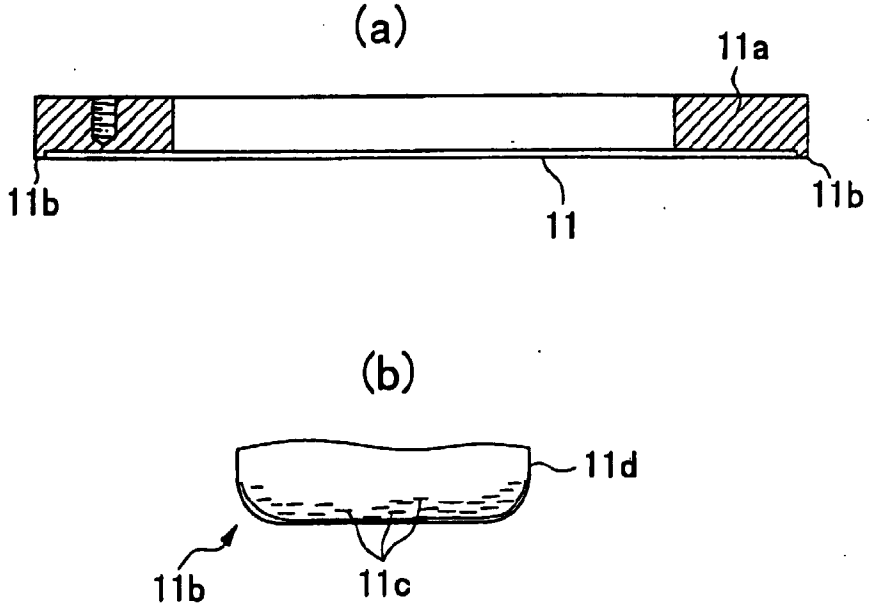


FIG. 19

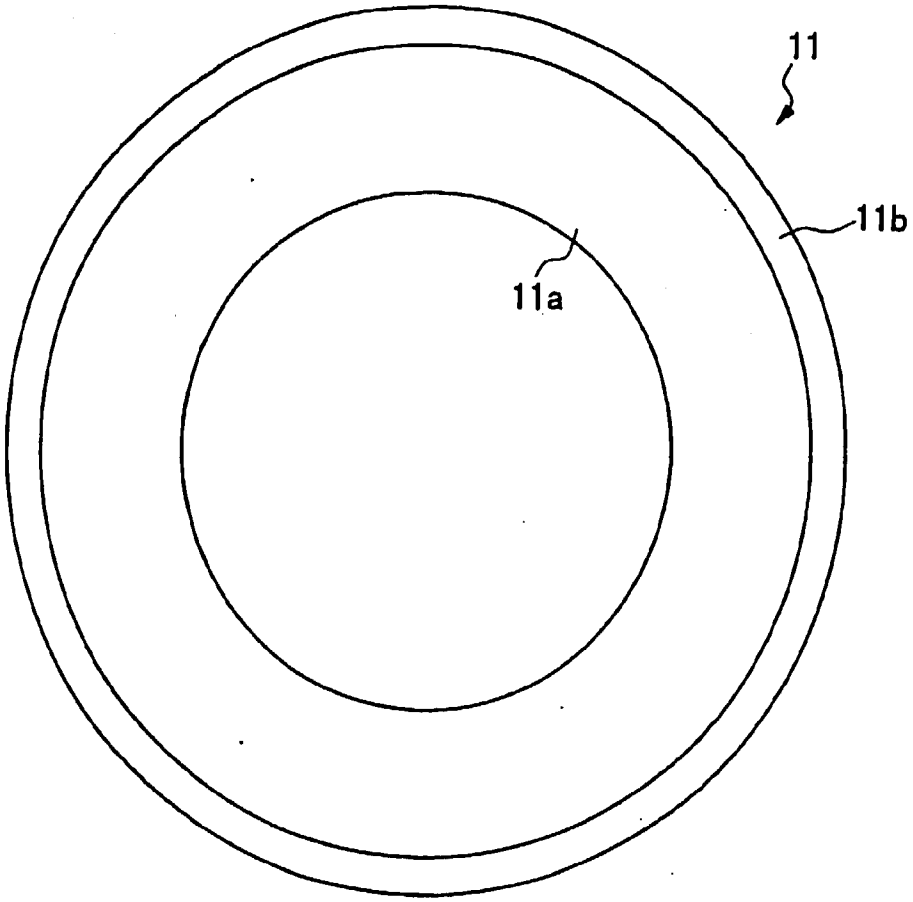


FIG. 20

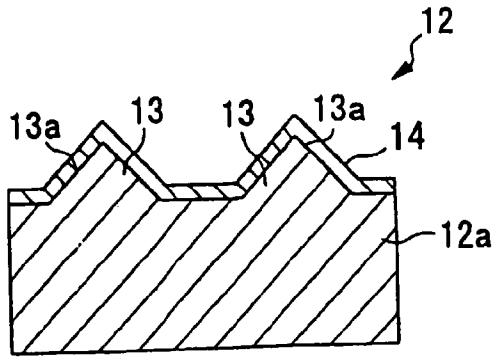
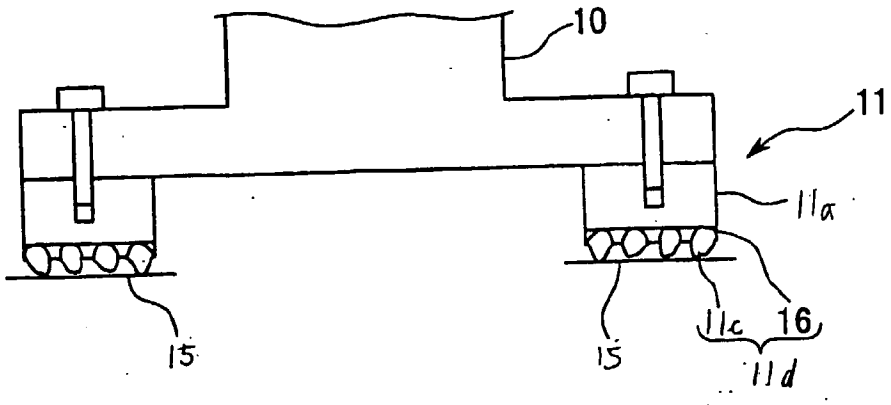


FIG. 21



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(22) Date of Filing 19.09.2000

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(51) INT CL[7]
C23C 16/44 , B22F 7/04 , B24B 53/12 , C23C 16/00 16/27

(52) UK CL (Edition T)
C7F FHE FP861 FP862 FP864 FR902
B3D DMN
C7D DB704
U1S S1578 S1645 S1652 S1660

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(58) Field of Search
UK CL (Edition R) **B3D DEN DMN , B5A AB18 AB19 ANA ATXP AT3P , C7D DB702 DB704 DB706 DB708 , C7F FHB FHE FHX**
INT CL[7] **B22F 7/04 , B24B 53/12 , B29C 33/42 39/02 39/10 41/08 41/20 45/37 , B29D 31/00 , C23C 16/00 16/27 16/44**
Online: WPI, EPODOC, JAPIO

(54) Abstract Title
Cast diamond tools and their formation by chemical vapor deposition; diamond hoses

(57) A method and design of cast diamond tools includes a mold that contains a negative body shape and surface finish of an intended diamond tool. Diamond deposited by a vapor phase, such as by chemical vapor deposition, is applied to the mold. After depositing diamond to a certain thickness, the mold is dissolved in acid or another suitable solvent, leaving behind the diamond cast that duplicates the intended body shape and surface finish. The diamond cast is then used to fabricate suitable tools, such as a cutting insert, or a wire-drawing die. In addition pad conditioners for polishing silicon wafers may be manufactured using this process, where the soluble mold is formed of silicon. In a variation a diamond hose is formed by overcoating a twisted wire with diamond after which the central metal core is dissolved leaving a hollow diamond hose which is then cast in an epoxy resin.

GB 2 366 804 A

FIG. 1a

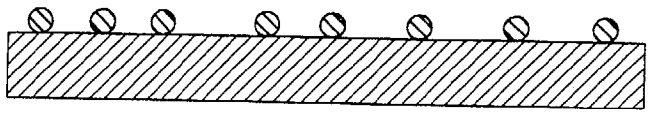


FIG. 1b

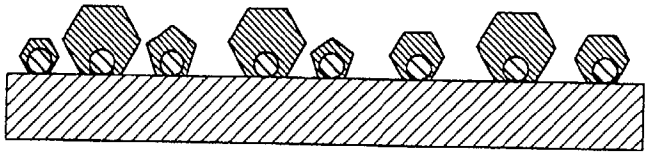
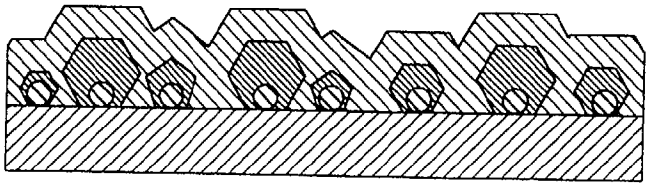


FIG. 1c



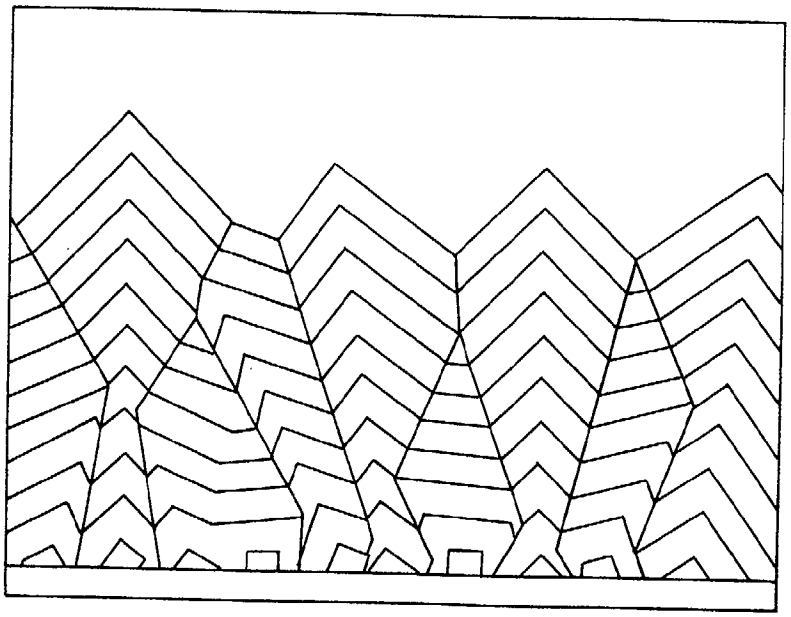
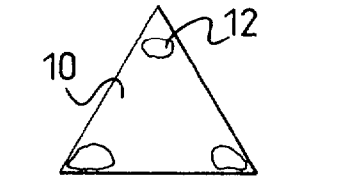


FIG. 1d



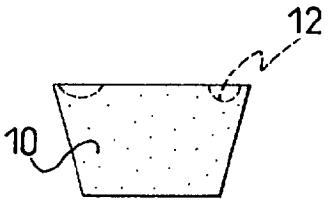
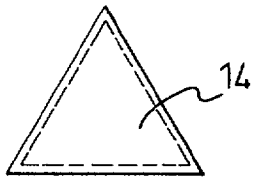


FIG. 2
PRIOR ART



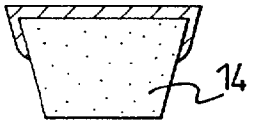
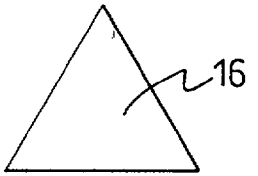


FIG. 3
PRIOR ART



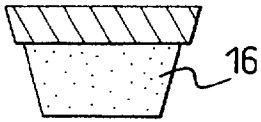


FIG. 4
PRIOR ART



FIG. 5

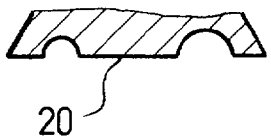


FIG. 6

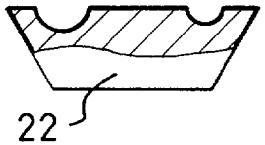


FIG. 7

Ex. 1003, Page 1113

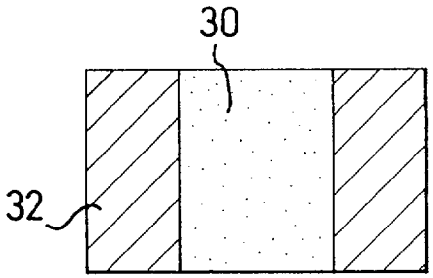


FIG. 8
PRIOR ART

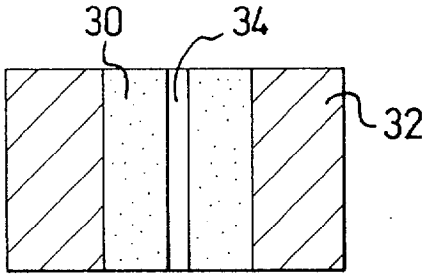


FIG. 9
PRIOR ART

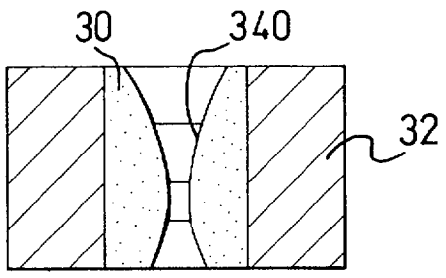


FIG.10
PRIOR ART

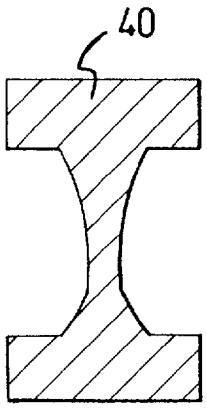


FIG.11

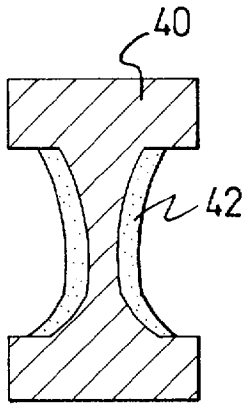


FIG.12

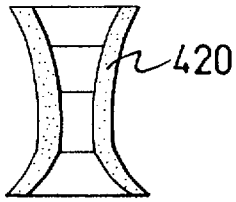


FIG.13

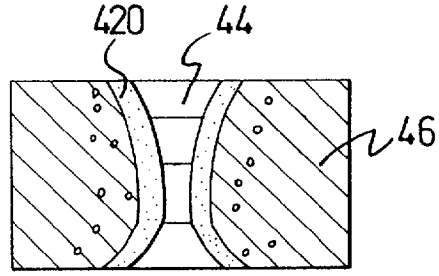


FIG.14

Ex. 1003, Page 1114

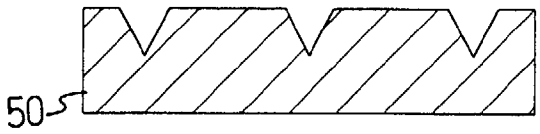


FIG. 15

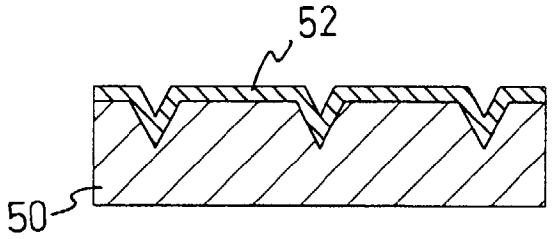


FIG. 16

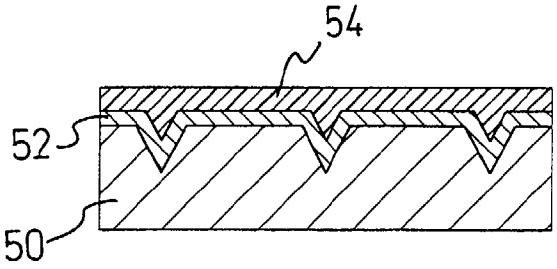


FIG. 17

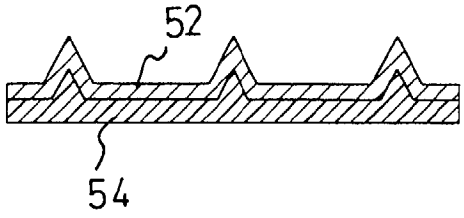


FIG. 18

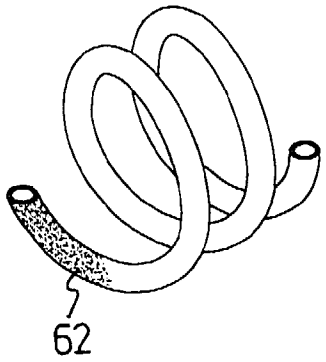


FIG. 21

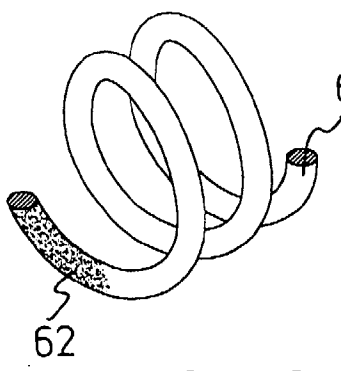


FIG. 20

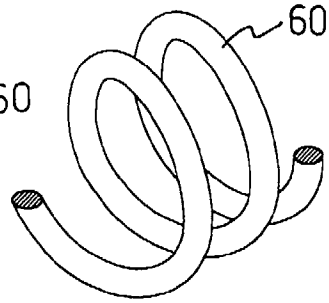


FIG. 19

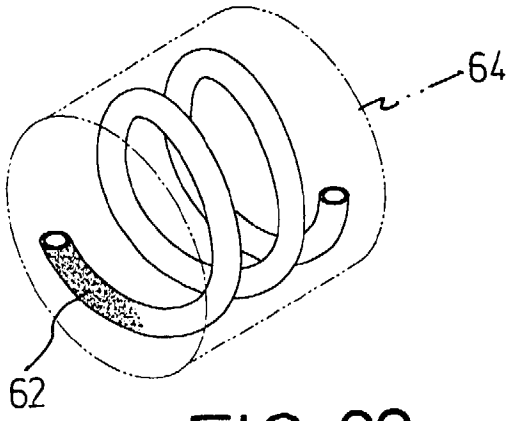


FIG. 22

CAST DIAMOND TOOLS AND THEIR FORMATION BY CHEMICAL VAPOR DEPOSITION

1. Field of the Invention

The present invention relates to a manufacturing method and design of cast diamond tools.

2. Description of Related Art

As a material, diamond has many extreme properties, such as high wear resistance, high thermal conductivity, rapid transmission of sound waves, and corrosion inertness. These superior properties have made diamond the ideal material for many advanced applications. For example, diamonds have been used widely as superabrasives, heat spreaders, acoustic devices, and chemical barriers. Conventionally, diamonds are synthesized under high pressure (more than fifty times atmospheric pressure), but such diamonds are typically in grit form. Although they are ideal for superabrasives (e.g., for diamond saws), they are not suitable for non-mechanical applications (e.g., heat spreaders).

In recent years, diamond films up to 1mm in thickness have also been deposited commercially. These films are deposited by CVD methods using gas reactants. The gases included typically a small amount (<5%) carbonaceous material, e.g., methane (CH4), that is diluted in an ample amount of

hydrogen (H2). During the process, the gases are heated to a high temperature so the carbonaceous gas will decompose to free up carbon atoms. At the same time, hydrogen molecules will dissociate to form atoms. Normally, carbon atoms will deposit as either amorphous carbon or graphite, but with the surrounding of hydrogen atoms, they will maintain the diamond structure (sp3 bond), as in the case of methane, and precipitate out as diamond. Even with the formation of non-diamond carbon, the ready presence of hydrogen will convert the carbon back to methane. Hence, hydrogen atoms play a key role in catalyzing the formation of diamond. Hence, the higher the concentration of hydrogen atoms, the better the quality of diamond that is formed.

There are various ways to heat the gas mixture, among them hot filament (e.g., using tungsten), microwave agitation, oxyacetylene flame, and direct current (DC) arc are commonly used. Although the temperature for diamond deposition is typically in the range of 800 ℃ to 900 ℃, the reaction temperature for the gases is much higher. In fact, the higher the reaction temperature is, the more complete the decomposition of the gases to form carbon and hydrogen atoms, and the faster the deposition rate of the diamond. Thus, the hot filament method can only reach 2000 ℃ or slightly over, so its

deposition is the slowest (about 1 micron per hour). The microwave agitation can heat the gases to a higher temperature, so the deposition rate is intermediate (about 10 microns per hour). The oxyacetylene can attain an even higher plasma temperature, so its deposition rate is quite high (e.g., 30 microns per hour). The DC arc method can surpass the gases to the highest temperature (about 6000 ℃) and hence it can deposit diamond at the highest rate (e.g., 50 microns per hour) of the above methods. However, the higher the deposition rate, the smaller the area of the deposition, and the less uniform the diamond film produced. Hence, there is a tradeoff between deposition rate and deposition area.

CVD diamond films contain polycrystalline diamond grains. Diamond nuclei are first formed on the surface of the substrate, and these nuclei will grow with ever increasing coarseness, as shown in Figs. 1a to 1d. Hence, the film on the nucleation side tends to show the same surface finish as the substrate material, but the growing side becomes ever-increasingly rough with the coarsening of the grain. For most applications (e.g., heat spreader), the rough surface must be ground and polished. However, as diamond is the hardest material known, the machining of the coarse diamond is extremely difficult and tedious. As a result, the cost associated with the finishing of a

diamond film is often higher than that for its deposition.Fig. 1 shows the nucleation and growth of a diamond film. Note the nucleation surface is a negative of the substrate surface, and the growing surface is becoming more and more rough with the deposition time.

Moreover, certain machining procedures, such as to cut a curved groove on the diamond surface, or to drill a square hole through diamond are almost impossible to achieve. Such limitations have severely constrained diamond films' potential applications.

For example, CVD diamond films have been used as a premium cutting insert. When it is used to cut ductile material (e.g., copper alloy), the long cutting thread must be interrupted from time to time. This is conveniently done by providing a trough near the cutting edge, as commonly done with other cutting tools, to bend and break the material being removed during the thread cutting operation. However, it is not possible to make such a trough on the flat diamond film. Hence, CVD diamond cutters, although extremely durable, are not suitable to cut ductile materials.

As another example, many advanced applications, e.g., circuitry in the electronics industry, would require using triangular, square, or irregularly-shaped shaped metal wires.

These wires cannot be drawn with conventional diamond wiredrawing dies that contain only circular holes. Hence, there is no suitable product to serve this significant demand from the market.

Furthermore, most applications use the surface (e.g., an extruding die) of diamond films, hence the property of the bulk body may not be critical. However, the conventional CVD method must produce the diamond film from the bottom up. Hence, if the top surface is required, the entire film must be grown slowly to reach the top portion. Such a tedious growth process can be very costly.

Example 1- Cutting Inserts Made of Diamond

Conventional diamond cutting inserts include two main types. The first type is to coat a WC insert with thin diamond film (e.g., 30 microns). The problem of this design is that the deposited diamond surface is rough, so the cutting surface does not have a fine finish. Alternatively, a thick diamond film (e.g., 300 microns) can be grown. The diamond film can then be ground and polished by a laser to form a triangular cutting tip. This tip is then brazed onto a WC insert. This method is tedious and expensive. In addition to the above described drawbacks, these diamond film cutting inserts suffer another deficiency which is that their top faces are always flat. Hence,

they do not possess chip breakers for efficiently cutting ductile materials.

Fig. 2 shows a conventional WC insert (10) with a depressed chip breaker (12) near each cutting corner. Fig. 3 shows a diamond coated WC insert (14) without a chip breaker. Fig. 4 illustrates a thick diamond brazed onto a WC insert (16), again without a chip breaker.

Example 2 - Wire Drawing Dies Made of Diamond

Many metal wires are drawn by using polycrystalline diamond (PCD) tools. The PCD (30) is enclosed by WC (32) (Fig. 8), and a hole (34) is drilled through the PCD (30) (Fig. 9), typically by a laser. The hole (34) is then enlarged to form a flare (340), as shown in Fig. 10, and the surface is polished by using fine diamond paste. Although there is much laborious finishing work involved, such PCD dies are still the best tools used for drawing metal wires. Even so, PCD dies contain only round holes, hence, it is not possible to draw polygonal wires, such as those with square cross-sections.

All PCDs contain more than 10% cobalt. As cobalt can reconvert diamond to amorphous carbon or graphite, so the PCD must be kept below a temperature of about 700 ℃. Hence, the lubrication and cooling by water or other liquid is critical.

However, during the drawing process, the metal wire tends to press against the PCD and it may weld with cobalt embedded in the PCD. As a result, excessive heating is inevitable and the PCD may deteriorate rapidly due to the reconversion to amorphopus carbon or graphite. Moreover, the dragging may damage the surface of the metal wire by causing weld spots and burn marks.

Example 3 - Pad Conditioners Made of Diamond

Chemical Mechanical Polishing (CMP) is an essential step for manufacture silicon chips with sophisticated architecture. During the CMP process, silicon wafers are pressed against a rotating pad typically made of polyurethane. The table is fed with a stream of slurry that contains ultrafine (less than 0.2 microns) abrasive (e.g., silica or alumina). The wafers are therefore polished by the abrasive to reach a certain flatness and smoothness. However, the polished debris can coat the pad and make the latter unusable, so a diamond conditioner is required to scrape off the deposited debris from time to time.

The pad conditioner contains a plurality of diamond grits that are attached to a metal substrate (e.g., stainless steel). These grits are used to rake the pad to prevent its top from glazing. The effectiveness in cleaning the pad, and the durability of the conditioner are dependent on two critical

factors: the separation of diamond grits, and the leveling of their tops. These two factors are notoriously difficult to control. Hence, almost all diamond conditioners used commercially contain randomly distributed diamond grits with a high variability of the top height.

The object of this invention to make diamond film products that either eliminate or minimize the expensive post-synthesis operations.

It is another object of this invention to produce diamond film products with irregular and novel body shapes and surface finishes.

It is yet another object of this invention to simplify the diamond manufacture process by casting only the critical part of the diamond film, and then filling in the non-critical part with fast grown diamond or other material.

In the drawings

Figs. 1 shows stages of diamond nuclei formed on a surface of a substrate;

Fig. 2 shows a conventional tungsten carbide tool insert;

Fig. 3 shows a conventional diamond coated tungssten carbide tool insert without a chip breaker;

Fig. 4 shows conventional tungsten carbide with a thick diamond film but without a chip breaker;

Fig. 5 shows a thin metal mold for use in the present invention;

Fig. 6 shows the mold of Fig. 5 filled with diamond film deposition, in accordance with the present invention;

Fig.7 shows the mold of Fig. 5 dissolved away;

Fig. 8 shows a prior art polycrystalline diamond (PCD) enclosed by tungsten carbide;

Fig. 9 shows the PCD of Fig. 8 with a hole drilled therethrough;

Fig. 10 shows the PCD of Fig. 9 with the hole enlarged;

Fig. 11 shows a mold for use with the present invention;

Fig. 12 shows the mold of Fig. 11with diamond deposition ;

Fig. 13 shows the diamond deposition of Fig. 12 formed as a die, with the mold dissolved away;

Fig. 14 shows the diamond of Fig. 13 with the diamond die encased by a metal;

Fig. 15 shows a silicon wafer in accordance with the present invention;

Fig. 16 shows the silicon wafer of Fig. 15 cast with chemical vapor deposition (CVD) diamond;

Fig. 17 shows the silicon wafer of Fig. 16 with an epoxy resin layer;

Fig. 18 shows a disk with diamond pyramids after the the

silicon has been dissolved away;

Fig. 19 shows a wire having been twisted, in accordance with the present invention;

Fig. 20 shows the wire of Fig. 19 coated with chemical vapor deposition diamond;

Fig. 21 shows the wire of Fig. 19 dissolved away, leaving a diamond hose; and

Fig. 22 shows the diamond hose of Fig. 21 encased in resin.

This invention reverses the common practice of growing diamond film to form a body and then machining it to a required shape. Instead, a diamond film is cast in a mold to form the body shape and surface finish it in a single process. A remaining portion can then be filled in at a later stage using a much less expensive material or method. This novel concept can produce the cast that duplicates the body shape and surface finish of the mold, hence, expensive post-synthesis machining works are eliminated. Moreover, the complicated body shape or delicate surface finish can both be achieved from the mold. As a result, diamond film products with novel and unique geometries can now be produced for the first time.

A key ingredient of this invention is the ability to reproduce a surface finish of the mold to the deposited diamond cast and experiments have been performed to test this

feasibility. Many materials with different surface finishes have been used as the substrate for depositing CVD diamond. The CVD reactor used is a large production system manufactured by sp3, Inc. of California. The reactor is a hot filament system with a deposition area of 30 cm x 40 cm. It has been discovered that if the substrate material is suitable (e.g., copper, tungsten carbide), and the surface treatment is proper (i.e., thoroughly cleaned), diamond films so deposited can faithfully reproduce the surface feature of the substrate. Hence, the concept of reverse deposition was proven.

Conventional diamond films have their growing sides used as appropriate tool surfaces. This invention relies on using a nucleation side for the application. The nucleation side contains diamond microcrystals that have been formed on the substrate. These newly formed nuclei may not be chemically pure, nor structurally sound. Moreover, amorphous carbon or pyrolitic graphite may be co-deposited there. As the nucleation side will be used as the tool surface, it is critical to make this side contain as much diamond as possible.

Several techniques have been applied to improve the diamond quality of the nucleation side. For example, during the early phase of diamond deposition, the methane flow rate is reduced and the gas pressure is increased. In this way, the

decomposition rate of carbon will decrease, but the concentration of hydrogen atoms will increase. The slow deposition rate coupled with the increased amount of catalyst can assure that diamond nuclei formed are of high quality.

Moreover, the nucleation rate must be increased to fill up the minute crevices of the substrate. The nucleation rate can be effectively boosted (up to one million times) by applying a negative bias (e.g., 100 V) on the substrate. Alternatively, the substrate can be polished by using a fine diamond paste. After polishing, the embedded diamond micron powders can serve as effective seeds for diamond nucleation. If the nucleation rate can be raised, the diamond quality on the nucleation side will increase, and the substrate finish can be faithfully translated onto the nucleated surface.

Certain metals, e.g., iron, cobalt, nickel and their alloys, can catalyze at a high temperature (>700 degrees Celsius) diamond back to amorphous carbon or graphite. It is important that the substrate material contains as little as possible of such metals. For example, a good substrate material for diamond deposition is cobalt cemented tungsten carbide (WC). If WC is used for diamond deposition, the mount of cobalt should be limited to 4% or less. In recent years, binder free WC materials have been available. These materials are suitable to

make molds (e.g., the hole for a wire-drawing die). If the WC grain is ultrafine (submicron), the diamond nucleation will further increase. The result is a very smooth surface of high diamond content, which is ideal for many applications.

Fig. 5 shows a thin metal mold (20) that has the negative geometry of a conventional cutting insert with chip breakers. The metal can be W, Mo, Ta, Zr, Ti, Cr, V, Cu, Si or other suitable material. Fig. 6 shows that this metal mold (20) is filled up by the deposition of diamond film. Fig. 7 shows that the metal mold (20) is dissolved away, e.g., by soaking in acid. A bottom part (22) of the remaining diamond film contains the same geometrical form of the metal mold (20). A top part is then packed with WC particles or other refractory grains (e.g., SiC) and infiltrated with an alloy (e.g., copper-manganese alloy). The solidified alloy can then serve as the substrate of the cutting insert as shown in Fig. 7. This diamond insert contains the original surface of the metal mold (20), including the chip breaker. This diamond cutting tool does not require expensive mechanical finishing work.

This invention can solve all the above mentioned problems of the prior art.

Referring to Fig. 11, a center column (40) made of a binderless WC (or W metal) is first fabricated with the

appropriate geometry and surface finish. As shown in Fig. 12, this center column (40) is then coated with CVD diamond (42) to a thickness of 50 to 100 microns. The center column (40) is subsequently dissolved in acid, leaving a diamond tube cast in the same geometry of the center column (40), as seen in Fig. 13. This diamond tube is placed at the center of a stainless steel ring (46), and a space between them is packed with WC particles or SiC grains. A pile of copper-manganese-nickel alloy is placed on top of these particles. The set up is next placed in a vacuum furnace and heated to cause the melting of the copper alloy. The copper alloy will then infiltrate into the powder and consolidated the assembly. This rigid assembly contains a stainless steel outer ring and a diamond inner tube (44). Moreover, the diamond tube is compressed by the shrinking copper alloy that reduces the volume significantly during the solidification process. This compression is highly desirable as it will protect the tube from expansion due to the outward pushing force exerted by the drawing wire. Furthermore, this compressional force is adjustable in that may be varied to suit the type of wire to be drawn (e.g., low for drawing copper and high for drawing tungsten). The compressional force can be varied simply by adjusting the powder/metal ration. the more metal used, the higher the

compression force is.

The above described novel technology not only eliminates the expensive finishing operation, and hence greatly reduces the production cost, but also it improves the quality of the wire drawing die in many aspects. For example, unlike PCD that contains less than 90% in volume of diamond, CVDD is made entirely of diamond, hence, its wear life can be much higher than PCD (the service life is not linearly proportional to the diamond content, but is an exponential function).

CVDD is much more slippery than PCD that contains metal adhering cobalt, hence the heat generated during wire drawing would be significantly less. Moreover, CVDD can stand a temperature of 1200 ℃ that is much higher than 700 ℃ for PCD. Hence, the use of liquid lubrication may not be necessary. The elimination of liquid lubricant not only pays for the cost of the wire drawing die itself, but also it avoids environmental contamination associated with the lubricant. Concern about protecting the environment is forcing the machining industry to operate "dry", so this invention anticipates such a world trend.

Furthermore, the elimination of cobalt in the contact surface can improve greatly the surface finish of the wire, e.g., to make it have a reflective finish. Such a high quality wire is

highly welcomed by the electronics industry (e.g., contamination-free copper wires) and the jewelry business (e.g., shinning gold wires).

An even more significant breakthrough based on this invention is that wire drawing with non-circular holes can be performed as easily as circular holes. Hence, wires with triangular or square cross sections can be produced readily. The introduction of non-circular wires currently unavailable can allow new designs of products for certain fields (e.g., in the electronics industry), hence it may spur the creation of a new industry.

Using the cast diamond concept as taught by this invention, an extremely high quality diamond conditioner can be fabricated with strict control of diamond separation and top height. Firstly, a silicon wafer (50) is machined with impressions of identical pyramids that are placed in specific locations (e.g., with a fixed distance from the neighbor) as shown in Fig. 15. Secondly, the engraved silicon wafer is cast with CVD diamond (52), as shown in Fig. 16. Thirdly, an epoxy resin (54) is then attached on the top, as shown in Fig. 17. The entire assembly is then dipped in hydrofluoric acid to dissolve the silicon substrate. The remaining disk, when inverted, will show identical diamond pyramids protruding to the same height,

as shown in Fig. 18. Such a diamond layout is ideal for making a CMP pad conditioner. This method can also allow new designs of pad conditioners. For example, the distribution of the pyramids may be such that they follow a spiral pattern. In this way, the slurry may be guided to follow the pattern so as to improve the distribution of the abrasive. The result can be an increased polishing rate of the wafer and a reduced consumption of the expensive slurry. Moreover, the uniformity and flatness of the wafer may also be improved.

Diamond Hose

This invention can allow the manufacture of novel and unique diamond devices, such as a diamond hose that can be used to transmit corrosive fluid. The manufacturing steps follow the same procedures as described above. Firstly, the hose is fabricated using a metal (e.g., by twisting a W wire (60)), as shown in Fig. 19. Secondly, the twisted wire (60) is overcoated by CVDD (62), as shown in Fig. 20, to form a center metal core. Thirdly, the center metal core is dissolved, leaving a hollow diamond hose, as shown in Fig. 21. Finally, this diamond hose is cast in an epoxy resin (64) to form an easily handled tool, as shown in Fig 22.

The same idea may be applied to manufacture of other novel objects, such as a diamond flask or a diamond gear.

There is no limitation of the type of shape that may be produced by CVD diamond.

The above few examples are merely used to illustrate the flexibility of applying this invention.

It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

CLAIMS:

1. A CVD diamond product cast by a mold with the surface features determined by contact interface of the mold.

2. The product as described in Claim 1, wherein the mold is made of metal.

3. The product as described in Claim 2, wherein the metal is essentially any metal selected from the group of W, Mo, Ta, Ti, Zr, V, Cr, or any of its carbides, and Cu.

4. The product as described in Claim 1, wherein the mold has a concave shape.

5. The product as described in Claim 4, wherein the concave shape is a cup.

6. The product as described in Claim 1, wherein the mold has a convex shape.

7. The product as described in Claim 6, wherein the convex shape is cylindrical.

8. The product as described in Claim 1, wherein the CVD diamond has a thickness of 30 to 200 microns.

9. The product as described in Claim 1, wherein the product is one of a cutting tool made of diamond, a wire drawing die made of diamond, a pad conditioner made of diamond, a diamond diaphragm, or a diamond pipe.

10. The product as described in Claim 9, wherein the

cutting tool contains chip breakers.

11. The product as described in claim 9, wherein the wire drawing die has a nonspherical hole.

12. The product as described in Claim 9, wherein the wire drawing die is produced by infiltrating molten alloy around a CVD diamond tube.

13. A method to make a CVD diamond product, comprising the following steps:

a. making a negative mold that contains a shape and a surface of an intended product;

b. depositing a CVD diamond to a desired thickness at an interface of the mold:

c. dissolving the mold by acid or another solvent; and

d. mounting a remaining diamond object in a suitable holder.

14. The method according to Claim 12, wherein the CVD diamond is deposited by a method using hot filament, microwave plasma. oxyacetylene flame, or DC arc to heat gas used therein.

15. The method according to Claim 13, wherein the gas contains methane and hydrogen.

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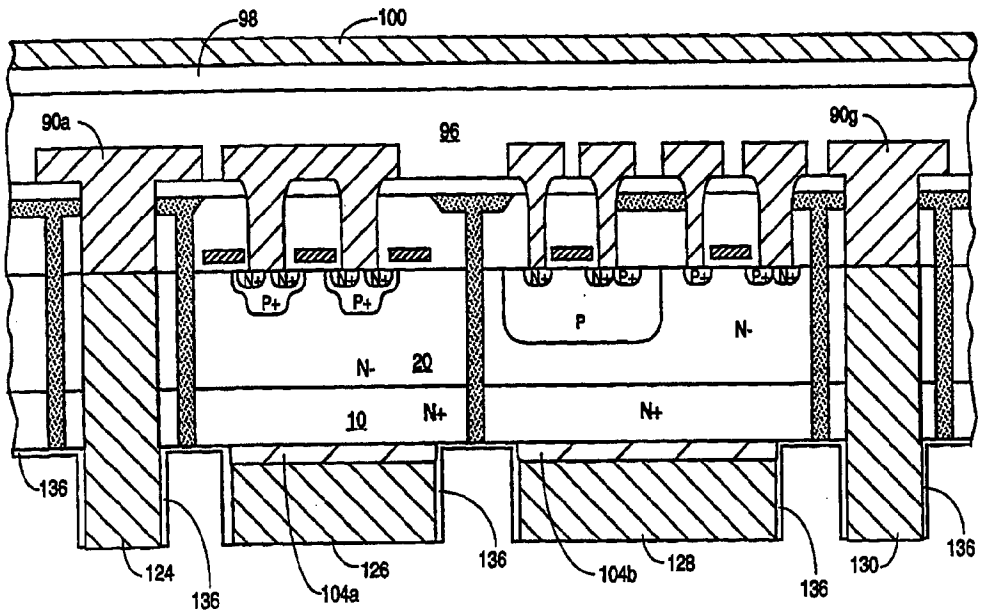
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(54) Title: SURFACE MOUNT AND FLIP CHIP TECHNOLOGY



(57) Abstract

An integrated circuit chip has full trench dielectric isolation of each portion of the chip. A heat sink cap (100) is attached to a diamond passivation layer (96) on the substrate front side surface. The passivation layer is a CVD diamond film which provides both electrical insulation and thermal conductivity. In a flip chip version, frontside electrical contacts (174a, 174b) extend through the frontside passivation layer to the heat sink cap. In a surface mount version, vias are etched through the substrate, with surface mount posts (90a, 90g) formed on the vias, to contact the frontside electrical contacts and provide all electrical contacts on the substrate backside surface. The wafer is then scribed into die in both versions without need for further packaging.

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SURFACE MOUNT AND FLIP CHIP TECHNOLOGY

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to integrated circuit electrical isolation, and more specifically to integrated circuit total isolation using both surface mount and flip chip fabrication technologies with a diamond film passivation layer.

Description of the Prior Art

Dielectric isolation for integrated circuits is well known. A trench or groove is formed in the semiconductor chip substrate and is lined or filled with an insulative material, to electrically isolate various portions of the chip. For instance, a particular portion of the chip such as power (high voltage) transistors is surrounded by an insulated trench, thereby electrically isolating the power transistors from logic type (low voltage) transistors.

This prior art trench isolation has the significant disadvantage that the bottom of each trench is an area of substantial mechanical stress in the silicon substrate, thereby being detrimental to chip functionality. Such trenches thus reduce yield (increase cost). This deficiency is sometimes overcome by using "round hole" techniques to form the bottom of

each trench (providing a U-shaped rather than a rectangular cross-section) which however, also tends to increase cost.

Another method for achieving isolation uses two wafers, with an oxide layer formed on a surface of one wafer which is then bonded to the second wafer; the oxide layer provides the isolation. After bonding the two wafers, the backside of one of the wafers is polished away down to the oxide layer to isolate a portion of the remaining substrate. However, this is very expensive because there can be no defects in the bond between the two wafers. Defects are often induced by particles in the bond between the two wafers, causing low production yield and hence high cost. Also, oxidation induced stacking faults (OISF) due to processing temperature cycles are undesirably more pronounced in such a bond than in bulk silicon.

Therefore, the prior art is deficient in not providing practical and inexpensive dielectric isolation, especially for use with power transistors but also for other types of integrated circuits.

SUMMARY OF THE INVENTION

An integrated circuit structure and a fabrication method use trench dielectric isolation. This trench dielectric isolation is part of a chip fabrication process which allows the packaging for each chip to be formed on the wafer, thereby eliminating the prior art separate step of packaging a semiconductor die after the wafer is scribed into multiple die. Therefore the disclosed process is the equivalent of assembly or packaging the integrated circuit die at "waferscale", since each die is already packaged before the wafer is scribed.

In accordance with the invention, transistors (or other semiconductor devices) are conventionally

fabricated on a semiconductor substrate. Some of these devices may be power transistors (operating at high voltage) and others may be lower voltage logic-type transistors formed in another portion of the substrate. In one embodiment, the devices are field effect transistors having gate electrodes formed in an insulated layer overlying the principal surface of the semiconductor substrate. Alternatively, the transistors are IGBT's (insulated gate bipolar transistors), or bipolar transistors, or other semiconductor devices. The fabrication process technology may be a CMOS, NMOS, PMOS, DMOS, BiCMOS, or bipolar technology, for example. Then an interconnect pattern is conventionally formed overlying and interconnecting the gate electrodes (or other transistor elements), and for contacting the semiconductor regions (e.g. source and drain) formed in the substrate.

A plurality of insulated trenches are then formed penetrating the principal surface of the substrate into the depth thereof, and surrounding (in a top view) various portions of the substrate. The trenches are conventionally insulated by filling or lining them with an insulative material followed by a planarization. This step may be prior to metallization. Then a portion of the backside of the substrate is removed by conventional machining or chemical processes, exposing the bottom portion of each of the trenches, and thereby achieving full (total) electrical isolation of the various substrate portions surrounded by each trench.

Prior to the step of removing the backside portion of the substrate, the frontside surface is bonded to a heat sink cap or plate (made for instance of silicon) using epoxy or similar bonding materials. This heat sink cap also provides the needed mechanical support for the substrate, which is otherwise quite thin

following the substrate removal step.

Electrical contact is achieved in two different embodiments. In a surface mount embodiment, vias penetrate from the backside surface of the substrate to its principal (frontside) surface, allowing electrically conductive material formed in the vias to contact an interconnect structure already formed on the substrate frontside surface. Extensions of the vias on the substrate backside define posts for surface mount electrical contacts. Other similar posts formed on the backside surface of the substrate make contact to the bulk substrate. The heat sink cap attached to the frontside substrate surface has a mechanical and heat dissipation function, with no electrical connections provided thereby.

In a flip chip type embodiment, the heat sink cap also carries on it an electrical interconnect, making electrical contact to the conventional interconnect on the substrate frontside surface. This heat sink cap may be attached to a conventional flip chip backplate. In this embodiment the electrical contacts formed on the substrate backside surface are the conventional drain or collector contacts for e.g. power integrated circuits.

In both embodiments, the individual integrated circuits are packaged while still being part of a single wafer, by the application of the heat sink cap which is attached (by epoxy or other adhesive) to the wafer frontside surface. This cap replaces the conventional plastic or ceramic packaging which in the prior art is applied only after the wafer is scribed into individual die. In the present case the full trench isolation between the die allows the die to be scribed adjacent to the isolation trenches, together with attached front end mechanical support plate (cap), so no further packaging is needed.

Typically, the thickness of the substrate after the substrate removal step is less than about 50 micrometers. This very thin substrate is free of heat induced mechanical stresses, due to its mechanical flexibility. Advantageously, integrated circuit chips in accordance with the invention are inexpensively fabricated using essentially conventional steps which provide a high yield, thus reducing cost.

The dielectric isolation trenches may conventionally be lined, for instance with silicon dioxide (formed from the silicon trench walls), or may be completely filled with silicon dioxide, or may be lined with silicon dioxide and then filled with another material such as CVD (chemical vapor deposition) nitride, polysilicon or oxide. In another embodiment, the trenches are filled with conventional spun on glass. Other insulating materials may be used for the trench dielectric.

The heat sink cap (plate) is typically silicon, silicon carbide, silicon nitride, aluminum nitride, molybdenum, or other material which provides sufficient heat transfer and is conveniently fabricated. The removal of the backside of the substrate advantageously eliminates mechanical stresses normally present at the bottom of a trench formed in silicon. Thus the principal problem with prior art trench isolation is overcome, resulting in a thin, flexible substrate.

Also, the prior art requirement for a semiconductor buried layer in the substrate is eliminated, due to the very thin substrate and formation of a layer of conductive material on selective areas of the substrate backside surface. Thus the processing problems associated in the prior art with establishing an effective buried layer are avoided, and the parasitic bipolar transistor effects typically present in prior art integrated circuits

(especially for power integrated circuits) are eliminated by a backside contact which is a metal plate or metallization layer rather than a buried semiconductor layer.

The metallized drain (or collector) contact on the backside surface, which is in relatively close proximity to the active transistors (due to the thinness of the substrate), increases current carrying capability over that of the prior art chips which require either the buried layer or current being transmitted through the relatively thick bulk of the semiconductor substrate. Thus advantageously the actual thickness of the final substrate itself is the minimum necessary to support (mechanically and electrically) the active transistor regions. This thickness may be as little as 10 microns, in contrast to prior art integrated circuits typically having a 400 micron die thickness needed for mechanical support for the integrated circuit.

Additionally, the step of removing the backside portion of the substrate after trench formation means that the initial trench depth need not be precisely determined. In the prior art, formation of trenches of precise depth is a significant processing limitation. In the present case, since the bottom portion of each trench is removed, exact trench depth is not critical.

Also, the fabrication process in accordance with the invention advantageously allows for an isolated backside contact structure which is not a single contact but a plurality of individual backside contacts, each contact associated with a particular portion of the die. This allows for instance a first backside contact to a power transistor portion of the integrated circuit, and a second backside contact associated with a low voltage transistor portion of the integrated circuit. Thus the backside contacts are

selectable for a particular portion of the integrated circuit, and various portions of the chip need not share a common collector or common drain.

In another embodiment, the passivation layer which serves as an isolation layer and an attachment layer to bond the IC wafer (substrate) to the heat sink cap or plate is a CVD (Chemical Vapor Deposition) diamond film. Such material advantageously has high thermal conductivity and high electric resistivity. The diamond film is deposited on top of the substrate after the final front side surface metal patterning. A thermally conductive adhesive (such as silver epoxy) is applied to the exposed surface of the deposited diamond film to attach the substrate to the plate. This use of diamond film is compatible both with the surface mount and flip chip embodiments described above. In accordance with the invention the diamond layer may be patterned so that particular portions of the metal contact or bonding pads are connected to and through the support plate to external leads from the front side of the wafer, in the flip chip embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 to 12 illustrate exemplary fabrication steps of the surface mount embodiment of the invention.

Figs. 13 to 17 illustrate exemplary fabrication steps of the flip chip type embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Surface Mount Embodiment

Figs. 1 to 12 illustrate steps to fabricate a surface mount integrated circuit chip in accordance with the invention. It is understood that these are conventionally drawn cross sections of an integrated

circuit showing only a small portion of the circuit, i.e. a small portion of a wafer. No topside views are provided, since the top side geometry of the integrated circuit is conventional, as will be understood by one of ordinary skill in the art from the following description. Also, this is only an illustration of the surface mount approach, which is not limited to semiconductor devices of the type shown.

Fig. 1 shows initial steps in fabrication of this embodiment. Fig. 1 is conventional both in structure and fabrication as typically used for integrated circuits which include both power transistors and low voltage transistors on one chip. See U.S. Patent Application No. 07/948,276, filed 9/21/92, Hamza Yilmaz et al., entitled "BiCDMOS Process Technology and Structure", incorporated by reference, for an example of such a fabrication process. Shown in Fig. 1 is silicon (or other material) substrate 10 which is conventionally N+ doped, having formed on an upper portion thereof in one embodiment an epitaxial (silicon) layer 20 which is conventionally N- doped. The epitaxial layer is an option but is not a necessary part of the invention; the active portions of the transistors may be formed in the substrate. (It is to be understood that materials, dimensions, transistor structure, conductivity types, and other elements disclosed herein are illustrative only and not limiting.)

Substrate 10 is approximately 500 micrometers thick, and silicon layer 20 is 1 to 50 micrometers thick. Conventionally formed (in this illustrative embodiment) in silicon layer 20 are two "deep body" conventionally doped P+ regions 22 and 24. Formed respectively in body regions 22 and 24 are N+ source regions 26, 28, 30 and 32 each of which is conventionally doped. It is to be appreciated that in

this embodiment P+ body regions 22 and 24 and the associated other doped regions are a part of a power portion of the integrated circuit, i.e. power transistors.

Formed adjacent to regions 22 and 24 is P tub 38 which is conventionally doped. Formed in P tub 38 are N+ doped regions 40 and 42. Also formed in silicon layer 20 are P+ regions 46 and 48 which are similar in their doping level and structure to region 44, and N+ region 50 which is similar to regions 40 and 42. Formed immediately overlying the upper surface of silicon layer 20 is a conventional gate oxide layer 60 of e.g. silicon dioxide.

Formed conventionally overlying oxide gate layer 60 is a doped polysilicon gate electrode layer 54 including (as a result of a masking step) portions 54a, 54b, 54c and 54d and 54e which in this embodiment form the gate electrodes of various transistors.

Overlying gate electrode layer 54 is a second overlying (upper) insulative layer 62 formed of silicon dioxide and also covering the respective side edges of the gate electrodes 54a, ..., 54e.

Overlying upper oxide layer 62 is a BPSG layer 64 (borophosphorsilicate glass) formed to a thickness of 0.5 to 1.5 micrometers and then conventionally reflowed to completely cover gate electrodes 54a, ..., 54e.

Fig. 2 shows subsequent processing with a conventional masking layer 70 formed overlying BPSG layer 64. Masking layer 70 is conventionally patterned and the underlying structure etched, with the etchant penetrating through silicon layer 20 and into substrate 10 to define trenches 72a, 72b, 72c, 72d, and 72e. These trenches are 0.5 to 5 micrometers in width and 5 to 50 micrometers in depth. (The depth is relatively arbitrary for reasons discussed later and the width dimension is also not critical.) The trench etch is a

conventional anisotropic process. It is to be understood that trenches 72a, ..., 72e as shown here in cross-section, would in a topside view interconnect so as to surround various portions of the integrated circuit, i.e. so as to surround the power transistor portion 22, 24 thereby separating this portion from the portion including P tub 38.

Then (not shown) the remaining portions of masking layer 70 are conventionally stripped off.

Next in Fig. 3, a glass layer 76 is formed conventionally such as by being spun on in each of trenches 72a, ..., 72e thereby filling each of these trenches, and also overlying the upper surface of BPSG layer 64, to a thickness of 1 to 2 micrometers. Alternatives to SOG for layer 76 are CVD formed materials or plasma enhanced CVD formed materials. After formation of spun on glass layer 76, this material is cured. Spun on glass 76 here is the trench dielectric insulating material. In other embodiments, the trenches e.g. are lined with a layer of grown silicon dioxide and then filled with another material such as CVD oxide, or nitride, or polysilicon. (These are conventional processes for forming dielectric layers.)

Next in Fig. 4, first an etch back (planarization) step using for instance CMP of the spun on glass layer 76 effectively removes those parts of layer 76 overlying the gate electrodes 54a, ..., 54e. An alternative to CMP is to apply a layer of photoresist then etch back using a dry etch.

Following the etch back step, an LTO (low temperature oxide) layer 80 is deposited over the upper surface of the structure to a thickness of 0.5 to 2.0 micrometers. Following the LTO layer 80 deposition, an electrical contact mask layer (not shown) is applied overlying LTO layer 80. The contact mask layer is then

conventionally patterned and the underlying layers etched, with the etch extending through LTO layer 80, through the remaining portions of spun on glass layer 76, and down to the principal surface of the silicon layer 20, thus exposing portions of the principal surface of the silicon layer 20 and defining contact openings 84a, ..., 84g.

Next in Fig. 5, a layer of conductive material 90 (such as aluminum) is conventionally deposited over the surface of the substrate, filling the various contact openings 84a, ..., 84g and making contact with the underlying semiconductor regions formed in silicon layer 20. Then conductive layer 90 is conventionally masked, the masking layer is patterned, and layer 90 is etched to define electrical contacts 90a, ..., 90g.

Then in Fig. 6 a conventional passivation layer of e.g. plasma nitride material is formed overlying electrical contacts 90a, ..., 90g. Passivation layer 96 is 0.5 to 2.5 micrometers thick.

Overlying passivation layer 96, an epoxy material layer 98 is conventionally deposited 25 to 250 micrometers thick. This epoxy material 98 is e.g. a high performance epoxy resin composition that is thermally conductive (such as silver epoxy).

Next a "cap" (plate) 100 is affixed to epoxy layer 98 which is then cured, bonding cap 100 to passivation layer 96. Cap 100 is about 500 micrometers thick and is e.g. undoped silicon. A single cap 100 covers the entire wafer which includes substrate 10 and silicon layer 20. Other bonding materials and processes other than epoxy may be used to affix cap 100. Cap 100 achieves thermal conductivity through epoxy layer 98 and also provides sufficient mechanical support for the substrate 10, silicon layer 20, and the active transistor regions and interconnect formed thereon.

Next in Fig. 7, the backside surface of substrate

10 is partially removed by grinding, etching, or CMP (chemical-mechanical polishing) so that the total thickness of substrate 10 and/or silicon layer 20 is in the range of 5 to 100 microns. This is in contrast to the original total thickness of structures 10 and 20 of about 500 microns. (Again, these dimensions are illustrative and not limiting.) The goal is to reduce the thickness of substrate 10 and silicon layer 20 to a minimum necessary for electrical functioning of the transistors formed therein. The removing step reduces the thickness of substrate 10 so that the bottom portion of each of trenches 72a, ..., 72e is exposed, and thereby the insulative material formed in each of these trenches is exposed at the backside surface of substrate 10. This achieves full electrical isolation of each portion of substrate 10. It is to be understood that in this case the attachment of heat sink cap 100 is done prior to the removing step to ensure that the substrate, after the removing step, remains in one integrated piece. Conventional masking, implantation, and annealing steps may be added to this process, as desired to form N+ or P+ contacts on the backside surface of substrate 10 for subsequent metal layer 104.

Next in Fig. 8, the backside surface of substrate 10 is metallized by a conventional sputtering or evaporative process to form a metal layer 104 (aluminum) thereon having a thickness of e.g. 0.15 to 1.5 micrometers. Then metal layer 104 is conventionally covered with a mask layer, the mask layer is patterned, and metal layer 104 then etched to define backside contact pads 104a, 104b on the backside surface of substrate 10. Each of contact pads 104a, 104b is associated with a selected portion of the integrated circuit die as defined by the trenches 72a, ..., 72e. Of course each portion of the die need not

have a contact pad; contact pads 104a, 104b are only provided to those portions of the die which require same. (It is to be understood that conventionally some types of transistors do not require backside contacts.)

Next in Fig. 9, a protective/passivation layer 110 is deposited on the backside surface of substrate 10 overlying contact pads 104a and 104b. Then layer 110 is conventionally patterned to define openings 112a and 112b. Each opening 112a and 112b is associated with a particular electrical contact 90a, 90g on the upper side surface of silicon layer 20, as shown.

Next in Fig. 10, a deep silicon etch is undertaken through openings 112a and 112b to define vias 116a, 116b extending through substrate 10 and/or silicon layer 20 to expose the underside portions of electrical contacts 90a, 90g. This deep silicon etching step uses a wet or wet/dry or dry etching technique.

Vias 116a, 116b need only be wide enough to establish good electrical paths to contacts 90a, 90g and otherwise their dimensions in terms of width are not critical; neither is their cross-sectional shape critical. Then as shown in Fig. 10 the remaining portions of layer 110 may be conventionally stripped off or kept as a passivation layer.

Next in Fig. 11 by a plating step (electrodeposition), vias 116a and 116b are filled with a solderable metal (e.g. nickel, gold, copper) to define posts 124, 130 extending therefrom. In the same electrodeposition step, metal posts 126, 128 are deposited on metal contacts 104a, 104b.

Alternatively, posts 126, 128 are formed by screen printing the desired type of metal on respectively the backside 104, 104b interconnection leads to establish the desired thickness for the surface mount posts. The diameter of the surface mount posts may vary, depending on the particular application.

Next in Fig. 12, an (optional) passivation layer 136 is deposited over all exposed surfaces of the surface mount posts 124, 126, 128 and 130 to a thickness of 0.8 to 1.2 micrometers. Passivation layer 136 is e.g. polyamide or low temperature oxide.

Then portions of passivation layer 136 are removed (by masking and etching or other means, for instance CMP) from the bottom surfaces of each surface mount post 124, 126, 128, 130, so as to leave the post bottom surfaces exposed for soldering, such as to a printed circuit board. The height of the surface mount posts extending from the lower backside surface of substrate 10 is conventionally 10 to 300 micrometers, or any other height as needed depending on the mounting application.

In Fig. 12 all of the electrical interconnections to outside of the chip are provided on the backside surface of substrate 10 by the surface mount posts 124, 126, 128 and 130.

Subsequently (not shown) the wafer is scribed into individual integrated circuit die along predescribed scribe lines which are for instance adjacent to dielectrically filled trenches. Thus as a result of the scribing step, the various integrated circuit die are already packaged by the top side cap 100 and the bottom side passivation layer 136; hence no further packaging is needed.

Flip Chip Embodiment

In the flip chip embodiment, the initial processing steps are identical to those shown in Figs. 1 to 5 for the surface mount embodiment, resulting in the structure of Fig. 13. Again, the flip chip embodiment is not limited to semiconductor devices of the type shown. The structure of Fig. 13 is identical to that of Fig. 5, except that in Fig. 13 the next step is that passivation layer 160 (which is similar in

material and thickness to passivation layer 96 in Fig. 6) is masked using a mask layer (not shown) which is patterned, with subsequent etching to define contact openings 164a, 164b, therethrough. Contact openings 164a, 164b, expose a portion of the underlying electrical contacts 90a, 90g. The goal in this embodiment is to define both substrate frontside and backside electrical contacts; openings 164a, 164b define the frontside contact openings.

Next in Fig. 14, silicon (or other suitable material) heat sink cap 172 is provided, having formed thereon (prior to assembly to the substrate 10) metal (aluminum or a solderable material) interconnect structures 176a, 176b. Interconnect structures 176a, 176b include interconnect lines on the surface of cap 172 which faces contacts 90a, 90b; these interconnect lines have a thickness of e.g. 10 to 50 micrometers. Cap 172 is electrically insulated on all surfaces by e.g. oxide dielectric layer 175. Interconnect structures 176a, 176b are then conventionally soldered or sintered to underlying contacts 90a, 90g. This electrical contact can be provided by any other conventional method.

Cap 172 is attached to the underlying structure by a high performance thermally conductive (and electrically insulative) epoxy resin layer 168 (or other high performance adhesive) formed on passivation layer 160 to a thickness of 25 to 250 micrometers. Adhesive layer 168 is prevented from fouling the electrical interconnections (between elements 176a, 176b and 90a, 90b) by masking and etching the adhesive layer 168 or by polishing it away from the interconnections. For instance, adhesive layer 168 is initially formed in a thick layer covering structures 176a, 176b, then etched back to expose the ends of structures 176a, 176b using a wet or dry etch.

It is to be understood that cap 172 serves as a heat sink and supports contact structures 176a, 176b which connect through vias extending through cap 172 to form interconnect contacts 174a, 174b on the opposite surface of cap 172. These interconnect contacts 174a, 174b are suitable for attachment to an underlying supporting conventional flip chip-type back plate (not shown) providing mechanical support and electrical bonds thereto.

Next in Fig. 15, (similar to Fig. 7) the backside surface of substrate 10 is polished or etched away to expose the lower portions of dielectrically insulated trenches 72a, ..., 72e. Again, the total thickness of substrate 10 and silicon layer 20 is minimized by this removing step to that needed for proper electrical functioning. Next in Fig. 16, backside contacts 178a, 178b are formed, similar to contacts 104a, 104b in Fig. 8. Next in Fig. 17, backside passivation layer 186 is deposited to a thickness of e.g. 0.5 to 2.5 micrometers using oxide or nitride or an oxide-nitride "sandwich" material over the backside surface of substrate 10 and initially over contact areas 178a and 178b, but is then removed from the exposed surfaces by use of a mask which is then patterned, and etching away of the unneeded portions of passivation layer 186. This exposes the bonding area of the power device drain contact 178a and a collector type drain contact 178b if desired. (Again the use of the backside contact depends on the nature of the associated semiconductor devices). Thus the flip chip configuration of Fig. 17 provides both frontside substrate electrical contacts 174a, 174b through cap 172 and also backside contacts 178a, 178b. The frontside leads are beam or tunnel lead structures or types to the transistors.

Again, after the steps of Fig. 17, the entire wafer is conventionally scribed along predetermined

scribe lines (not shown); thus as a result of scribing the chip is complete (packaged), advantageously without any need for further packaging steps.

Diamond Film Passivation Layer Embodiment

The above-described flip chip type and surface mount embodiments use conventional silicon dioxide or nitride as the dielectric insulation and passivation layer between the semiconductor wafer itself and the heat sink plate. These materials are known to provide relatively poor heat conduction, due to for instance the very low thermal conductivity of silicon dioxide of approximately 2 W/mK. In contrast, diamond film (which is also a good dielectric insulating material) provides thermal conductivities of about 2,000 W/mK. Also diamond is well known to be chemically inert, and due to its having the densest crystal lattice of any known material, the diffusion of other elements into diamond is very low. Thus diamond is not only a good dielectric insulator with excellent thermal conductivity but it is also a material which serves effectively as a passivation layer, providing good corrosion protection.

It has been determined in accordance with invention that diamond film has the best combination of thermal conductivity and electrical resistivity of available materials. Other materials such as aluminum nitride, aluminum oxide, or silicon carbide also provide high dielectric insulation but much less thermal conductivity than diamond. The only materials providing thermal conductivity similar to that of diamond film are electrically conductive metals such as copper and silver, which are not useful for passivation.

It is well known to provide chemical vapor deposition (CVD) of diamond film deposited at

temperatures of 600° to 950°C and at sub-atmospheric pressures. Typically methane or acetylene is used as the carbon source with significant partial pressure of atomic hydrogen. Excitation sources used include microwave and radio frequency plasmas, hot filament and thermal plasmas and combustion flames.

It has also been known to achieve a diamond deposition at temperatures below 600°C, for instance by using other process gas mixtures such as adding rare gases to the commonly utilized mixtures of carbon containing gases and hydrogen, mixtures of alcohols and water, halogenated gases and other gaseous combination. Typically growth rates of about 0.2 micrometers per hour have been achieved at deposition temperatures of about 400°C.

Methods for depositing diamond film in accordance with the present invention include low temperature microwave plasma assisted CVD. An alternative is an arc jet CVD process. It is known to pattern diamond films using conventional oxygen-based RIE (reactive ion etching) processes, as are well known in semi-conductor fabrication.

Thus in accordance with the invention for the above-described surface mount embodiment, a diamond film formed by one of the above described processes (or any other process) is substituted for passivation layer 96. The diamond film is formed to be a layer e.g. approximately 0.5 to 10 micrometers thick (but this is not limiting). Then the next substitution is, instead of using an ordinary epoxy material layer 98, a thermally conductive adhesive such as commercially available silver epoxy is used to bond the plate 100 to the diamond film. All other processing steps are as described above for this embodiment.

Similarly, for the above-described flip chip type embodiment, passivation layer 160 is a CVD (or other

type) diamond film approximately 0.5 to 10 micrometers thick (again this dimension is not limiting). This diamond film is, as described above for the non-diamond film flip chip type embodiment, masked using a mask layer to pattern it to define the contact openings 164A, 164B therethrough. The remaining of the processing is as described above, using a thermally conductive (but electrically insulative) high performance adhesive to bond the heat sink cap 172 to the diamond film passivation layer 160. Thus the process steps in terms of structure are similar to those described above for the non-diamond film flip chip type embodiment, except for the presence of the diamond film passivation layer material.

The above description is illustrative and not limiting; it will be understood by one of ordinary skill in the art that further modifications will be apparent in view of this disclosure, and fall within the scope of the appended claims.

We Claim:

1. An integrated circuit comprising:

A semiconductor substrate having a principal surface;

a plurality of semiconductor devices formed in the substrate;

a pattern of conductive lines formed overlying the principal surface and in electrical contact with the devices;

a diamond film at least partially overlying the pattern of conductive lines;

a thermally conductive plate bonded to the diamond film and overlying the pattern of conductive lines; and

a plurality of insulated trenches extending from the principal surface of the substrate through the substrate and to an opposing backside surface thereof.

2. The integrated circuit of Claim 1, further comprising a plurality of electrically conductive contacts formed on the backside surface of the substrate, each conductive contact being in contact with a selected portion of the backside surface as defined by the plurality of trenches.

3. The integrated circuit of Claim 1, wherein a thickness of the substrate is less than about 50 micrometers.

4. The integrated circuit of Claim 1, further comprising a second pattern of conductive lines juxtaposed to the plate and in electrical contact with the first pattern.

5. The integrated circuit of Claim 1, wherein the substrate defines a plurality of conductive vias extending from the principal surface thereof to the backside surface thereof, each via being in electrical contact on the principal surface with a portion of the pattern of conductive lines, and each via forming an electrical contact on the backside surface.

6. The integrated circuit of Claim 5, wherein the electrical contacts on the backside surface are each a post extending from the backside surface.

7. The integrated circuit of Claim 1, wherein the diamond film has a thickness in the range of 0.5 to 10 micrometers.

8. The integrated circuit of Claim 1, wherein the diamond film is bonded to the plate by a thermally conductive adhesive layer.

9. A method of forming an integrated circuit, comprising the steps of:

providing a semiconductor substrate having a principal surface;

forming a plurality of semiconductor devices in the substrate;

forming a plurality of trenches in the substrate extending from the principal surface thereof into the substrate to a particular depth;

forming a layer of insulating material in each of the trenches;

forming a pattern of conductive lines overlying the principal surface and in electrical contact with the devices;

forming a diamond film layer overlying the substrate;

bonding a thermal conductive plate to the diamond film layer and overlying the principal surface of the substrate; and

removing a portion of the substrate from a backside surface thereof opposing the principal surface, thereby exposing at least a bottom part of each of the trenches.

10. The method of Claim 9, further comprising the steps of:

forming a conductive layer on the backside surface; and

patterning the conductive layer into a plurality of contact regions, each contact region being in contact with a selected portion of the backside surface as defined by the plurality of trenches.

11. The method of Claim 9 wherein the step of removing leaves a remaining thickness of the substrate of less than about 100 micrometers.

12. The method of Claim 9, further comprising the step of forming a second pattern of conductive lines on a surface of the plate prior to the step of bonding;

wherein the step of bonding comprises electrically contacting portions of the second pattern to portions of the first pattern.

13. The method of Claim 9 wherein the step of bonding comprises applying a thermally conductive adhesive between the diamond film layer and the plate.

14. The method of Claim 9, further comprising the steps of:

forming a plurality of vias extending from the backside surface to the principal surface of the substrate, after the step of removing;

providing conductive material in each of the vias, the conductive material in each via being in electrical contact on the principal surface with a portion of the pattern of conductive lines, and the conductive material in each via forming an electrical contact on the backside surface.

15. The method of Claim 14, wherein the step of providing conductive material comprises forming a layer of the conductive material on the backside surface, and further comprising:

forming the layer of conductive material into a plurality of posts extending outward from the backside surface, each post being electrically connected to the conductive material in one of the vias.

16. The method of Claim 9, wherein the diamond film layer is formed to a thickness in a range of 0.5 to 10 micrometers.

AMENDED CLAIMS

[received by the International Bureau on 18 September 1995 (18.09.95); original claims 1,6-9,11,13 and 16 amended; new claims 17 and 18 added; remaining claims unchanged (4 pages)]

1. An integrated circuit comprising:

A semiconductor substrate having a principal surface and a thickness less than about 100 micrometers;

a plurality of semiconductor devices formed in the substrate;

a pattern of conductive lines formed overlying the principal surface and in electrical contact with the devices;

an electrically insulating film at least partially overlying the pattern of conductive lines;

a thermally conductive plate permanently bonded to the insulating film and overlying the pattern of conductive lines; and

a plurality of insulated trenches extending from the principal surface of the substrate through the substrate and to an opposing backside surface thereof.

2. The integrated circuit of Claim 1, further comprising a plurality of electrically conductive contacts formed on the backside surface of the substrate, each conductive contact being in contact with a selected portion of the backside surface as defined by the plurality of trenches.

3. The integrated circuit of Claim 1, wherein a thickness of the substrate is less than about 50 micrometers.

4. The integrated circuit of Claim 1, further comprising a second pattern of conductive lines juxtaposed to the plate and in electrical contact with the first pattern.

5. The integrated circuit of Claim 1, wherein the substrate defines a plurality of conductive vias extending from the principal surface thereof to the backside surface thereof, each via being in electrical contact on the principal surface with a portion of the pattern of conductive lines, and each via forming an electrical contact on the backside surface.

6. The integrated circuit of Claim 5, wherein the electrical contacts on the backside surface are each a post extending from the backside surface.

7. The integrated circuit of Claim 1, wherein the insulating film has a thickness in the range of 0.5 to 10 micrometers.

8. The integrated circuit of Claim 1, wherein the insulating film is bonded to the plate by a thermally conductive adhesive layer.

9. A method of forming an integrated circuit, comprising the steps of:

providing a semiconductor substrate having a principal surface;

forming a plurality of semiconductor devices in the substrate;

forming a plurality of trenches in the substrate extending from the principal surface thereof into the substrate to a particular depth;

forming a layer of insulating material in each of the trenches;

forming a pattern of conductive lines overlying the principal surface and in electrical contact with the devices;

forming an electrically insulating film layer overlying the substrate;

permanently bonding a thermal conductive plate to the insulating film layer and overlying the principal surface of the substrate; and

removing a portion of the substrate from a backside surface thereof opposing the principal surface, thereby exposing at least a bottom part of each of the trenches and reducing a thickness of the substrate to less than about 100 micrometers.

10. The method of Claim 9, further comprising the steps of:

forming a conductive layer on the backside surface; and

patterning the conductive layer into a plurality of contact regions, each contact region being in contact with a selected portion of the backside surface as defined by the plurality of trenches.

11. The method of Claim 9 wherein the step of removing leaves a remaining thickness of the substrate of less than about 50 micrometers.

12. The method of Claim 9, further comprising the step of forming a second pattern of conductive lines on a surface of the plate prior to the step of bonding;

wherein the step of bonding comprises electrically contacting portions of the second pattern to portions of the first pattern.

13. The method of Claim 9 wherein the step of bonding comprises applying a thermally conductive adhesive between the insulating film layer and the plate.

14. The method of Claim 9, further comprising the steps of:

forming a plurality of vias extending from the backside surface to the principal surface of the substrate, after the step of removing;

providing conductive material in each of the vias, the conductive material in each via being in electrical contact on the principal surface with a portion of the pattern of conductive lines, and the conductive material in each via forming an electrical contact on the backside surface.

15. The method of Claim 14, wherein the step of providing conductive material comprises forming a layer of the conductive material on the backside surface, and further comprising:

forming the layer of conductive material into a plurality of posts extending outward from the backside surface, each post being electrically connected to the conductive material in one of the vias.

16. The method of Claim 9, wherein the insulating film layer is formed to a thickness in a range of 0.5 to 10 micrometers.

17. The integrated circuit of Claim 1, wherein the insulating film is a diamond film.

18. The method of Claim 9, wherein the insulating film is a diamond film.

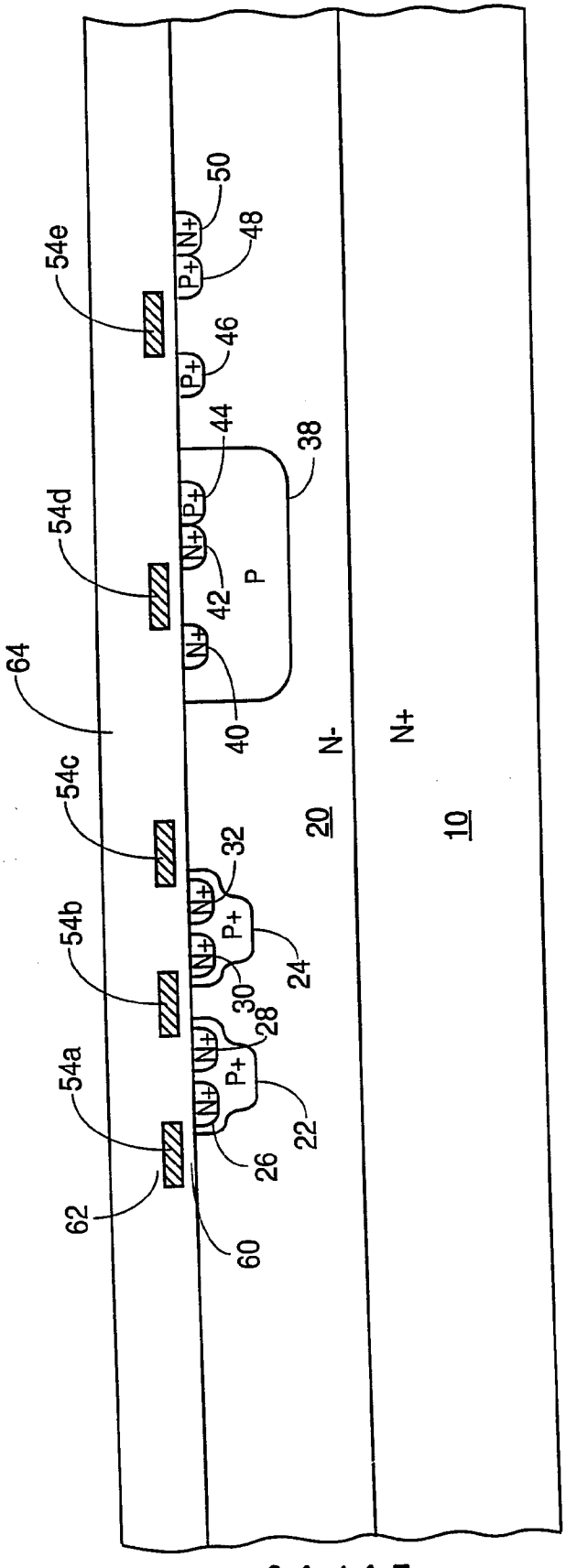

54e
54d
54c
54b
54a
62
64
60
50
48
46
44
38
42
40
32
24
30
28
26
22
P+
N+
P
N-
20
10

Fig. 1

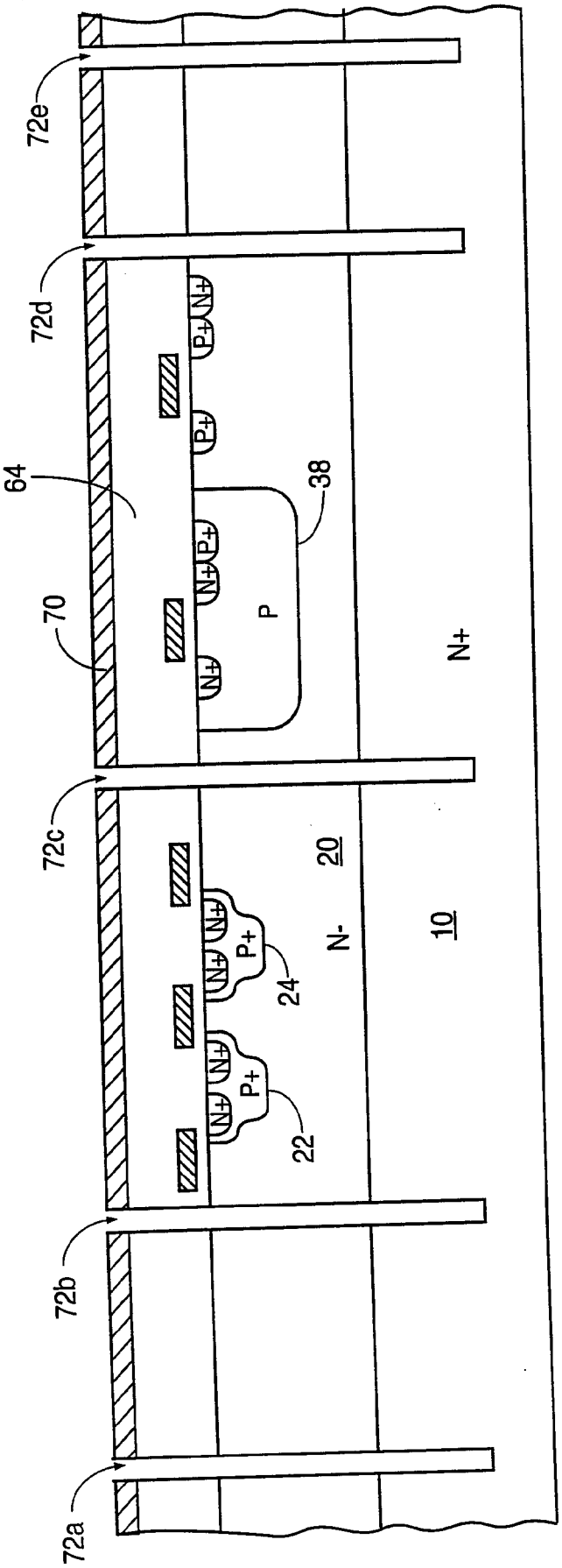


Fig. 2

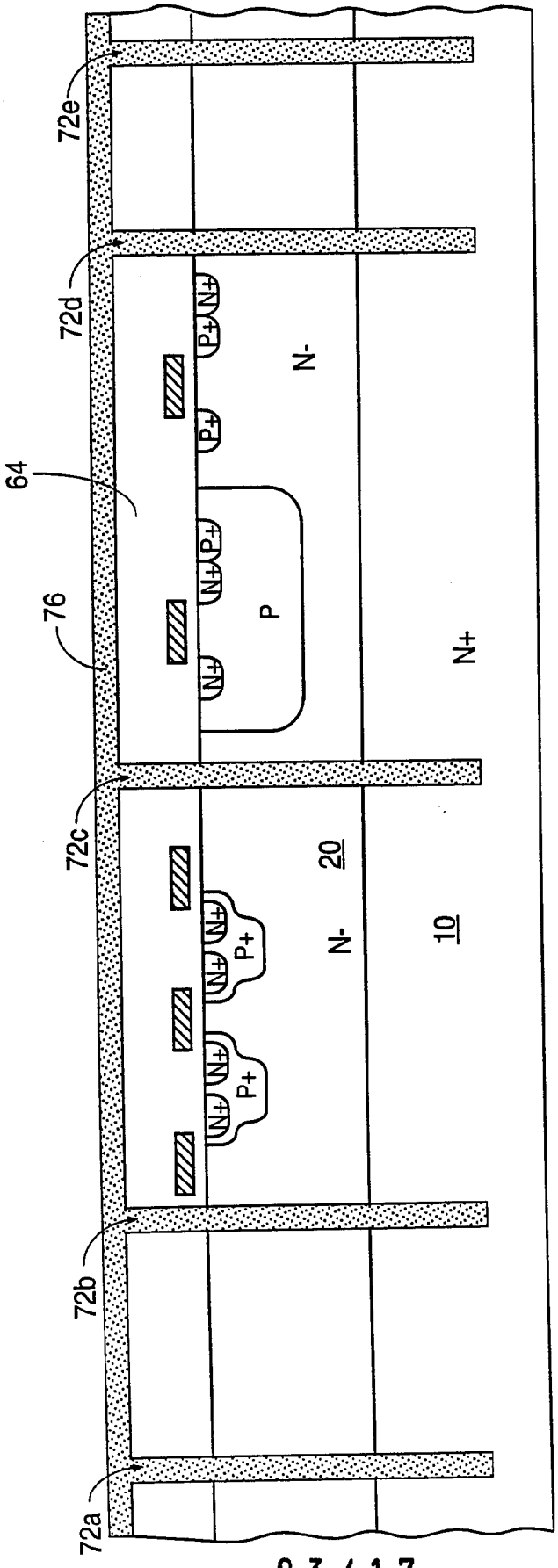


Fig. 3

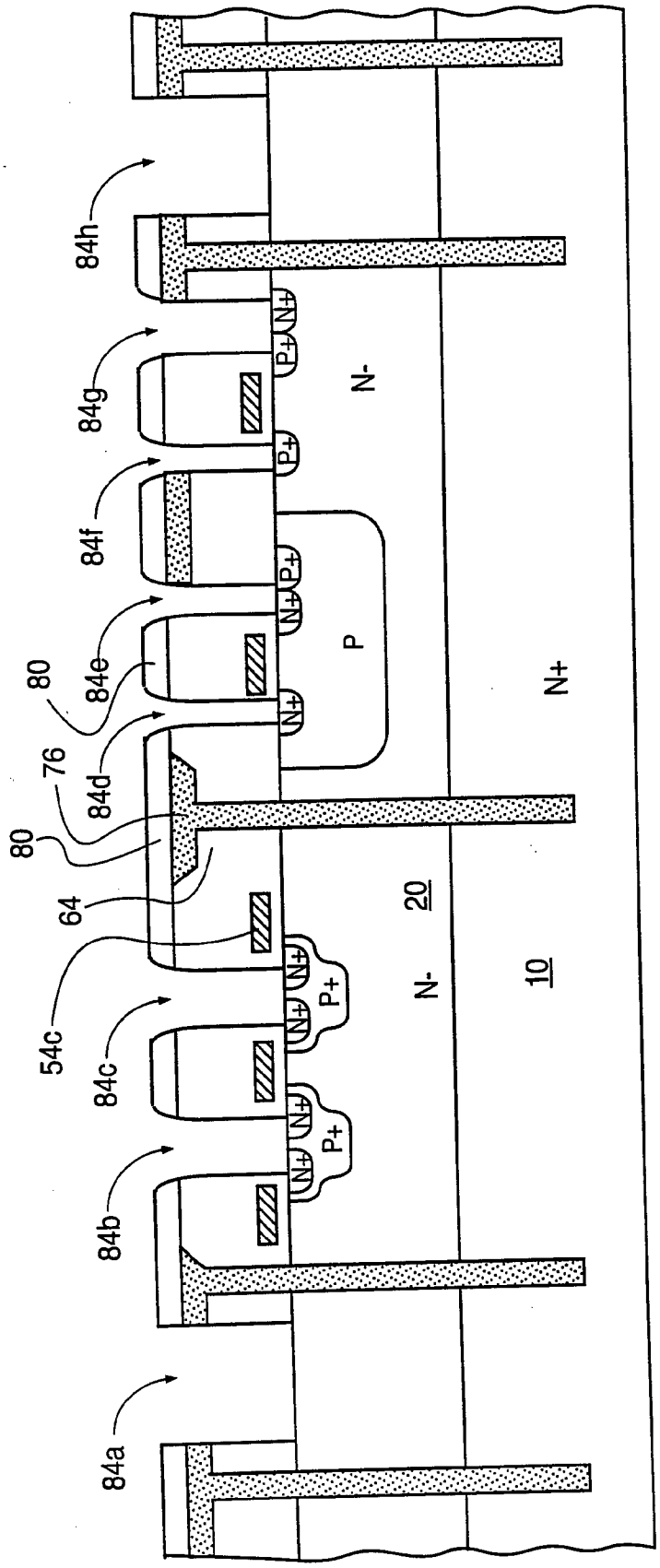

84h
84g
84f
84e
80
84d
76
80
64
54c
84c
84b
84a
N+
P+
N-
P
N+
P+
N+
P+
N+
P+
N+
N+
N-
20
10

Fig. 4

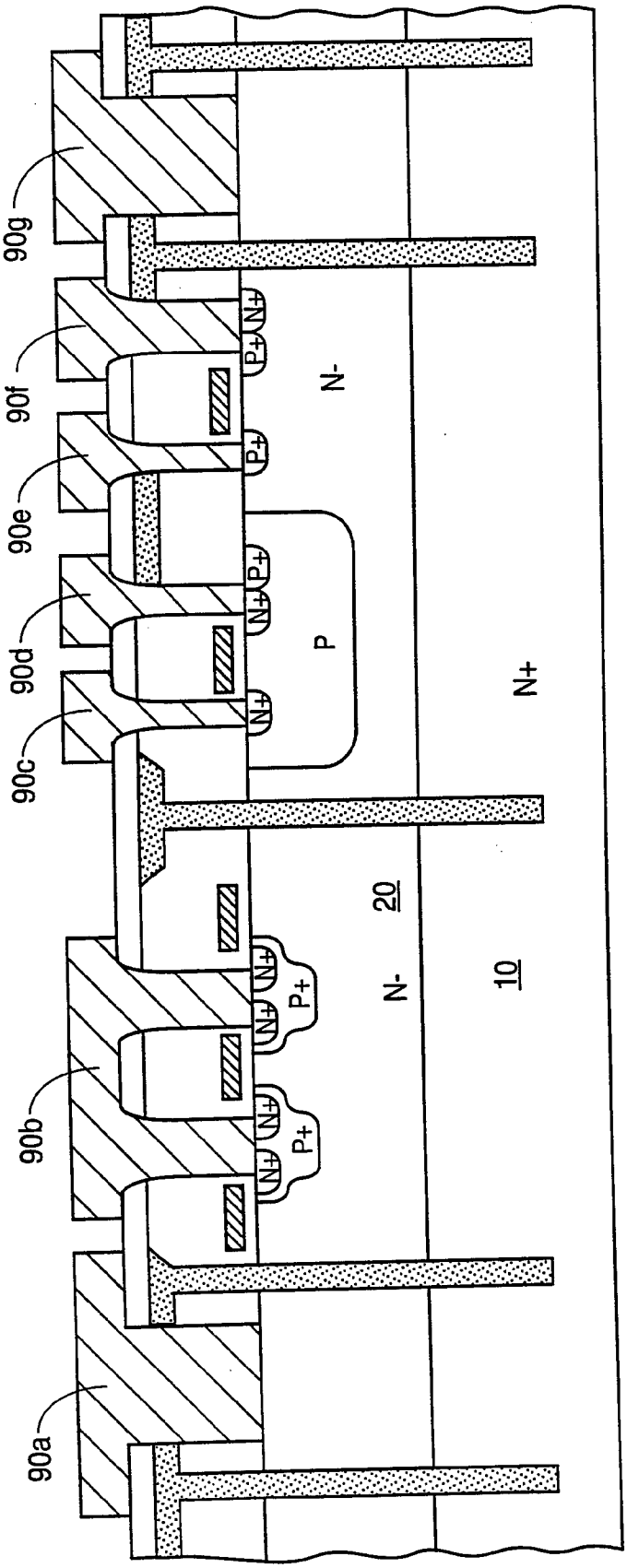


Fig. 5

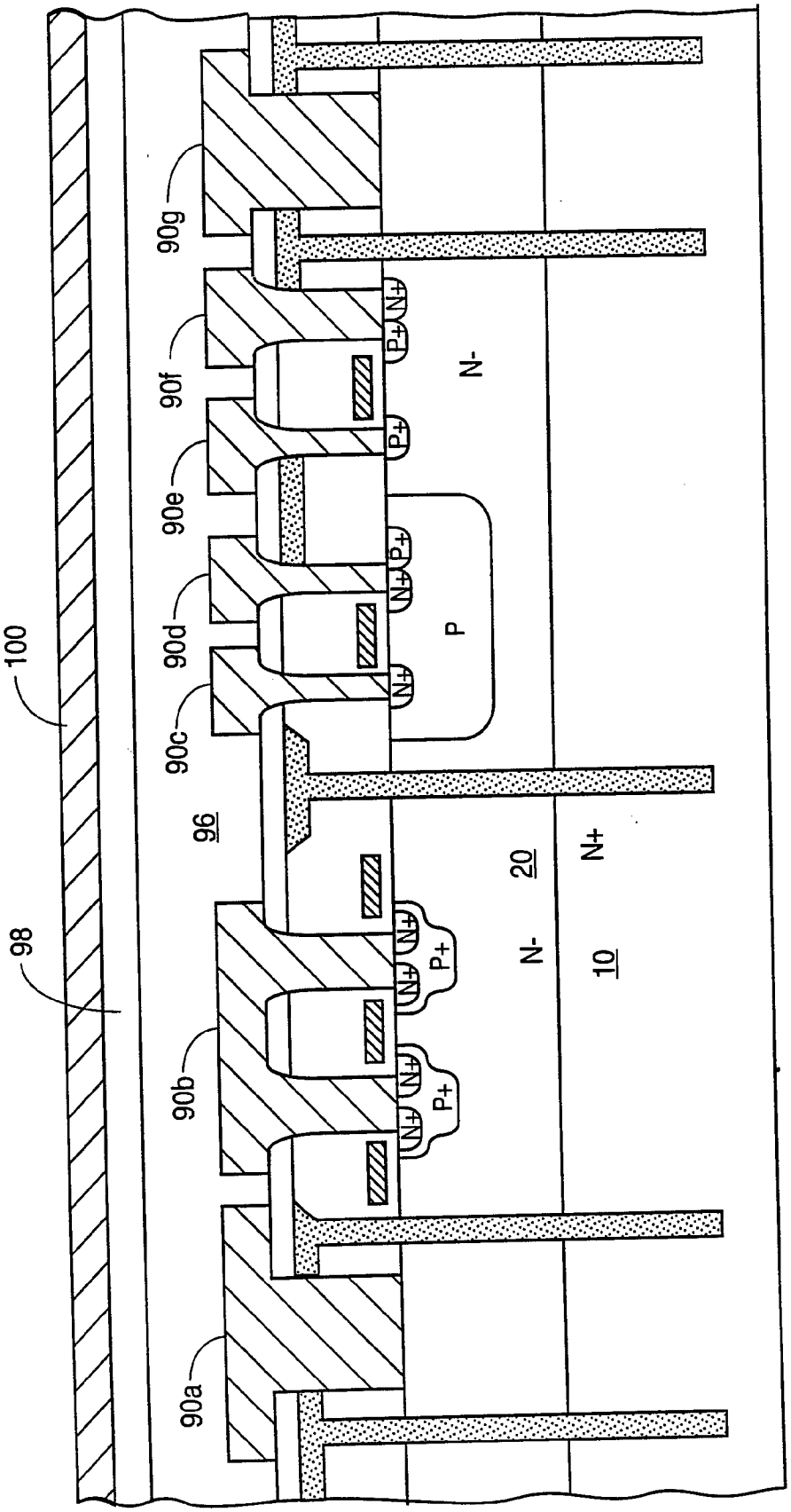


Fig. 6

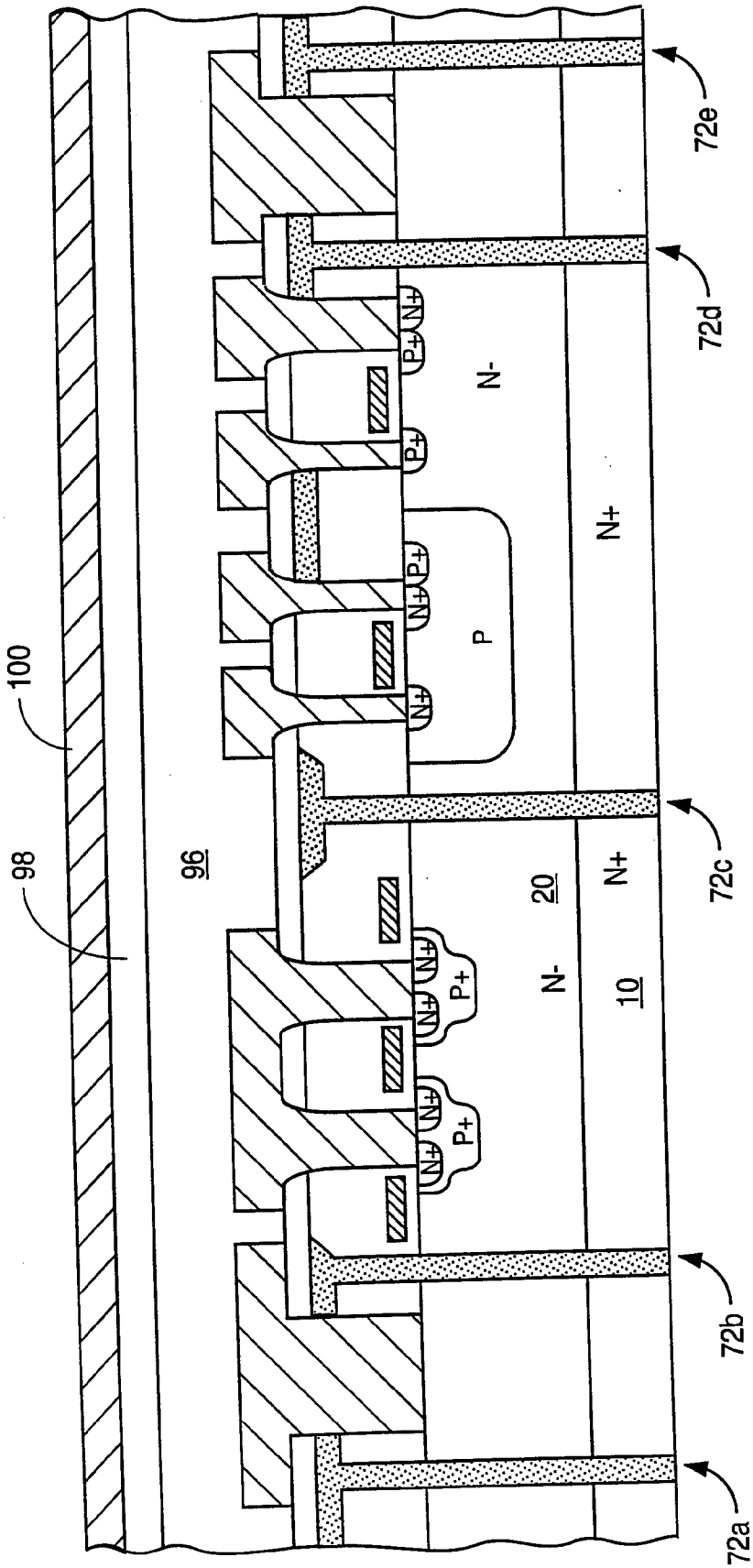


Fig. 7

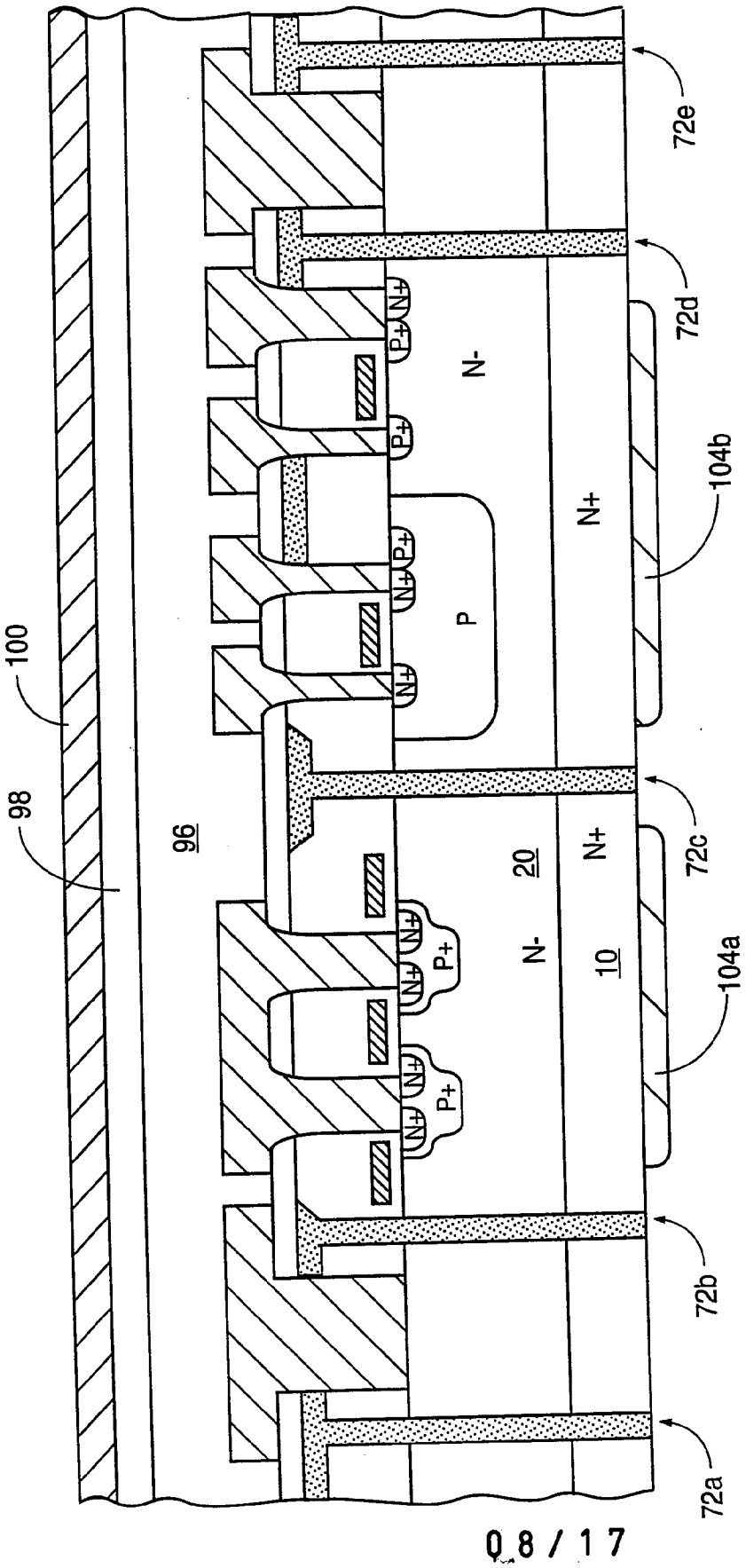


Fig. 8

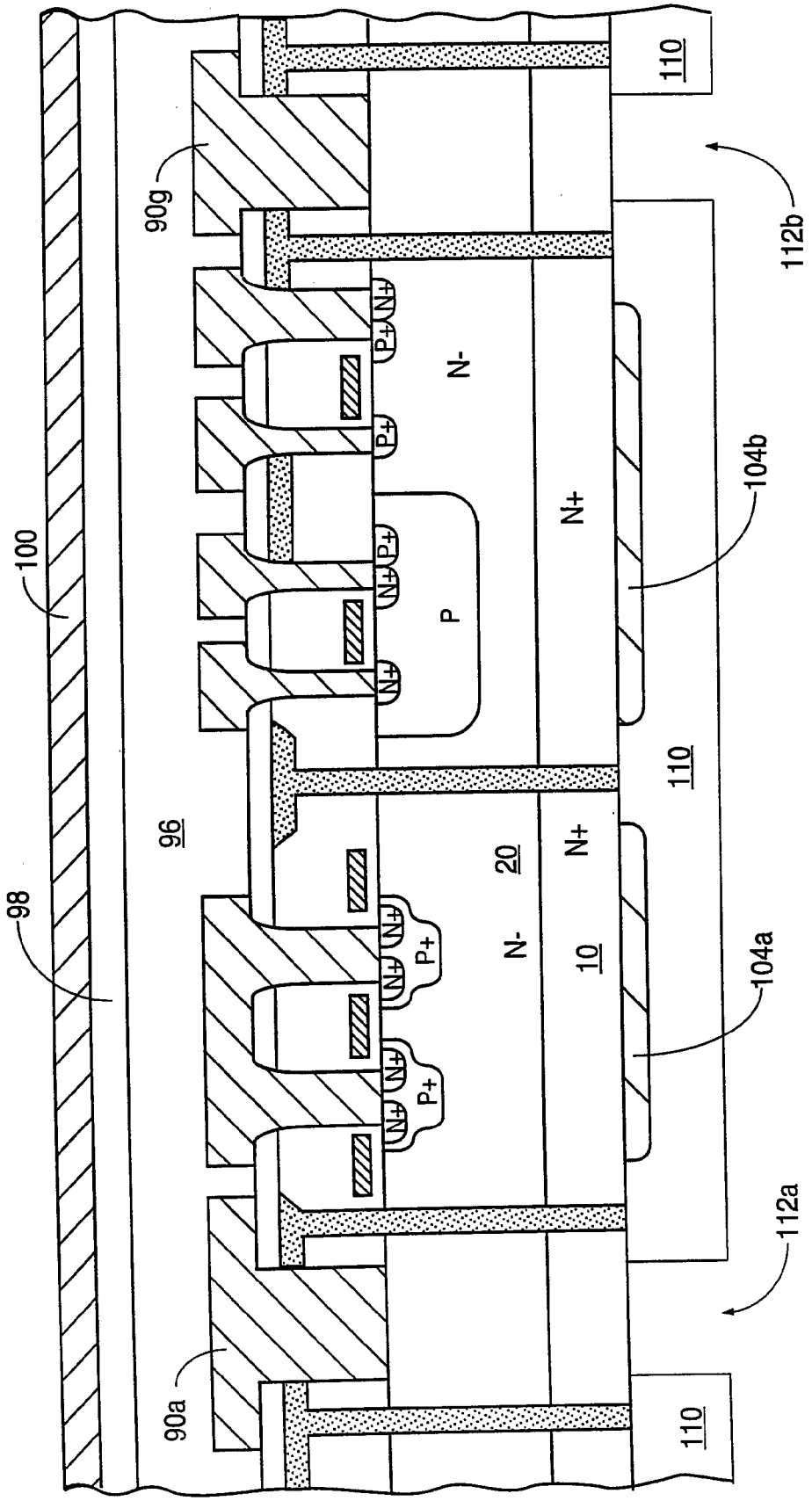


Fig. 9

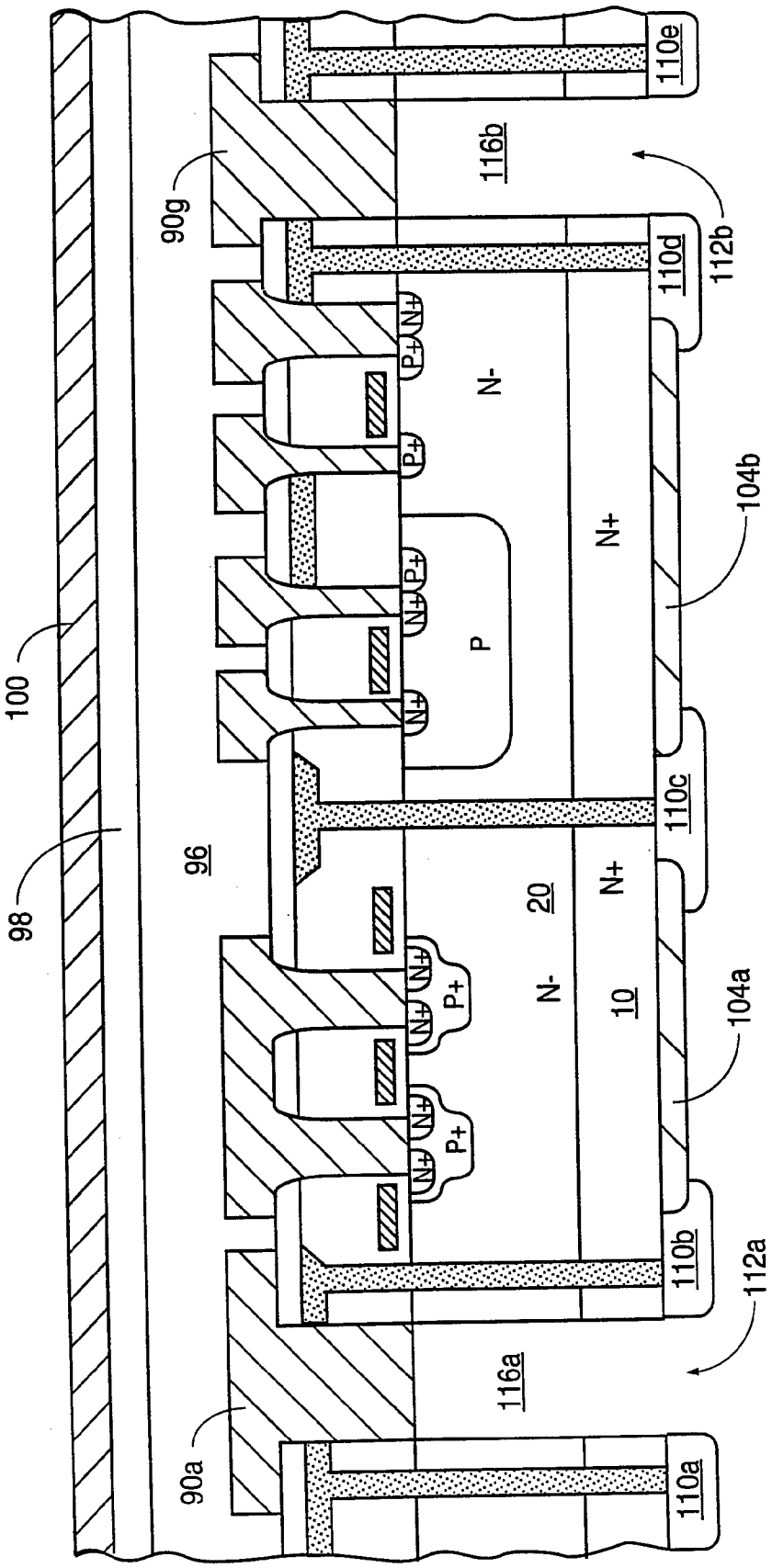

110e
116b
90g
112b
110d
N-
P+
N+
P+
P
N+
P+
N+
104b
100
110c
96
98
20
N+
N-
P+
10
N+
P+
104a
110b
112a
116a
90a
110a

Fig. 10

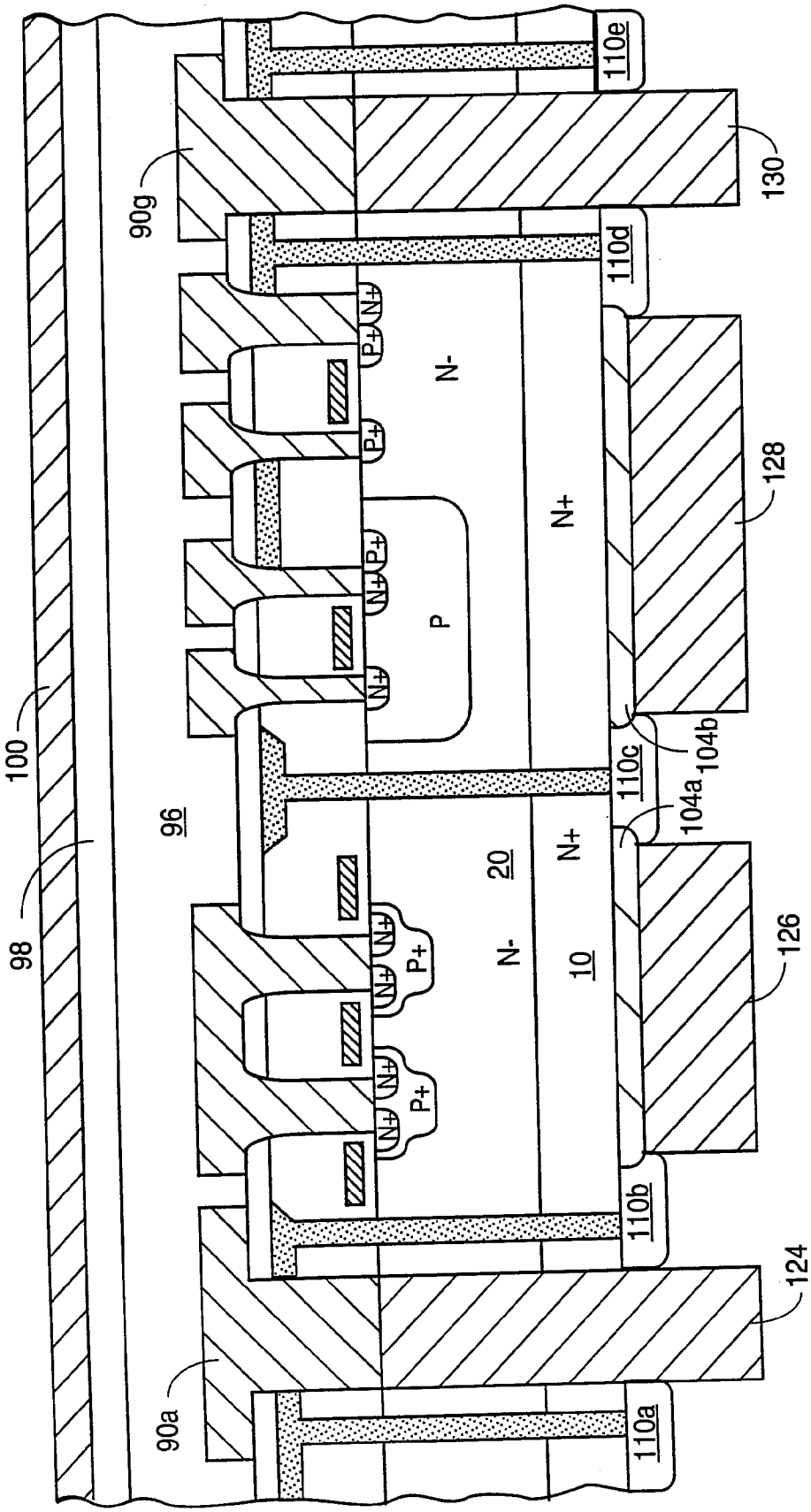

110e
130
90g
110d
N+
P+
N-
P+
128
N+
P
P+
N+
N+
104b
110c
104a
100
96
98
20
N+
N-
10
P+
126
110b
124
90a
110a

Fig. 11

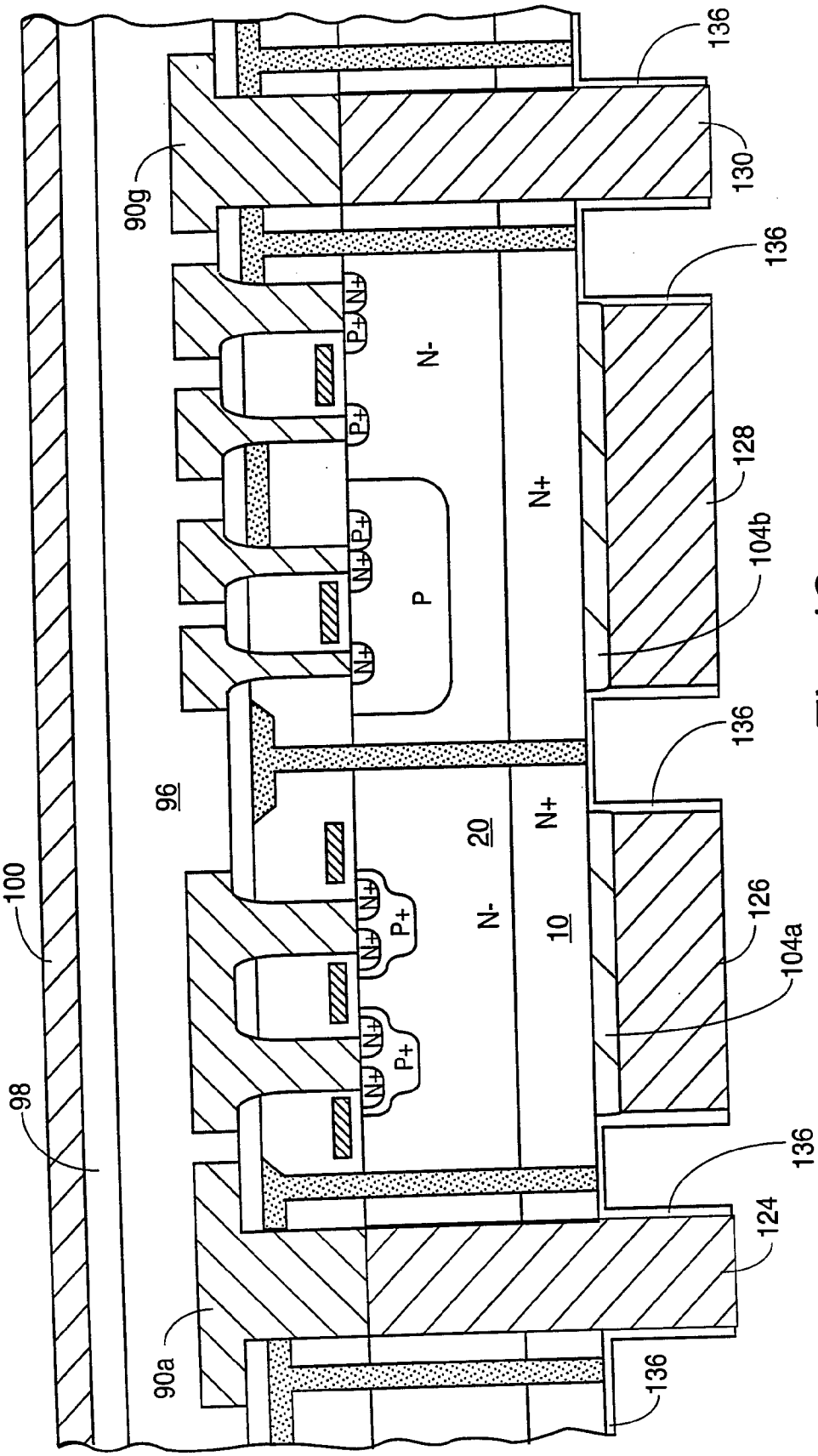

136
130
90g
136
N+
P+
N-
128
P+
104b
N+
P
N+
136
96
20
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N+
P+
N-
10
126
104a
P+
98
100
136
124
90a
136

Fig. 12

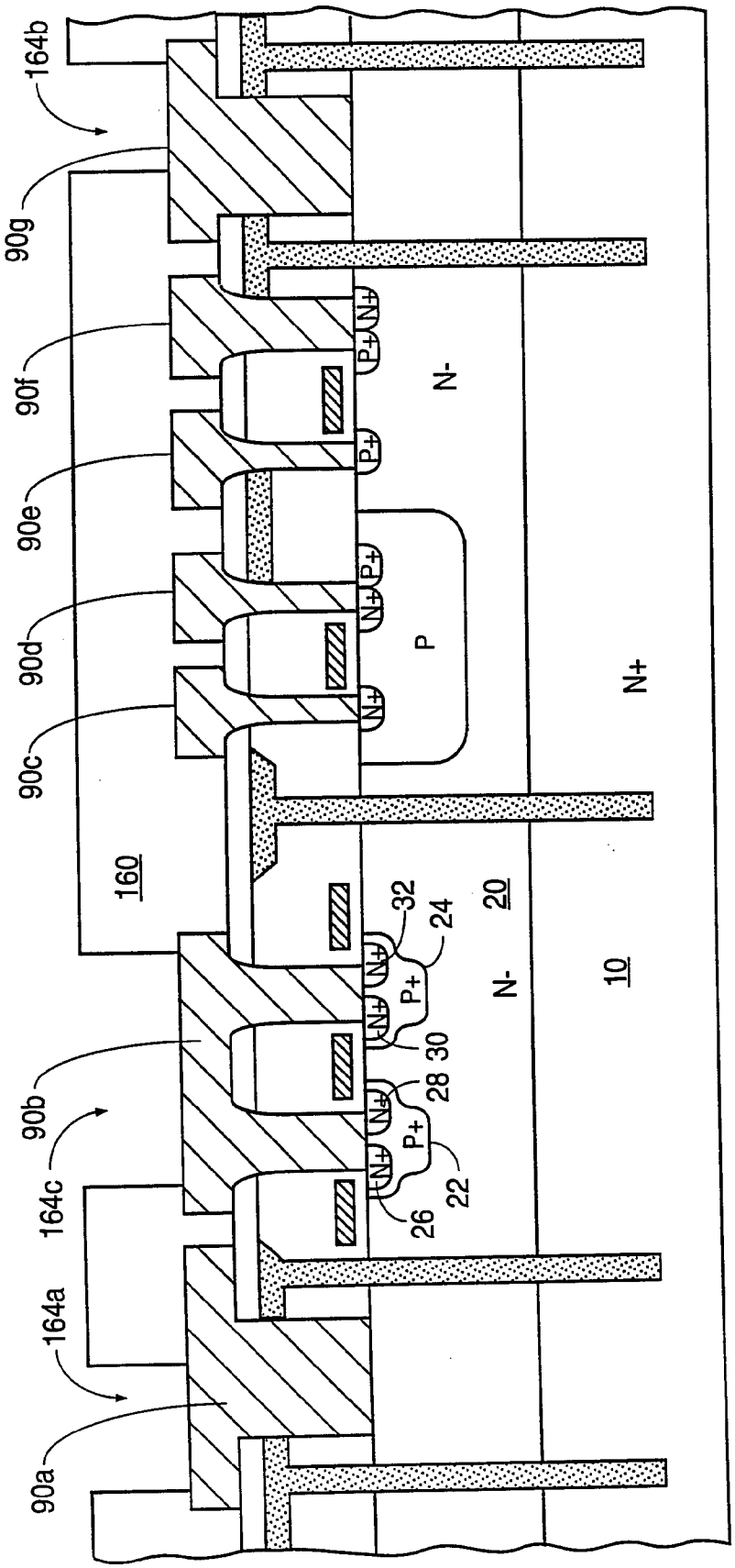

164b
90g
90f
90e
90d
90c
90b
164c
164a
90a
160
N-
P
N+
N-
20
10
32
24
30
28
22
26
N+
P+

Fig. 13

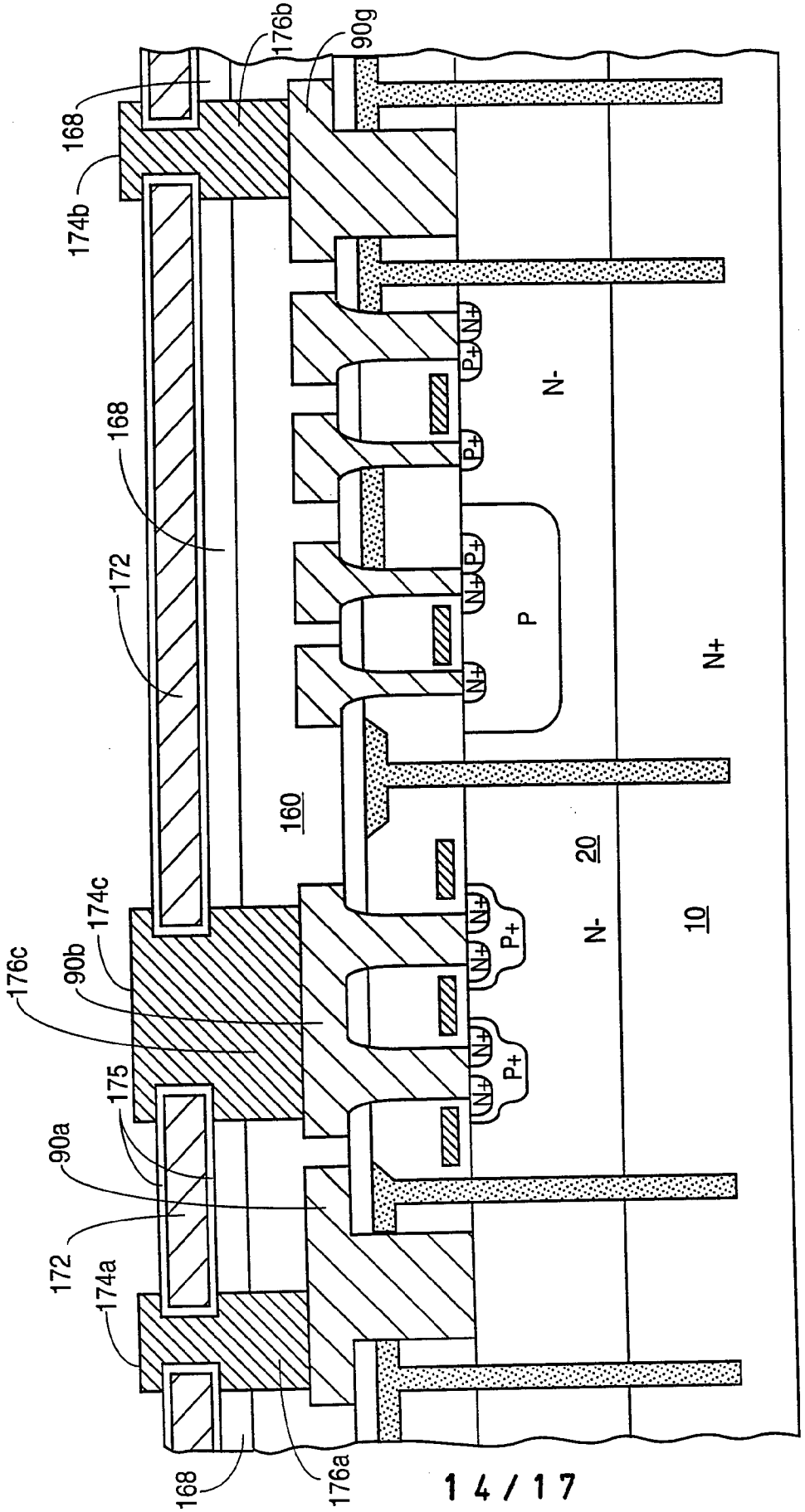

168
174b
176b
90g
168
172
160
174c
176c
90b
175
90a
172
174a
168
176a
N-
P+
N+
P
N+
N-
20
10

Fig. 14

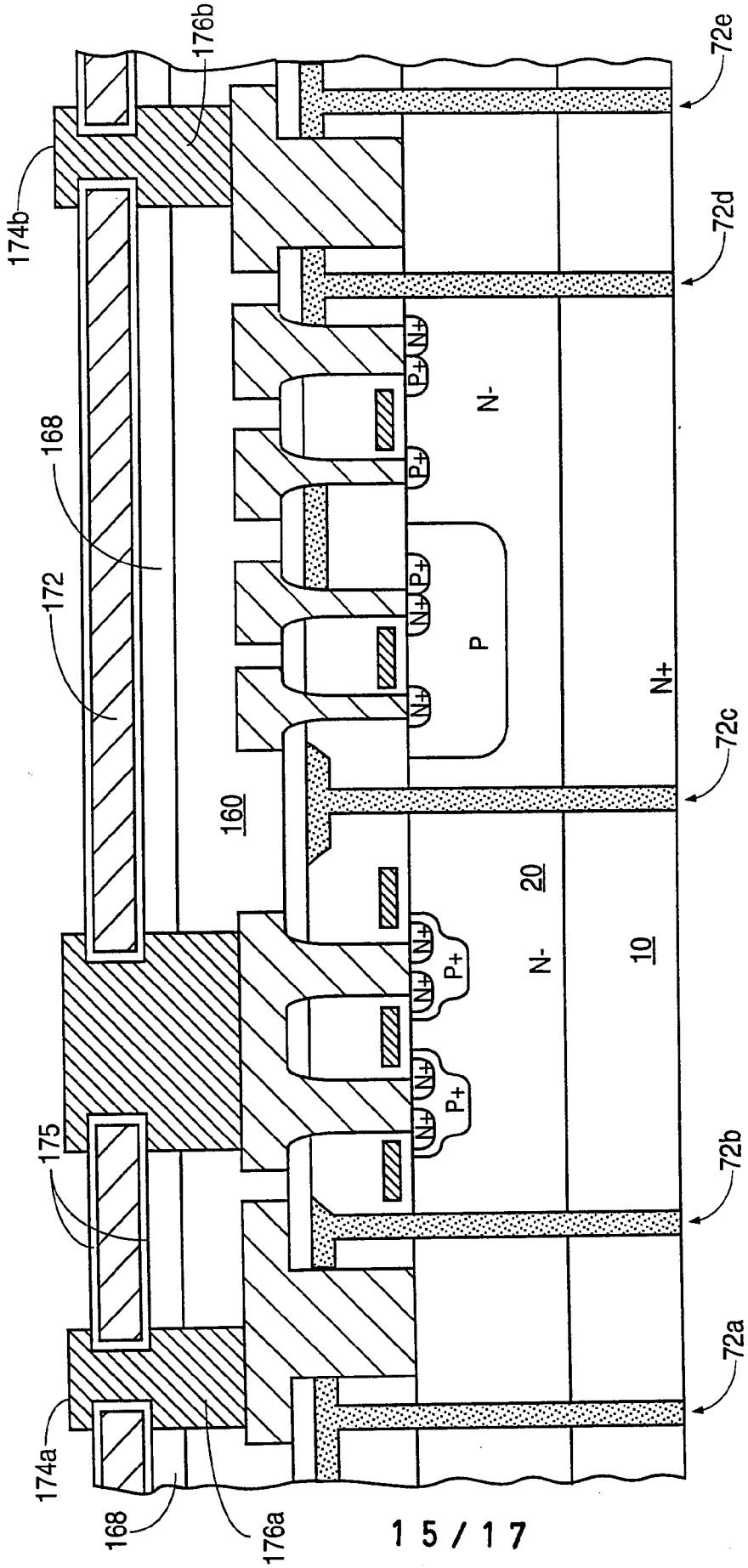


Fig. 15

Ex. 1003, Page 1181

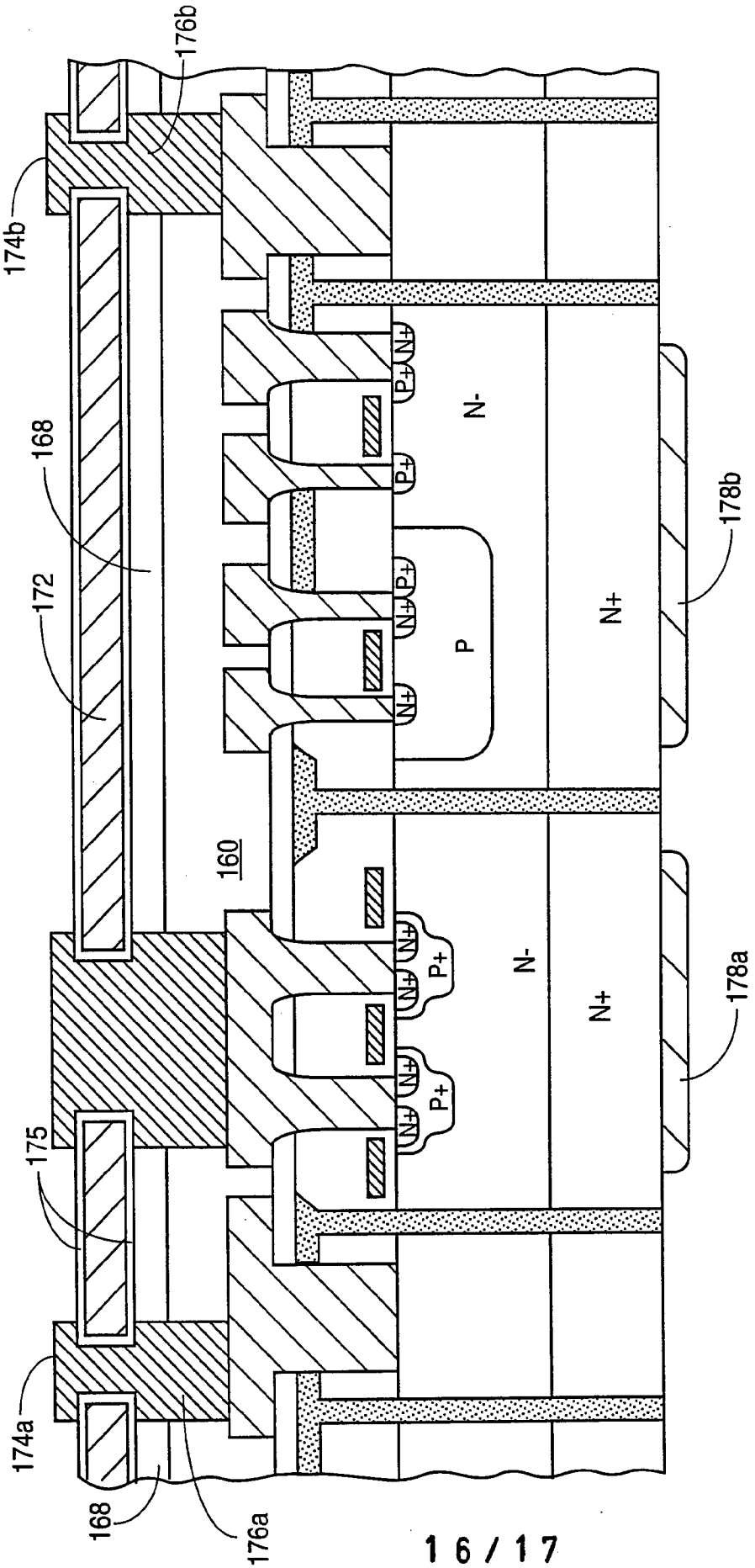


Fig. 16

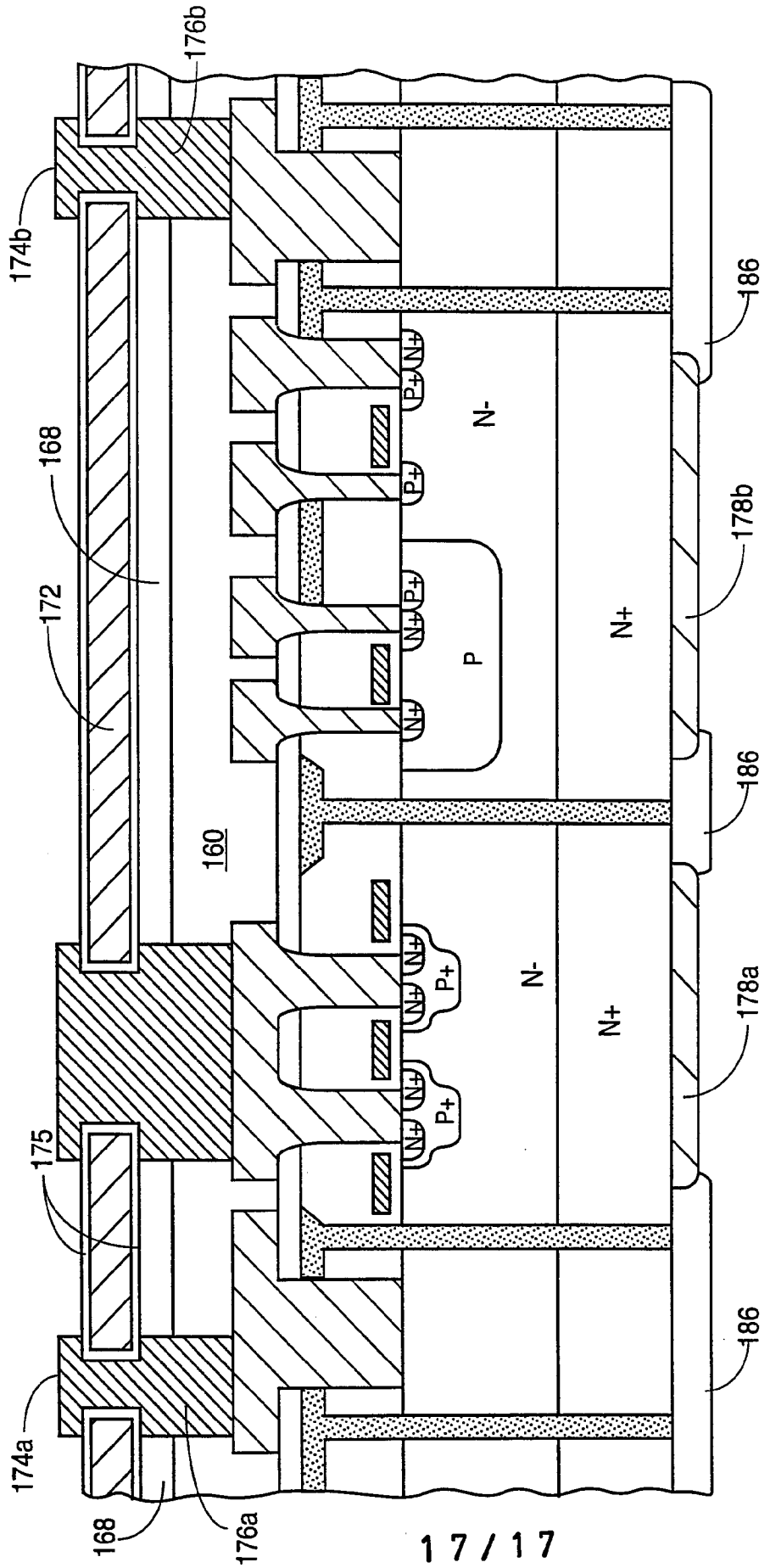


Fig. 17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/05217

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :H01L 23/48, 21/76
US CL :257/631,686,706,724; 437/62,63
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 257/631,686,706,724; 437/62,63

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

USAPS

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y, E	US,A 5,426,072 (FINNILA) 20 JUNE 1995, SEE FIGURE 6.	3,5,6, 11,14,15
Y	US,A 5,272,104 (SCHRANTZ ET AL.) 21 DECEMBER 1993, SEE FIGURE 1F.	1-16
Y	US,A 5,229,643 (OHTA ET AL.) 20 JULY 1993, SEE FIGURE 6,30,31.	1-16
Y	US,A 5,170,930 (DOLBEAR ET AL.) 15 DECEMBER 1992, SEE FIGURE 4.	8,13
Y	US,A 5,091,331 (DELGADO ET AL.) 25 FEBRUARY 1992, SEE FIGURE 1E,6,7.	1-16
Y	4,972,250 (OMORI ET AL.) 20 NOVEMBER 1990, SEE WHOLE DOCUMENT	1-16

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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Date of the actual completion of the international search	Date of mailing of the international search report
07 JULY 1995	19 JUL 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer J. CARROLL Telephone No. (703) 308-4926

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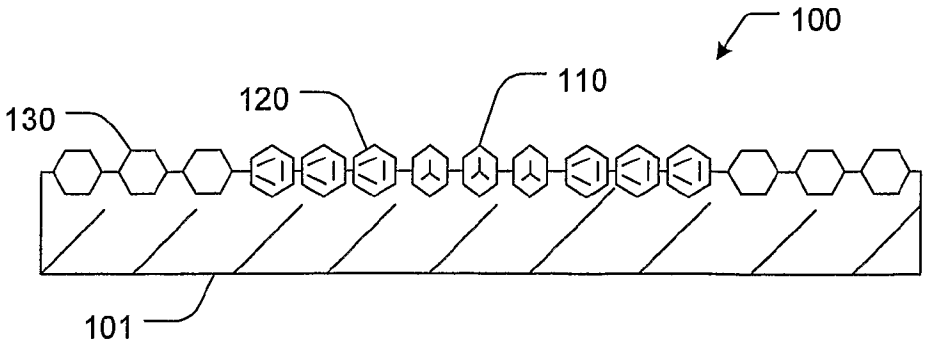
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: CMP PADE DRESSER WITH ORIENTED PARTICLES AND ASSOCIATED METHODS



(57) Abstract: CMP pad dressers (100) with superabrasive particles (130, 120, 110) oriented into an attitude that controls CMP pad performance, and methods associated therewith are disclosed and described. The controlled CMP pad performance may be selected to optimize CMP pad dressing rate and dresser wear.

WO 2006/039413 A2

CMP PAD DRESSER WITH ORIENTED PARTICLES AND ASSOCIATED METHODS

FIELD OF THE INVENTION

The present invention relates generally to devices and methods for use in connection with dressing or conditioning a chemical mechanical polishing (CMP) pad. Accordingly, the present invention involves the chemical and material science fields.

BACKGROUND OF THE INVENTION

Chemical mechanical process (CMP) has become a widely used technique for polishing certain work pieces. Particularly, the computer manufacturing industry has begun to rely heavily on CMP processes for polishing wafers of ceramics, silicon, glass, quartz, metals, and mixtures thereof for use in semiconductor fabrication. Such polishing processes generally entail applying the wafer against a rotating pad made from a durable organic substance such as polyurethane. To the pad is added a chemical slurry containing a chemical solution capable of breaking down the wafer substance and an amount of abrasive particles which act to physically erode the wafer surface. The slurry is continually added to the spinning CMP pad, and the dual chemical and mechanical forces exerted on the wafer cause it to be polished in a desired manner.

Of particular importance to the quality of polishing achieved, is the distribution of the abrasive particles throughout the pad. The top of the pad holds the particles, usually by a mechanism such as fibers, or small pores, which provide a friction force sufficient to prevent the particles from being thrown off of the pad due to the centrifugal force exerted by the pad's spinning motion. Therefore, it is important to keep the top of the pad as flexible as possible, and to keep the fibers as erect as possible, or to assure that there are an abundance of openings and pores available to receive new abrasive particles.

A problem with maintaining the top of the pad is caused by an accumulation of polishing debris coming from the work piece, abrasive slurry, and dressing disk. This accumulation causes a "glazing" or hardening of the top of the pad that mats the fibers down, thus making the pad less able to hold the abrasive particles of the slurry, and thus significantly decreases the pad's overall polishing performance. Further, with many pads the pores used to hold the slurry become clogged, and the overall asperity of the pad's polishing surface becomes depressed and matted. Therefore, attempts have been made to revive the top of the pad by "combing" or "cutting" it with various devices. This process has come to be

known as "dressing" or "conditioning" the CMP pad. Many types of devices and processes have been used for this purpose. One such device is a disk with a plurality of super hard crystalline particles, such as diamond particles attached to a surface, or substrate thereof.

Yet another disadvantage with modern CMP pad dressers is reduced life of the pad conditioner and CMP pad. As noted, abrasive particles and CMP pads can wear out prematurely when the particles cut too deeply into the pad and consume the pad unnecessarily. Such premature wear reduces the ability of the CMP pad dresser to effectively polish the work piece. When functioning optimally, the abrasive particles act to refurbish the asperities in the CMP pad, and thus create an optimal polishing environment.

The rate at which a CMP pad is dressed may affect the surface roughness of the pad, which in turn may determine the amount of slurry held on the surface and thus affect polishing rate. In general, the polishing rate of the wafer is proportional to the dressing rate. However, if he dressing rate is excessive, the pad surface may become overly rough, and thus decrease the uniformity of the polished wafer. As such, optimizing the dressing rate may improve polishing rate without adversely affecting the quality of the wafer.

In view of the foregoing, it is desirable to obtain CMP pad dressers and methods configured to control dresser performance in order to achieve optimal dressing results, with maximized efficiency and lifespan for various applications.

SUMMARY OF THE INVENTION

Accordingly, in one aspect, the present invention provides methods and CMP pad dresser configurations for controlling CMP pad dresser performance. In one such method, a CMP pad dresser is provided which employs a plurality of superabrasive particles each coupled to a substrate member and oriented into an attitude that provides anticipated performance characteristic as part of the CMP pad dresser fabrication performance. In other aspects, the performance characteristic of the present invention can optimize dressing rate and dresser wear. Furthermore, in another aspect of the present invention, the performance characteristic can be an optimized balance of dressing rate and dresser wear. It has been discovered that orienting the superabrasive particles in a predetermined pattern or configuration can enhance and optimize the dressing rate and dresser wear. More particularly, a method that employs superabrasive particles to have a predetermined attitude can control the dresser performance characteristics.

In accordance with one aspect of the present invention, the method involves providing a substrate, and then coupling a plurality of superabrasive particles to the substrate such that

the superabrasive particles are oriented in an attitude that provides optimal dresser characteristics. The coupled superabrasive particles can be substantially configured in an attitude having an apex portion oriented towards a pad to be dressed. Further, the superabrasive particles can be configured in an attitude having an edge portion or face portion oriented towards a pad to be dressed. Such varied orientation can alter the dresser performance characteristics to obtain a dresser that has an optimized dressing rate and dresser wear.

In an another aspect, superabrasive particles in a central location can be oriented in an attitude having an apex portion oriented toward a pad to be dressed and superabrasive particles in a peripheral location can be disposed on the substrate or surface in an attitude having either a face or an edge portion oriented toward a pad to be dressed. Varied orientations can create various asperity patterns in the CMP pad. Such patterns can provide variability in the dresser performance by providing asperities that increase the wafer polishing rate while reducing the particle wear. For example, in one aspect, the dresser rate and dresser wear can be balanced by configuring the attitude of centrally located particles to be an apex, the attitude of the peripherally located particles to be a face and any particles therebetween to have an attitude of an edge oriented towards a pad to be dressed.

In yet another aspect of the present invention, a method for optimizing dresser performance may include providing a CMP pad dresser having a plurality of superabrasive particles centrally located which are of a lower quality than peripherally located superabrasive particles. The lower quality can be a number of characteristics such as, lower internal quality, lower shape quality, etc. It has been found that particles of lower shape quality, such as irregular shapes, can dress a CMP pad more aggressively than those of higher shape quality, however, the lower quality particles have a slower pad dressing rate because they are prone to chipping and breaking. On the other hand, the higher shape qualities, such as octahedral or cubo-octahedral, dress less aggressively, however, have more durability, allowing for a higher dressing rate. The durability also helps shield the inner or central particles from excessive wear. Therefore, placing a lower quality particle in the central location of the pad dresser and a higher quality particle on the peripheral, can result in a balanced dressing rate and dresser wear.

In addition to the above-recited methods of use, the present invention also includes methods for producing a CMP pad dresser that optimizes dresser performance by orienting the superabrasive particles in a predetermined pattern. Generally speaking, such a method may include providing a substrate, selecting an attitude for superabrasive particles that

provides an anticipated performance characteristic, orienting the superabrasive particles in an attitude in relation to the substrate, and bonding the superabrasive particles to the substrate in the selected attitude.

Using the methods described above, CMP pad dressers exhibiting considerable advantages may be created. For example, the CMP pad dressing performance can be controlled to optimize CMP pad dressing rate and dresser wear. Such optimized performance can create a balance between dresser wear and dressing rate, thus lengthening the service life of the dresser, while maximizing the rate at which the dresser grooms the pad.

The above-recited features and advantages of the present invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side view of a CMP pad dresser in accordance with one embodiment of the present invention.

FIG. 2 is a side view of a CMP pad dresser in accordance with one embodiment of the present invention.

FIG. 3 is a side view of a CMP pad dresser in accordance with one embodiment of the present invention.

FIG. 4 is a side view of a CMP pad dresser in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Before the present CMP pad dresser and accompanying methods of use and manufacture are disclosed and described, it is to be understood that this invention is not limited to the particular process steps and materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

It must be noted that, as used in this specification and the appended claims, the singular forms "a," and, "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to an "abrasive particle" or a "grit" includes reference to one or more of such abrasive particles or grits.

Definitions

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

As used herein, "superabrasive particles" and "superabrasive grit" or similar phrases may be used interchangeably, and refer to any natural or synthetic super hard crystalline, or polycrystalline substance, or mixture of substances and include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), and polycrystalline cubic boron nitride (PcBN). Further, the terms "abrasive particle," "grit," "diamond," "polycrystalline diamond (PCD)," "cubic boron nitride," and "polycrystalline cubic boron nitride, (PcBN)," may be used interchangeably.

As used herein, "superhard" and "superabrasive" may be used interchangeably, and refer to a crystalline, or polycrystalline material, or mixture of such materials having a Vicker's hardness of about 4000 Kg/mm^2 or greater. Such materials may include without limitation, diamond, and cubic boron nitride (cBN), as well as other materials known to those skilled in the art. While superabrasive materials are very inert and thus difficult to form chemical bonds with, it is known that certain reactive elements, such as chromium and titanium are capable of chemically reacting with superabrasive materials at certain temperatures.

As used herein, "substrate" means a portion of a CMP dresser which supports abrasive particles, and to which abrasive particles may be affixed. Substrates useful in the present invention may be any shape, thickness, or material, that is capable of supporting abrasive particles in a manner that is sufficient provide a tool useful for its intended purpose. Substrates may be of a solid material, a powdered material that becomes solid when processed, or a flexible material. Examples of typical substrate materials include without limitation, metals, metal alloys, ceramics, and mixtures thereof. Further the substrate may include brazing alloy material.

As used herein, "leading edge" means the edge of a CMP pad dresser that is a frontal edge based on the direction that the CMP pad is moving, or the direction that the pad is moving, or both. Notably, in some aspects, the leading edge may be considered to encompass not only the area specifically at the edge of a dresser, but may also include portions of the dresser which extend slightly inward from the actual edge. In one aspect, the leading edge may be located along an outer edge of the CMP pad dresser. In another aspect, the CMP pad dresser may be configured with a pattern of abrasive particles that provides at least one effective leading edge on a central or inner portion of the CMP pad dresser working

surface. In other words, a central or inner portion of the dresser may be configured to provide a functional effect similar to that of a leading edge on the outer edge of the dresser.

As used herein, "sharp portion" means any narrow portion to which a crystal may come, including but not limited to corners, ridges, edges, obelisks, and other protrusions.

As used herein, "centrally located particle," "particle in a central location" and the like mean any particle of a dresser that is located in an area of a dresser that originates at a center point of the dresser and extends outwardly towards the dresser's edge for up to about 90% of the radius of the dresser. In some aspects, the area may extend outwardly from about 20% to about 90% of the radius. In other aspects, the area may extend out to about 50% of the radius. In yet another aspect, the area may extend out to about 33% of the radius of a dresser.

As used herein, "peripherally located," "particles in a peripheral location" and the like, mean any particle of a dresser that is located in an area that originates at the leading edge or outer rim of a dresser and extends inwardly towards the center for up to about 90% of the radius of the dresser. In some aspects, the area may extend inwardly from about 20% to 90% of the radius. In other aspects, the area may extend in to about 50% of the radius. In yet another aspect, the area may extend in to about 33% of the radius of a dresser (i.e. 66% away from the center).

As used herein, "working end" refers to an end of a particle which is oriented towards the CMP pad and during a dressing operation makes contact with the pad. Most often the working end of a particle will be distal from a substrate to which the particle is attached.

As used herein, "quality" means a degree or grade of excellence. Each characteristic or property of a superabrasive particle such as internal crystalline perfection, shape, etc. may be ranked in order to determine the quality of the particle. A number of established quality scales exist in the area of diamonds and other superabrasives, such as the Gemological Institute of America (GIA) Diamond Grading Report or the GIA Scale, which will be well recognized by those of ordinary skill in the art.

As used herein, "amorphous braze" refers to a homogenous braze composition having a non-crystalline structure. Such alloys contain substantially no eutectic phases that melt incongruently when heated. Although precise alloy composition is difficult to ensure, the amorphous brazing alloy as used herein should exhibit a substantially congruent melting behavior over a narrow temperature range.

As used herein, "alloy" refers to a solid or liquid mixture of a metal with a second material, said second material may be a non-metal, such as carbon, a metal, or an alloy which enhances or improves the properties of the metal.

As used herein, "metal brazing alloy," "brazing alloy," "braze alloy," "braze material," and "braze," may be used interchangeably, and refer to a metal alloy which is capable of chemically bonding to superabrasive particles, and to a matrix support material, or substrate, so as to substantially bind the two together. The particular braze alloy components and compositions disclosed herein are not limited to the particular embodiment disclosed in conjunction therewith, but may be used in any of the embodiments of the present invention disclosed herein.

As used herein, the process of "brazing" is intended to refer to the creation of chemical bonds between the atoms of the superabrasive particles and the braze material. Further, "chemical bond" means a covalent bond, such as a carbide, nitride, or boride bond, rather than mechanical or weaker inter-atom attractive forces. Thus, when "brazing" is used in connection with superabrasive particles a true chemical bond is being formed. However, when "brazing" is used in connection with metal to metal bonding the term is used in the more traditional sense of a metallurgical bond. Therefore, brazing of a superabrasive segment to a tool body does not require the presence of a carbide, nitride, or boride former.

As used herein, in conjunction with the brazing process, "directly" is intended to identify the formation of a chemical bond between the superabrasive particles and the identified material using a single brazing metal or alloy as the bonding medium.

As used herein, "ceramic" refers to a hard, often crystalline, substantially heat and corrosion resistant material which may be made by firing a non-metallic material, sometimes with a metallic material. A number of oxide, nitride, and carbide materials considered to be ceramic are well known in the art, including without limitation, aluminum oxides, silicon oxides, boron nitrides, silicon nitrides, and silicon carbides, tungsten carbides, etc.

As used herein, "metallic" means any type of metal, metal alloy, or mixture thereof, and specifically includes but is not limited to steel, iron, and stainless steel.

As used herein, "grid" means a pattern of lines forming multiple squares.

As used herein with respect to distances and sizes, "uniform" refers to dimensions that differ by less than about 75 total micrometers.

As used herein, "attitude" means the position or arrangement of a superabrasive particle in relation to a defined surface, such as a substrate to which it is attached, or a CMP pad to which it is to be applied during a work operation. For example, a superabrasive

particle can have an attitude that provides a specific portion of the particle in orientation toward a CMP pad.

As used herein, "working end" refers to an end of a particle which is oriented towards the CMP pad and during a dressing operation makes contact with the pad. Most often the working end of a particle will be distal from a substrate to which the particle is attached.

As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

Concentrations, amounts, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc.

This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides devices and methods for optimizing the dressing performance of a chemical mechanical polishing (CMP) pad dresser that employs superabrasive particles. By orienting such particles into certain attitudes, it has been discovered that the dressing rate and dresser wear can be controlled. In one aspect, performance is optimized through configurations that improve the longevity of the superabrasive particles on the dresser and the useful service life of the CMP pad, while maintaining sufficient CMP pad dressing rates.

FIG. 1 shows a CMP pad dresser in accordance with one embodiment of the present invention. The CMP pad conditioner 100 includes a substantially flat substrate 101, having a plurality of superabrasive particles 110, 120, and 130 coupled thereto. Each of the superabrasive particles is oriented in a particular attitude that provides a desired working portion such as an apex, an edge, or a face that contacts the CMP pad during a dressing operation.

The optimization of wear of the dresser and the dressing rate of a CMP pad is dependent on many factors, among them the orientation of the superabrasive particles. Various types of superabrasive particles may be utilized in various aspects of the present invention. For example, such materials may include without limitation, diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN) and polycrystalline cubic born nitride (PcBN). In some aspects, the superabrasive particles may include diamond. In one aspect, the diamond superabrasive particles may exhibit a combination of cubic and octahedral faces. Further, the superabrasive particles can be of a predetermined shape. For example, the superabrasive particles can be a euhedral shape or either a octahedral or cubo-octahedral shape. Though virtually any size of superabrasive particle would be considered to be within the scope of the present invention, in one aspect the particles may range in size from about 100 to 350 micrometers. Additionally, the superabrasive particles can be oriented in many directions relative to the pad, but there are three major orientations or attitudes that may affect the particle's cutting or grooming behavior. These attitudes a expose either an apex, an edge, or a face of the superabrasive particle towards a CMP pad being dressed.

Orienting the superabrasive particles in a specific attitude in relation to the CMP pad to be dressed creates different asperities in the pad surface, thus altering the performance of the CMP pad. Different asperities retain slurry in different manners and thus polish the silicon chip wafer differently according to asperity depth, width, density, etc. The superabrasive particles of a CMP pad dresser can be oriented according to the desired polishing characteristics of the CMP pad. For example, if the superabrasive particles predominantly have an apex oriented towards the CMP pad, the asperities of the pad will be narrow and deep. The advantage of narrow and deep asperities are that the pad can better retain the polishing slurry, and thus the polishing rate of the wafer increases. However, the increased polishing rate may also increase the wear rate of the superabrasive particles. As such, wear rate may vary considerably depending on the attitude of the superabrasive particles, and therefore, the orientation of each superabrasive particle may be considered when designing a device with desired performance characteristics. Generally speaking,

superabrasive particle attitudes that provide higher dressing rates (i.e. deeper penetration into a pad) also wear particles out at a higher rate.

In contrast, if the superabrasive particles are oriented with a face towards the pad, the resulting asperities may polish at a lower rate. The face of the particle is generally thought to be more durable, but does not typically cut deep and narrow asperities in the pad, but rather asperities that are shallow and broad. Therefore the face portion of a particle will dress a CMP pad at a reduced rate compared to the apex portion of a particle, but the superabrasive particle will wear at a much lower rate.

The edge portions of a superabrasive particle have dressing and wear characteristics that are between those of the face and apex portions. It has been thought that if the edge portion is utilized to dress a CMP pad, the asperities are not as deep or narrow as those dressed with an apex portion, but may provide asperities having desirable intermediate characteristics. Further, the edge portion of the particle does not wear at such a high rate as that of an apex. Hence, a CMP pad dresser utilizing all or a portion of superabrasive particles having exposed edge portions may provide a number of advantages.

Referring again to FIG. 1, the plurality of superabrasive particles are shown having various attitudes with respect to the substrate 101. Such attitudes may include an apex oriented toward a pad to be dressed as with centrally located particles 110, and edge oriented toward a pad to be dressed as with particles 120, or a face oriented toward the pad to be dressed as with peripherally located particles 130. Such an embodiment of the present invention may provide both dressing rate and dresser wear advantages. The arrangement provides centrally located particles that have aggressive dressing characteristics, while the particles located on the periphery may be more durable and shield the inner and central particles from excessive wear.

In another aspect of the present invention, FIG. 2 shows a CMP pad dresser 200 having a plurality of superabrasive particles disposed along a substrate 101, where the centrally located superabrasive particles 110 are disposed in an attitude with an apex oriented toward a pad to be dressed, and the remaining superabrasive particles 130 are disposed in an attitude with a face oriented toward a pad to be dressed.

FIG. 3 shows yet another embodiment of the present invention. In this embodiment, a CMP pad dresser 300 is shown having a plurality of superabrasive particles disposed along a substrate 101, where the superabrasive particles that are centrally located are disposed in an attitude with an apex oriented toward a pad to be dressed 110, and the remaining superabrasive particles have an attitude of an edge oriented toward a pad to be dressed 120.

In still another aspect of the present invention, as depicted in FIG. 4, a CMP pad dresser 400 is shown, having a plurality of abrasive particles disposed along a substrate 101, where centrally located superabrasive particles are oriented in an attitude having an edge portion oriented toward a CMP pad to be dressed 120, and peripherally located superabrasive particles being oriented in an attitude having a face orient towards the CMP pad 130. In other aspects, substantially all of the superabrasive particles may be oriented in an attitude having an apex oriented towards the CMP pad (not shown), or substantially all superabrasive particles may be oriented in an attitude having an edge oriented toward the CMP pad (not shown). Various aspects are also contemplated wherein substantially all of the superabrasive particles may be oriented in an attitude having a face oriented toward the CMP pad (not shown).

In an alternative embodiment (not illustrated), the present invention discloses a method for optimizing CMP pad dressing performance by utilizing abrasive particles of different qualities. The qualities referred to can include external superabrasive particle shapes and internal superabrasive particle flaws or defects. Irregular shaped (euhedral shaped) particles often contain sharp portions or apexes which enable aggressive dressing. These sharp portions cut deep asperities in the pad that tend to increase polishing rate. However, because the irregular particles can be of a lower internal quality, they are prone to chipping that may cause wafer scratching. In contrast, abrasive particles exhibiting octahedral or cubo-octahedral shapes provide a higher shape quality and/or higher durability quality. The higher quality particles lacks sharp portions as compared to irregular particles, and are thus less prone to chipping, breaking, and subsequently scratching the wafer.

The present invention further provides a method to utilize abrasive particles having different qualities. For example, the present invention discloses a CMP pad dresser having a plurality of superabrasive particles coupled to a substrate, where the centrally located superabrasive particles are of a lower quality than the peripherally located superabrasive particles. In other words, the peripherally located superabrasive particles are of a higher quality. Lower quality can include a lower internal quality, a lower shape quality, etc. A lower internal quality can include the number of flaws and/or inclusions in a superabrasive particle. A lower shape quality can include a superabrasive particle having an irregular shape, while a higher shape quality can include a superabrasive particle having an octahedral or cubo-octahedral shape. The present invention presents an arrangement of superabrasive particles where the higher quality superabrasive particles are located near the periphery of the dresser, which helps to protect and shield the centrally located lower quality particles from

chipping and breaking. The present configuration can control CMP pad dresser performance, thus optimizing dresser wear and dressing rate.

The present invention additionally encompasses methods for manufacturing a CMP pad dresser as recited herein. In one aspect, such a method may include providing a substrate, selecting an attitude for superabrasive particles that provides an anticipated performance characteristic, orienting the superabrasive particles into the selected attitude in relation to the substrate, and bonding the abrasive particles to the substrate in the selected attitude. The substrate of the various aspects of the present invention can be made of a metallic, a ceramic, a powder, a metallic powder, or a flexible material. In a one embodiment the substrate can be stainless steel.

Particle placement and methods and materials for affixing superabrasive particles to a substrate in predetermined configurations, such as grid, may be found in U.S. Patent 6,039,641, U.S. Patent 6,286,498, U.S. Patent 6,368,198, and Applicant's copending U.S. Patent Application Serial No. 10/109,531 filed March 27, 2002, each of which is incorporated herein by reference in their entirety.

Finally, the superabrasive particles may be coupled to a substrate that is made of metallic powders. Metallic powders may be selected from a number of materials known for forming a substrate. Further such metallic powder may contain brazing alloys to facilitate the brazing of the superabrasive particles. In a preprocess step, in forming a substrate, the superabrasive particles may be disposed into the metallic powder prior to solidification or consolidation. During the brazing or consolidation step, the abrasive particles are chemically bonded to the substrate, providing a durable CMP pad dresser which may be less vulnerable to particle chipping and dislodging. In addition, to the brazing method previously described, the particles may be affixed to a substrate through electroplating methods.

In various aspects of the present invention, orienting the superabrasive particles in a particular attitude can be accomplished by using magnetic fields or vacuums. Placement and orientation of superabrasive particles through magnetic methods are discussed in U.S. Patent 4,916,869 and U.S. Patent 5,203,881, which are incorporated herein by reference. An example of a suitable vacuum method may be found in U.S. Patent 4,680,199, which is incorporated herein by reference. Essentially, a vacuum having a chuck designed to retrieve abrasive particles through vacuum means and then dispose the abrasive particles on a substrate is discussed. The vacuum chuck tubes in the chuck can be configured with openings that orient the superabrasive particles into selected attitudes though a mechanical matching process. Once the superabrasive particles have been properly oriented, the vacuum

disposes the superabrasive particles on the substrate to which they will be fixed without disturbing or altering the attitude of the particles. The result is a CMP pad dresser with oriented particles configured to optimize dresser performance for a desired aspect.

Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function, manner of operation, assembly, and use may be made without departing from the principles and concepts set forth herein.

CLAIMS

1. A method for controlling CMP pad dresser performance in a CMP pad dresser as part of the pad dresser fabrication process, the pad dresser employing a plurality of superabrasive particles comprising:

orienting the superabrasive particles into an attitude that provides an anticipated performance characteristic.

2. The method of claim 1, wherein the performance characteristic is an optimal pad dressing rate.

3. The method of claim 1, wherein the performance characteristic is optimal pad dresser wear.

4. The method of claim 1, wherein the performance characteristic is an optimized balance of dressing rate and dresser wear.

5. The method of claim 1, wherein the superabrasive particles include members selected from a group consisting of: diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), and polycrystalline cubic boron nitride (PCBN).

6. The method of claim 5, wherein the superabrasive particles include diamond.

7. The method of claim 1, wherein the superabrasive particles are arranged in a predetermined pattern.

8. The method of claim 7, wherein the predetermined pattern is a grid.

9. The method of claim 1, wherein the superabrasive particles have a predetermined shape.

10. The method of claim 9, wherein the predetermined shape is a euhedral shape.

11. The method of claim 9, wherein the predetermined shape is either an octahedral or cubo-octahedral shape.

12. The method of claim 1, wherein the superabrasive particles are attached to a substrate selected from the group consisting essentially of metallic materials, flexible materials, ceramic materials and mixtures thereof.

13. The method claim 1, wherein said superabrasive particles are substantially all configured in an attitude having an apex portion oriented towards a pad to be dressed.

14. The method of claim 1, wherein said superabrasive particles are substantially all configured in an attitude having an edge portion oriented toward a pad to be dressed.

15. The method of claim 1, wherein said superabrasive particles are substantially all configured in an attitude having a face portion oriented toward a pad to be dressed.

16. The method of claim 12, wherein said superabrasive particles are chemically bonded to said substrate.

17. The method of claim 12, wherein said superabrasive particles are electroplated to said substrate.

18. The method of claim 1, wherein superabrasive particles in a central location on the dresser are disposed in an attitude with an apex oriented toward a pad to be dressed, and remaining abrasive particles are disposed in an attitude of either a face or an edge oriented toward a pad to be dressed.

19. The method of claim 1, wherein superabrasive particles in a central location on the dresser are disposed in an attitude with an apex oriented toward a pad to be dressed, superabrasive particles in a peripheral location on the dresser are disposed in an attitude with a face oriented toward a pad to be dressed, and any particles therebetween are disposed in an attitude with an edge oriented towards a pad to be dressed.

20. The method of claim 1, wherein superabrasive particles in a central location on the dresser are of a lower quality than superabrasive particles in a peripheral location on the dresser.

21. The method of claim 20, wherein the lower quality is a lower internal quality.

22. The method of claim 20, wherein the lower quality is a lower shape quality

23. The method of claim 22, wherein the lower quality is an irregular shape.

24. The method of claim 20, wherein the peripherally located superabrasive particles have either an octahedral or cubo-octahedral shape.

25. The method of claim 23, wherein the irregular shape provides a more aggressive dressing action than an octahedral shape.

26. The method of claim 1, wherein said superabrasive particles have a size from about 100 to 350 micrometers.

27. A chemical mechanical polishing (CMP) pad dresser comprising:

a substrate; and

a plurality of superabrasive particles attached to the substrate, said particles being configured in an attitude that controls CMP pad dresser performance.

28. The CMP pad dresser of claim 27, wherein said superabrasive particles include members selected from the group consisting of: diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), and polycrystalline cubic boron nitride (PCBN).

29. The CMP pad dresser of claim 28, wherein said superabrasive particles include diamond.

30. The CMP pad dresser of claim 29, wherein said superabrasive particles have a predetermined shape.

31. The CMP pad dresser of claim 30, wherein the predetermined shape is a euhedral shape.

32. The CMP pad dresser of claim 30, wherein the predetermined shape is a octahedral or cubo-octahedral shape.

33. The CMP pad dresser of claim 27, wherein said superabrasive particles are substantially all configured in an attitude having an apex portion oriented towards a pad to be dressed.

34. The CMP pad dresser of claim 27, wherein said superabrasive particles are substantially all configured in an attitude having an edge portion oriented toward a pad to be dressed.

35. The CMP pad dresser of claim 27, wherein said superabrasive particles are substantially all configured in an attitude having a face portion oriented toward a pad to be dressed.

36. The CMP pad dresser of claim 27, wherein said superabrasive particles are arranged in a predetermined pattern.

37. The CMP pad dresser of claim 36, wherein the predetermined pattern is a grid.

38. The CMP pad dresser of claim 27, wherein said superabrasive particles are chemically bonded to said substrate.

39. The CMP pad dresser of claim 27, wherein said superabrasive particles are electroplated to said substrate.

40. The CMP pad dresser of claim 27, wherein superabrasive particles that are centrally located are disposed in an attitude with an apex oriented toward a pad to be dressed, and any remaining abrasive particles are disposed in an attitude of either a face or an edge oriented toward a pad to be dressed.

41. The CMP pad dresser of claim 27, wherein superabrasive particles that are centrally located are disposed in an attitude with an apex oriented toward a pad to be dressed, superabrasive particles that are peripherally located are disposed in an attitude with a face oriented toward a pad to be dressed, and any particles therebetween are disposed in an attitude of an edge oriented toward a pad to be dressed.

42. The CMP pad dresser of claim 27, wherein centrally located superabrasive particles are of a lower quality than peripherally located particles.

43. The CMP pad dresser of claim 42, wherein the lower quality is a lower internal quality.

44. The CMP pad dresser of claim 42, wherein the lower quality is a lower shape quality.

45. The CMP pad dresser of claim 44, wherein the lower quality is an irregular shape.

46. The CMP pad dresser of claim 42, wherein the higher quality shape is an octahedral or cubo-octahedral shape.

47. The CMP pad dresser of claim 45, wherein the irregular shape provides a more aggressive dressing action than the octahedral shape.

48. The CMP pad dresser of claim 27, wherein said superabrasive particles have a size from about 100 to 350 micrometers.

49. A method for manufacturing a CMP pad dresser as recited in Claim 27, comprising the steps of:

providing a substrate;

selecting an attitude for superabrasive particles that provides an anticipated performance characteristic;

orienting the superabrasive particles into the selected attitude in relation to the substrate; and

bonding the abrasive particles to the substrate in the selected attitude.

1/1

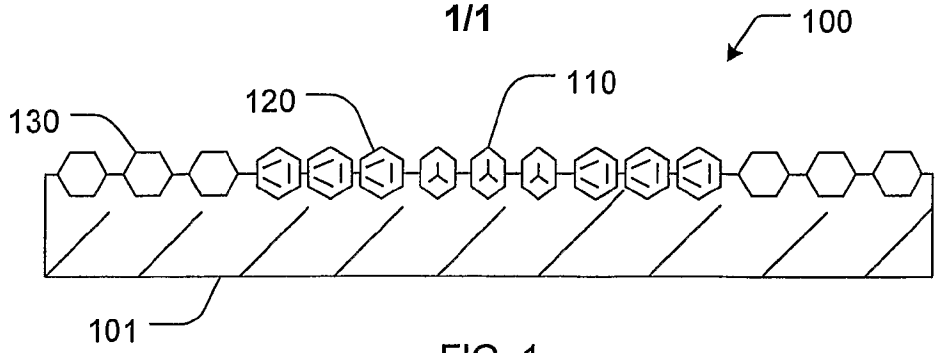


FIG. 1

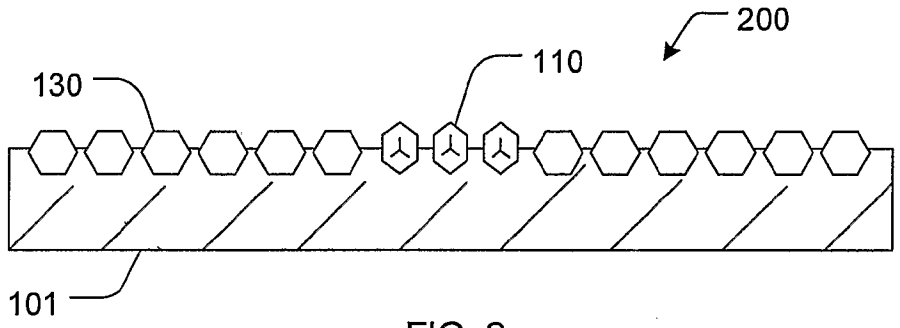


FIG. 2

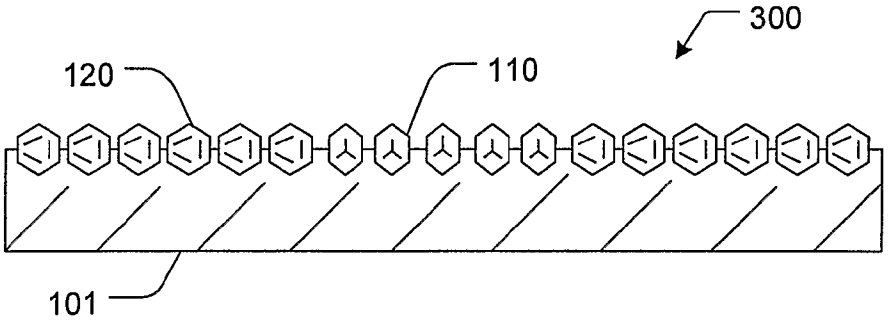


FIG. 3

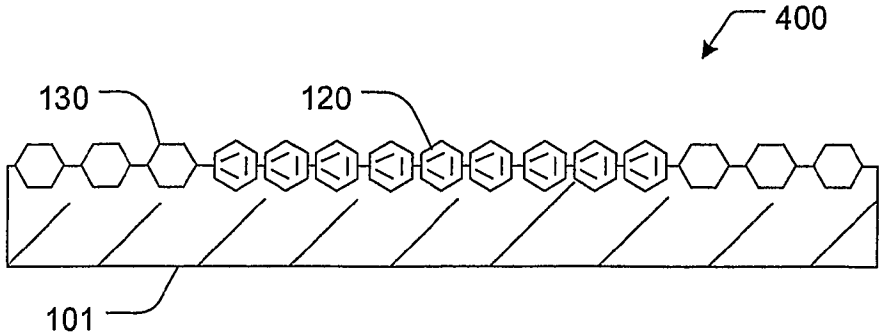


FIG. 4

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[Continued on next page]

(54) Title: CMP PAD CONDITIONERS WITH MOSAIC ABRASIVE SEGMENTS AND ASSOCIATED METHODS

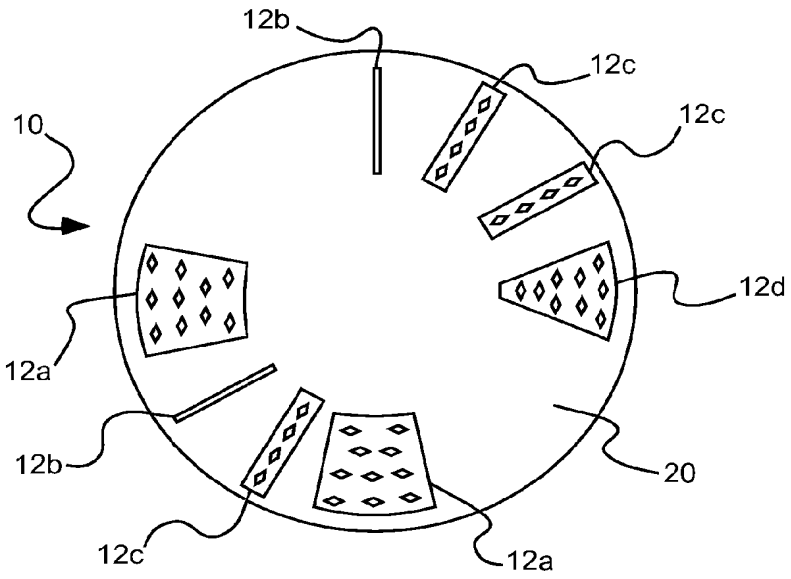


FIG. 1

(57) Abstract: A CMP pad conditioner comprises a plurality of abrasive segments. Each abrasive segment includes a segment blank and an abrasive layer attached to the segment blank, the abrasive layer including a superhard abrasive material, A pad conditioner substrate is also provided. Each of the plurality of abrasive segments is permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

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B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
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Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean Utility models and applications for Utility models since 1975
Japanese Utility models and applications for Utility models since 1975

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKIPASS(KIPO internal)&keywords: "abrasive", "conditioner"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2003/0054746 A1 (NUSSBAUMER, J. et al.) 20 March 2003 See abstract and figures 1& 2	1-41
A	US 6905571 B2 (SAKUMA, N.; TSUNENARI, K.) 14 June 2005 See abstract and figure 1	1-41
A	JP 2003-071718 A (NIPPON STEEL CORP.) 12 March 2003 See abstract and figure 1	1-41

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

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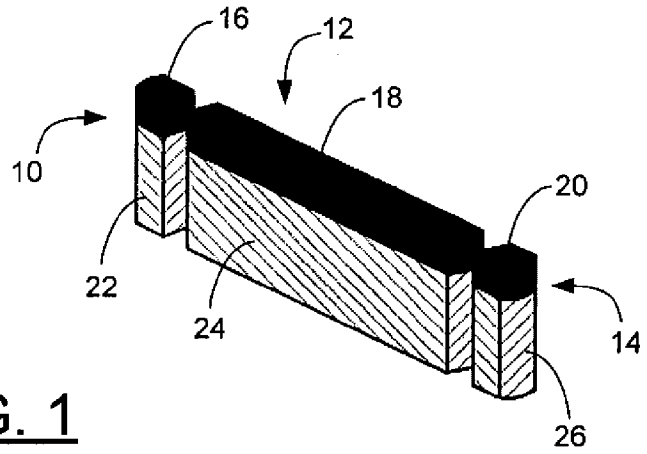


FIG. 1

(57) **Abstract:** An abrasive tool (112) includes an assembly of tool precursors (116). At least one of the tool precursors has a continuous polycrystalline diamond, polycrystalline cubic boron nitride, or ceramic material cutting element (18) formed into a blade shape. The abrasive tool can additionally include a setting material (68), which is configured to attach the tool precursors and form a single mass. The selection, arrangement, and setting of the tool precursors can result in an abrasive tool having a predetermined cutting configuration. Methods for forming such an abrasive tool are also disclosed.

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CMP PAD DRESSERS

PRIORITY CLAIM

This application claims the benefit of: U.S. Provisional Patent Application Serial No. 60/987,687, filed November 13, 2007; and U.S. Provisional Patent Application Serial No. 60/988,643, filed November 16, 2007, each of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to devices and methods for use in connection with dressing or conditioning a chemical mechanical polishing (CMP) pad. Accordingly, the present invention involves the fields of chemical engineering, chemistry, metallurgy, and materials science.

BACKGROUND OF THE INVENTION

Chemical mechanical process (CMP) has become a widely used technique for polishing certain work pieces. Particularly, the computer manufacturing industry has begun to rely heavily on CMP processes for polishing wafers of ceramics, silicon, glass, quartz, metals, and mixtures thereof for use in semiconductor fabrication. Such polishing processes generally entail applying the wafer against a rotating pad made from a durable organic substance such as polyurethane. To the pad is added a chemical slurry containing a chemical solution capable of breaking down the wafer substance and an amount of abrasive particles which act to physically erode the wafer surface. The slurry is continually added to the spinning CMP pad, and the dual chemical and mechanical forces exerted on the wafer cause it to be polished in a desired manner.

To effectively work over a period of time, a CMP pad needs to be kept in good condition so that distribution of abrasive particles is optimized for each polishing. One method of reducing "glazing" or accumulation of debris on the CMP pad is dressing or conditioning the pad. Dressing refers to attempts made to revive the top of the pad by "combing" or "cutting" it with various devices. Many types of devices and processes have been used for this purpose. Some CMP pad dressers cause the CMP pads to prematurely wear out.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, an abrasive tool can be provided and can include an assembly of tool precursors. At least one of the tool precursors can include a continuous polycrystalline diamond or polycrystalline cubic boron nitride, or other ceramic material cutting element formed into a blade shape. The abrasive tool can additionally include a setting material, which is configured to attach the tool precursors and form a single mass. The selection, arrangement, and setting of the tool precursors can result in an abrasive tool having a predetermined cutting configuration.

In accordance with another aspect of the invention, an abrasive tool can be provided and can include an assembly of tool precursors. The tool precursors can include at least one elongated substrate with a continuous polycrystalline diamond, cubic boron nitride (cBN), or other ceramic material cutting element on a surface thereof. The precursor assembly can provide a tool having a surface with a predetermined cutting configuration. The abrasive tool can further include a setting material configured to attach the tool precursors into a single mass that forms the predetermined cutting configuration.

In accordance with another aspect of the invention, a method of forming an abrasive tool can be provided, including providing a plurality of tool precursors. At least one of the tool precursors can have a continuous diamond or cubic boron nitride, or other ceramic cutting element formed in a blade shape. The method can further include securing the tool precursors together to form a tool having a working surface that includes the polycrystalline diamond, cubic boron nitride, or other ceramic material cutting element formed into a blade shape.

In accordance with another aspect of the invention, a CMP pad conditioner can be provided, including a base and a plurality of cutting elements extending from the base. The plurality of cutting elements can each have a cutting tip operable to engage material of the CMP pad. At least some of the cutting elements can have a cutting tip oriented at a different elevation relative to cutting tips of other cutting elements.

In accordance with another aspect of the invention, at least one of the cutting elements can include a cutting tip oriented at a greater elevation, relative to a base of

the pad conditioner, than does a cutting tip of an immediately adjacent cutting element.

In accordance with another aspect of the invention, the at least one cutting element abuts the immediately adjacent cutting element.

In accordance with another aspect of the invention, the cutting elements can include a cutting face oriented at 90 degrees or less relative to a surface of the CMP pad conditioned by the cutting elements.

In accordance with another aspect of the invention, the cutting elements can include a trailing edge angled to provide a relief area between the cutting elements and a surface of the CMP pad conditioned by the cutting elements.

In accordance with another aspect of the invention, the cutting elements and the base can be formed from an integral piece of material. In one embodiment, the cutting elements and the base are formed from an integral piece of a polycrystalline diamond compact.

In accordance with another aspect of the invention, the cutting elements can be coupled to the base.

In accordance with another aspect of the invention, at least two of the cutting elements are arranged such that movement of the pad conditioner and the CMP pad relative to one another results in a first, lower elevation cutting element removing material from the CMP pad, followed by a second, higher elevation cutting element removing further material from the CMP pad.

In accordance with another aspect of the invention, a method of conditioning a CMP pad is provided, including: engaging material of the CMP pad with a cutting tip of at least one cutting element; moving the cutting element and the CMP pad relative to one another to thereby remove material from the CMP pad with the cutting tip of the cutting element to create an exposed layer of CMP pad material; engaging the exposed layer of CMP pad material with the cutting tip of the cutting element, or with a cutting tip of a second cutting element; and moving the cutting element engaged with the exposed layer of CMP pad material and the CMP pad relative to one another to thereby remove the exposed layer of CMP pad material.

In accordance with another aspect of the invention, engaging the exposed layer of CMP pad material comprises engaging the exposed layer with the cutting tip of the cutting element used to create the exposed layer.

In one embodiment, engaging the exposed layer of CMP pad material comprises engaging the exposed layer with the cutting tip of the second cutting element.

In accordance with another aspect of the invention, the cutting element and the second cutting element extend from a common base.

In accordance with another aspect of the invention, a method of conditioning a CMP pad is provided, including: removing, with a cutting element, a thin layer of material from the CMP pad; and removing, with the same or a different cutting element, a second layer of material from the CMP, the second layer of material being revealed by removal of the thin layer of material.

There has thus been outlined, rather broadly, various features of the invention so that the detailed description thereof that follows may be better understood, and so that the present contribution to the art may be better appreciated. Other features of the present invention will become clearer from the following detailed description of the invention, taken with the accompanying claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side perspective view of a plurality of tool precursors, in accordance with an embodiment of the present invention;

FIG. 2 is a side perspective view of a tool precursor having a PCD or cBN, or ceramic layer in a blade formation, in accordance with an embodiment of the present invention;

FIG. 3 is a side perspective view of a tool precursor having a PCD or cBN, or ceramic layer formed in a plurality of asperities, in accordance with an embodiment of the present invention;

FIG. 4 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 5 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 6 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 7 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 8 is a side view of a tool precursors leveled and set in an epoxy, thus forming an abrasive tool, in accordance with an embodiment of the present invention;

FIG. 9 is a top view of an abrasive tool having tool precursors arranged in a spoke formation, in accordance with an embodiment of the present invention;

FIG. 10 is a perspective view of a mass from which tool precursors can optionally be formed, in accordance with an embodiment of the present invention;

FIG. 11 is a perspective view of a mass from which tool precursors can optionally be formed, in accordance with an embodiment of the present invention;

FIG. 12 is a side view of a mass, similar to FIG. 11, from which tool precursors can optionally be formed, in accordance with an embodiment of the present invention;

FIG. 13 is a side perspective view of a tool precursor having a PCD or CBN or ceramic layer in a blade formation, in accordance with an embodiment of the present invention;

FIG. 14 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 15 is a side cross-sectional view of an abrasive tool, in accordance with an embodiment of the present invention;

FIG. 16 is a side view of a pad conditioner engaging a CMP pad in accordance with an embodiment of the invention;

FIG. 17 is a side view of another pad conditioner engaging a CMP pad in accordance with an embodiment of the invention;

FIG. 18 is a side view of another pad conditioner engaging a CMP pad in accordance with an embodiment of the invention;

FIG. 19 is a partial view of a pad being conditioned in accordance with another embodiment of the invention;

FIG. 20 is a top view of an exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 21 is a top view of another exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 22 is a top view of another exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 23 is a top view of another exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 24 illustrates the performance of various cutting teeth (varied in both shape and spacing) of the present invention; and

FIG. 25 illustrates a comparison of a pad dresser in accordance with the present invention as compared to conventional technology.

It will be understood that the above figures are merely for illustrative purposes in furthering an understanding of the invention. Further, the figures are not drawn to scale, thus dimensions and other aspects may, and generally are, exaggerated or changed to make illustrations thereof clearer. Therefore, departure can be made from the specific dimensions and aspects shown in the figures in order to produce abrasive tools or tool precursors of the present invention.

DETAILED DESCRIPTION

Before the present invention is disclosed and described, it is to be understood that this invention is not limited to the particular structures, process steps, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

It must be noted that, as used in this specification and the appended claims, the singular forms "a," "an" and, "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a CMP pad dresser" includes one or more of such dressers, reference to "an operating parameter" includes reference to one or

more of such operating parameters, and reference to "the asperity" includes reference to one or more of such asperities.

Definitions

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" translucent would mean that the object is either completely translucent or nearly completely translucent. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. In other words, a composition that is "substantially free of" an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.

The terms "dressing" and "conditioning" are interchangeable and refer to the process of rejuvenating a CMP pad by removing debris from the pad, as well as optionally lifting matted fibers and creating new grooves. Likewise, the terms "dresser" and "conditioner" are used interchangeably and indicate the apparatus used for dressing or conditioning.

As used herein, "substrate" means a material which supports or can support a PCD or cBN, or ceramic layer, and to which a PCD or cBN, or ceramic layer may be affixed. Substrates useful in the present invention may be any shape, thickness, or material, that is capable of supporting abrasive particles in a manner that is sufficient provide a tool useful for its intended purpose. Substrates may be of a solid material, a powdered material that becomes solid when processed, or a flexible material. Examples of typical substrate materials include without limitation, metals, metal alloys, ceramics, solidified resins and polymeric materials and mixtures thereof.

As used herein, the terms "base" or "substrate" can be used to refer to a

portion of a pad conditioner that supports abrasive materials, and to which abrasive materials may be affixed, or may extend from. Substrates useful in the present invention may be any shape, thickness, or material, that is capable of supporting abrasive materials in a manner that is sufficient provide a pad conditioner useful for its intended purpose. Substrates may be of a solid material, a powdered material that becomes solid when processed, or a flexible material. Examples of typical substrate materials include without limitation, metals, metal alloys, ceramics, relatively hard polymers or other organic materials, glasses, and mixtures thereof. Further the substrate may include material that aids in attaching abrasive materials to the substrate, including, without limitation, brazing alloy material, sintering aids and the like. The substrate and the abrasive cutting elements can, in some embodiments, be formed from the same material and can be formed from an integral, single piece of material.

As used herein, "leading edge" means the edge of a CMP pad dresser that is a frontal edge based on the direction that the CMP pad is moving, or the direction that the pad is moving, or both. Notably, in some aspects, the leading edge may be considered to encompass not only the area specifically at the edge of a dresser, but may also include portions of the dresser which extend slightly inward from the actual edge. In one aspect, the leading edge may be located along an outer edge of the CMP pad dresser. In another aspect, the CMP pad dresser may be configured with a pattern of abrasive particles that provides at least one effective leading edge on a central or inner portion of the CMP pad dresser working surface. In other words, a central or inner portion of the dresser may be configured to provide a functional effect similar to that of a leading edge on the outer edge of the dresser.

As used herein, the process of "brazing" is intended to refer to the creation of chemical bonds between the atoms of the non-metallic, such as diamond, CBN, or ceramic materials and the braze material. Further, "chemical bond" means a covalent bond, such as a carbide, nitride, or boride bond, rather than mechanical or weaker inter-atom attractive forces. Thus, when "brazing" is used in connection with superabrasive particles a true chemical bond is being formed. However, when "brazing" is used in connection with metal to metal bonding the term is used in the

more traditional sense of a metallurgical bond. Therefore, brazing of a superabrasive segment to a tool body does not require the presence of a carbide, nitride, or boride former.

As used herein, "ceramic" refers to a hard, often crystalline, substantially heat and corrosion resistant material which may be made by firing a non-metallic material, sometimes with a metallic material. A number of oxide, nitride, and carbide materials considered to be ceramic are well known in the art, including without limitation, aluminum oxides, silicon oxides, boron nitrides, silicon nitrides, and silicon carbides, tungsten carbides, etc.

As used herein, "metallic" means any type of metal, metal alloy, or mixture thereof, and specifically includes but is not limited to steel, iron, and stainless steel.

As used herein, "abrasive profile" is to be understood to refer to a shape or a space defined by abrasive materials that can be used to remove material from a CMP pad. Examples of abrasive profiles include, without limitation, rectangular shapes, tapering rectangular shapes, truncated wedge shapes, wedge shapes, and the like. In some embodiments, the abrasive profile exhibited by abrasive segments of the present invention will apparent when viewed through a plane in which the CMP pad will be oriented during removal of material from the CMP pad.

As used herein, "superhard" may be used to refer to any crystalline, or polycrystalline material, or mixture of such materials which has a Mohr's hardness of about 8 or greater. In some aspects, the Mohr's hardness may be about 9.5 or greater. Such materials include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), polycrystalline cubic boron nitride (PcBN), corundum and sapphire, as well as other superhard materials known to those skilled in the art. Superhard materials may be incorporated into the present invention in a variety of forms including particles, grits, films, layers, pieces, segments, etc. In some cases, the superhard materials of the present invention are in the form of polycrystalline superhard materials, such as PCD and PcBN materials.

As used herein, "organic material" refers to a semisolid or solid complex amorphous mix of organic compounds. As such, "organic material layer" and "organic material matrix" may be used interchangeably, refer to a layer or mass of a

semisolid or solid complex amorphous mix of organic compounds. Preferably the organic material will be a polymer or copolymer formed from the polymerization of one or more monomers.

As used herein, "particle" and "grit" may be used interchangeably.

As used herein, the term "abrasive" can be used to describe a variety of structures capable of removing (e.g., cutting, polishing, scraping) material from a CMP pad. An abrasive can include a mass having several cutting points, ridges or mesas formed thereon or therein. It is notable that such cutting points, ridges or mesas may be from a multiplicity of protrusions or asperities included in the mass. Furthermore, an abrasive can include a plurality of individual abrasive particles that may have only one cutting point, ridge or mesa formed thereon or therein. An abrasive can also include composite masses, such as PCD pieces, segment or blanks, either individually comprising the abrasive layer or collectively comprising the abrasive layer.

As used herein, the term "cutting tip" is generally used to refer to a portion of a cutting element that engages and removes material from a workpiece (generally a CMP pad). "Cutting tips" can include points, edges, surfaces, etc., that are capable of cutting material from a CMP pad. The terms "cutting tip," "edge," "blade," etc., can be, but are not always, used interchangeably.

As used herein, a plurality of components may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a *de facto* equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

Concentrations, amounts, particle sizes, volumes, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-

ranges encompassed within that range as if each numerical value and sub-range is explicitly recited.

As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc. This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

It has been found that the overall CMP process can be improved through dressing or conditioning with a CMP pad dresser that effectively dresses the CMP pad, so as to optimally allow for extended CMP pad life, while reducing glazing and other negative effects on the CMP pad. Such improvements can occur as a result of precisely-machined CMP pad dressers. By utilizing dressers as disclosed herein, CMP pads can be refreshed, without losing CMP pad life as with the use of typical CMP pad dressers. Furthermore, the methods disclosed herein for creating such dressers provide a relative fast and economical way to create such precise tools. Additionally, the method provides for the creation of a CMP pad dresser that has a predetermined working surface.

In accordance with embodiments presented herein, various details are provided which are applicable to each of the CMP pad dressers and method for creating or forming the CMP pad dressers. Thus, discussion of one specific embodiment is related to and provides support for this discussion in the context of the other related embodiments.

An abrasive tool can include an assembly of tool precursors. Tool precursors can be of a variety of shapes and sizes. FIGs 1-3 illustrate a plurality of tool precursors. FIG. 1 illustrates three tool precursors 10, 12, 14. Each of the illustrated precursors includes a polycrystalline diamond (PCD), cubic boron nitride (PcBN), or ceramic layer 16, 18, 20, on one surface of a substrate 22, 24, 26, of the tool precursor. In each embodiment, the layer could alternatively comprise or consist essentially of

either PCD or PcBN. Additionally, the layer may comprise or consist of diamond in other forms, including CVD deposited diamond and also various ceramic materials. In one embodiment (not shown), the layer may be a ceramic or PcBN layer which is overlayed with an outer layer of CVD diamond. The layers illustrated are substantially uniform in thickness across the full area of the surface of the substrate. Tool precursor 12 illustrates an elongated tool precursor having a continuous polycrystalline diamond or polycrystalline cubic boron nitride cutting element formed thereon. In one embodiment, the tool precursor 12 of FIG. 1 can be further machined to form a blade shape as illustrated in FIG. 2. As shown, the tool precursor 30 includes an elongated substrate 32 and a continuous polycrystalline diamond or cubic boron nitride cutting element 34 on a surface of the substrate. The cutting element is formed into of a blade shape, having a single tip 36 of the cutting element substantially along the length the elongated tool precursor.

It should be understood that while much discussion is directed to PCD, diamond, PcBN, and/or cubic boron nitride cutting elements, other materials can be used as the cutting element, either alone or in combination with other materials, and are to be included in the scope of the disclosure herein. For example, the cutting element can comprise or consist essentially of ceramics, or other diamond or cBN films, including those deposited via chemical vapor deposition (CVD). Non-limiting examples of ceramics that can be used as a cutting element include alumina, aluminum carbide, silica, silicon carbide, silicon nitride, zirconia, zirconium carbide, and mixtures thereof. Cutting elements can be, in one embodiment, sintered masses, partially sintered masses, and/or layers of material attached to the substrate of the tool precursor according to any method known in the art. The cutting element can, in one aspect, include a mixture, homogeneous or otherwise, of a plurality of materials, optionally including abrasive particles. In another aspect, the cutting element can include a plurality of layers of material. As a non-limiting example, the cutting element can include a ceramic overcoated with CVD diamond.

In one aspect, the tool precursor of FIG. 2 can be further machined to form a plurality of asperities as illustrated in FIG. 3. As shown, the tool precursor 40 has an elongated substrate 42 with a continuous polycrystalline diamond or cubic boron

nitride cutting element 44 on one surface of the substrate. The diamond or cubic boron nitride cutting element is formed into a plurality of asperities 46 having a single tip or point. As shown, the asperities are of a pyramidal shape. Although pyramidal shape is illustrated as the asperity shape, any shape having a tip that can form an asperity is to be explicitly included herein. Regarding pyramidal shapes, the pyramidal shaped asperities can include irregular and regularly shaped pyramids. Such asperities can include any three-dimensional shape having triangular non-base surfaces that converge on one point. The base shape is typically quadrilateral or trilateral, but can be any polygon shape. In the case of FIG. 3, pyramid shaped asperities having a triangular base are shown and such pyramids have a substantially flat vertical side as will be explained in more detail. Alternatively, pyramids with a cubic base could be used. One of the faces of the pyramidal asperities of FIG. 3 is substantially perpendicular to the plane of the substrate surface. In such case, it is possible to pair two similar tool precursors in a back-to-front manner so as to form a pyramid shape having a larger base, i.e. each tool precursor would provide approximately one half of the asperity. In the case of arranging the tool precursors of FIG. 3 in a back-to-front manner, the pyramids formed by aligning two of the tool precursors together to form a single line of pyramidal asperities have a quadrilateral base shape, with half of each base being provided by a single tool precursor. In one embodiment, tool precursors of the present invention can be prepared by forming a PCD or PcBN blank with a PCD or PcBN layer attached to a substrate as shown in FIG. 10, and an elongated segment can be removed as shown. Next, an electro discharge machining (EDM) wire can be used to form the tool precursors by shaping the PCD or PcBN layer of each segment. The precursors can then be assembled into a finished tool.

In one aspect, a substrate having a continuous PCD or PcBN layer can be formed into a blade shape, either through EDM wire or other grinding or material removal method. Such blade shape is illustrated in FIG. 2. With the blade shape formed, asperities can be formed through use of EDM wire, or other precise material removal method. In forming asperities from a blade shape, the asperities can be formed immediately adjacent to each other, or can be spaced. The angles of each

asperity can be uniform or non-uniform. The EDM wire and other tools are easily used to sculpt the PCD or PcBN of the segments because of the fact that the individual segments present a two dimensional area to be carved rather than a three dimensional area that would have portions not easily accessible by the wire.

As noted, the abrasive tool is an assembly of tool precursors. The assembly can include any number of tool precursors, and can include tool precursors of varying design. Alternatively, the assembly can include a plurality of tool precursors having substantially the same shape and cutting elements. The assembly can be arranged so as to have a pattern of cutting element design. In one embodiment, an alternating design may be desirable. Furthermore, assembly of the tool precursors can include varying the height dimension, or the difference of asperity or blade projection in relation to adjacent tool precursors to effectuate a particular predetermined cutting configuration.

Non-limiting examples of arrangement of tool precursors includes alternating, as illustrated in FIG. 4, with alternating asperities 50 and blades 52 tool precursors; leading as in FIG. 5, with a blade 54 on one end and a plurality of asperity tool 56 precursors attached thereto; a following pattern as in FIG. 6, with a plurality of asperities aligned such that each tip is substantially in line with the asperities of the adjacent tool precursors; and offset patterns as in FIG. 7 with a plurality of tool precursors having asperities, where the asperities are aligned so as to not be in line with the asperities of the adjacent tool precursors. It should be noted that the illustrations are non-limiting arrangements of the tool precursors. Those illustrated could be combined in various ways. Additionally, blanks could be used in a variety of ways with patterns and predetermined placement so as to create a predetermined cutting configuration. Blanks can include simple substrate without PCD, or could include a layer of PCD or PcBN, continuous or discontinuous, as an unformed layer or coating. Furthermore, the arrangements illustrated do not account for the variety obtained from orienting one or more tool precursor in a reverse direction, such as the back-to-front orientation with the pyramidal shaped asperities. Such orientation of the tool precursors greatly increases the possibilities available for creating a cutting configuration. It should also be noted that the assemblies of tool precursors illustrated

in FIGs 4-7 can, along with a setting material, constitute the abrasive tool, or they may alternatively be a portion of an assembly of tool precursors in an abrasive tool.

Substrates used in the abrasive tool can be of a variety of compositions and shapes. In one aspect, the substrate can comprise or consist essentially of metals, metallics, ceramics, organics, and combinations thereof. Furthermore, the substrate can be directly in contact with the PCD or PcBN layer, or may include a layer, continuous or discontinuous, along the interface of the PCD or PcBN and substrate.

Forming an abrasive tool includes providing a plurality of tool precursors and securing the tool precursors together, into a tool having a working surface. The working surface can include a polycrystalline diamond or polycrystalline cubic boron nitride cutting element thereon. Securing the tool precursors together can include a variety of steps. In one aspect, a setting material can be used to form the consolidated tool. Non-limiting examples of steps used to secure the assembly of tool precursors include brazing, soldering, sintering, cementing, and combinations thereof. As such, setting materials can include braze material, soldering material, sintering agents, cementing material, organic materials including polymeric materials and resins, and combinations thereof. Furthermore, a setting material can include an adhesive.

Any process and any related material or materials can be used to set the tool precursors into a single mass. Such materials can be distributed or used between some or each of the tool precursors, or can be used to encompass that thereby set the tool precursors. One non-limiting example of a process that can be used to secure abrasive tool precursors can include securing the abrasive precursors with an organic material. The abrasive precursors can be arranged as desired against a steel or other plate, with the asperity, blade, or other tips arranged as desired. In the illustrated case of FIG. 8, the tips 60 of the asperities of the tool precursors 62 are arranged against a plate 64 so as to be level. The tips can be covered with an adhesive or other covering 66, and then an epoxy 68 can be placed over the arranged tool precursors. In one aspect, the epoxy can be reinforced with glass fibers, color-coded with pigments, reinforced with backing, or any combination thereof. Once the epoxy is cured, the tool precursors are arranged and set in a manner so as to provide a desired cutting surface. It should be noted that arranging the asperities and other tips in a level

manner is illustrated by the example, however such arrangement is only one embodiment of the present method and tool. It can be beneficial to deliberately arrange the tips tool precursors so as to provide for a vertical pattern, such that the asperity and other tips or points protrude different amounts from the working surface.

Various reverse casting methods may be utilized to set the tool precursors into a single mass. For example, a spacer layer of a material sufficiently soft so as to allow penetration of at least a tip portion of the precursors thereinto, may be applied to a working surface of a temporary substrate. The tool precursors can be arranged so that at least a portion of the cutting element of each precursor is at least partially embedded in the spacer layer and comes in contact with, or nearly in contact with, the temporary substrate. In one aspect, the tool precursors can be pressed by any mechanism or means such that the tips of asperities and/or blades come into contact with the temporary substrate. In this manner, the temporary substrate can define the final leveling contour of the assembled mass. As such, the temporary substrate can include any contour, levelness, slope, stepped, etc., according to the desired contours of the assembled mass. In an alternative aspect, the spacer layer may be optional. In yet another aspect, the spacer may be an adhesive or other organic resin.

An adhesive may be optionally applied to the temporary substrate and/or the spacer layer and/or the cutting elements to facilitate proper arrangement and temporary attachment. The adhesive used on any noted surface may be any adhesive known to one skilled in the art, such as, without limitation, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a pariffin, a phenolic resin, a wax emulsion, an acrylic resin, or combinations thereof. In one aspect, the fixative is a sprayed acrylic glue.

The spacer layer may be made from any soft, deformable material with a relatively uniform thickness, and may be selected according to particular needs of manufacturing, future use, compositional considerations of tool precursors, etc. Examples of useful materials include, but are not limited to, rubbers, plastics, waxes, graphites, clays, tapes, grafoils, metals, powders, and combinations thereof. In one aspect, the spacer layer may be a rolled sheet comprising a metal or other powder and

a binder. For example, the metal may be a stainless steel powder and a polyethylene glycol binder. Various binders can be utilized, which are well known to those skilled in the art, such as, but not limited to, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a pariffin, a phenolic resin, a wax emulsions, an acrylic resin, and combinations thereof.

An at least partially uncured resin material can be applied to the spacer layer opposite of the temporary substrate. A mold, e.g. of stainless steel or otherwise, may be utilized to contain the uncured resin material during manufacture. Upon curing the resin material, a resin layer is formed, cementing at least a portion of tool precursor. Optionally, a permanent tool substrate may be coupled to the resin layer to facilitate its use in dressing a CMP pad or in other uses. In one aspect, the permanent substrate may be coupled to the resin layer by means of an appropriate adhesive. The coupling may be facilitated by roughing the contact surfaces between the permanent substrate and the resin layer. In another aspect, the permanent substrate may be associated with the resin material, and thus become coupled to the resin layer as a result of curing.

The mold and the temporary substrate can subsequently be removed from the CMP pad dresser once the resin is cured. Additionally, the spacer layer can be removed from the resin layer. This may be accomplished by any mechanism known in the art including peeling, grinding, sandblasting, scraping, rubbing, abrasion, etc. Therefore, the protrusion of the tool precursors from the resin is dependent on the amount covered or concealed by the spacer layer. Additionally, the arrangement of the tool precursors is relatively fixed by the resin. As such, the tool precursors can be placed in a variety of configurations, thus creating a variety of configurations of a surface of an assembled tool.

Furthermore, the tool precursors can be set in a parallel formation, such as illustrated in FIGs 4-7, or can be placed in any arrangement that forms a desired cutting configuration. In one aspect, the tool precursors can be arranged in a spoke formation as illustrated in FIG. 9, wherein the tool precursors 70 are arranged as spokes of a wheel of the illustrated circular abrasive tool.

Tool precursors can be arranged at various angles to form abrasive tools. Blades can be angled to better interact with the various materials they contact. For

example, it may be found that angling a blade shaped tool precursor at a specific angle, or angling a plurality of blade shaped tool precursors at differing angles, can better handle material removal from a CMP pad.

In one embodiment, the tool precursors can be formed from a single mass. For example, a substrate, such as tungsten carbide, can be formed into a desired overall tool shape. Such formation of the overall tool is not required. In FIG. 10, however, a single substrate 72 is formed into a truncated cylindrical shape. One of the circular surfaces can be covered with a PCD or PcBN layer 74. A continuous layer is illustrated in the figure; however, a discontinuous layer could likewise be used. With the PCD or PcBN layer on the substrate, the individual tool precursors can be cut from the overall piece shown in FIG. 10. Once cut from the larger body, they can be of the form illustrated in FIG. 1, or any other shape cut from the larger body. Once cut, they can be further shaped, if desired. Once the tool precursors are formed, they can be optionally returned to the larger body, wherein each piece includes an inverse-image of neighboring surfaces as from being cut from the same original mass. Thus would form an abrasive tool having a substantially continuous PCD or PcBN layer, supposing the original mass included a substantially continuous PCD or PcBN layer. Optionally, only portions of the original mass can be reformed into the abrasive tool. In such case, the working surface of the abrasive tool may or may not include a substantially continuous PCD or PcBN layer, depending on the tool precursors selected to form the abrasive tool.

In another embodiment, another overall piece, such as that shown in FIG. 10, can be cut at a different angle, as illustrated in FIG. 11. As with FIG. 10, FIG. 11 depicts a single substrate 72 formed into a truncated cylindrical shape, with one of the circular surfaces covered with a PCD or PcBN layer 74. In this case, however, the overall piece is cut at a plane between perpendicular and parallel to the surface of the PCD or PcBN layer. A view of the side of the overall piece, including an additional cutting line and illustrating the cutting angle of FIG. 11 is illustrated in FIG. 12. Cutting or dividing the overall piece at an angle can produce a tool precursor as shown in FIG. 13, having an elongated substrate 78 and a continuous polycrystalline diamond or continuous polycrystalline cubic boron nitride, or other ceramic material cutting

element 80 on a surface of the substrate. The cutting element is formed into a blade shape, having a single tip of the cutting element substantially along the length the elongated tool precursor, as a result of cutting the tool precursor from the overall piece. To compare, the tool precursor of FIG. 13 is similar to the tool precursor of FIG. 2, where the FIG. 2 tool precursor has been cut and undergone a shaping step to produce the blade formation. One notable difference between the two tool precursors is the flat base of the elongated substrate in FIG. 2 versus the angled base of the elongated substrate of FIG. 13.

The cutting element of the abrasive tool precursors of FIG. 13 can be further shaped as with the other tool precursors disclosed herein. In a specific embodiment, a plurality of asperities can optionally be formed of the blade shape of the cutting element. Furthermore, the cutting elements having the angled base can be assembled as with other tool precursors disclosed herein. One non-limiting example is illustrated in FIG. 14, wherein abrasive precursors having a blade shaped cutting element and those having pyramidal asperities are alternated. It should be noted that blanks, i.e. substrates having no cutting element, other spacers, and other configurations of tool precursors in patterned or random arrangement are contemplated by the present disclosure. Furthermore, the tool precursors having angled bases and those having flat bases can be used in combination to form abrasive tools.

As with previously-disclosed tool precursors, the tool precursors having a angled bases can be included in an abrasive tool. Such tool precursors can be included along with other tool precursors, or the abrasive tool can be composed of tool precursors only having the angled bases. An example abrasive tool is shown as FIG. 15, wherein the substrates 82 and cutting element 74, in this embodiment, each shaped with a plurality of asperities, are held together with an epoxy 86. Such tool can be manufactured according to the methods disclosed herein, particularly with respect to the discussion around FIG. 8, and the resulting tool differs from previous embodiments primarily in that the base of the tool precursors is angled and thus creates a zig-zag design along the epoxy interface 88.

FIGs. 21-23 illustrate various other manners in which the tool precursors or cutting elements 70 can be arranged on the abrasive tool or pad dresser 112 to

maximize particular abrading functions while minimizing possible damage to the pad or workpiece being abraded. In these embodiments, the precursors or cutting elements are arranged such that the pad dresser or abrasive tool can "sweep" across the pad and completely, or nearly completely, dress the pad without internal features of cutting elements catching or "snagging" the pad to cause unwanted asperities.

As will appreciated, a periphery of any particular cutting element (or precursor) "knot" or assemblage is closed, such that the precursor assemblage can approach a portion of a pad (or the pad can approach the precursor assemblage) from any angle without having internal angles formed by the precursors "snag" on the pad material. Also, using this technique, more of the cutting tips can be faced outwardly (from any particular assemblage of cutting elements or precursors) in the direction of pad movement. The inner side can contain fewer cutting tips for less work (and less wear). In essence, one precursor (or cutting element) assemblage is defined in the embodiments of FIGs. 21 and 22 (each assemblage formed from a plurality of the precursors 70), whereas a plurality of knots or assemblages 71 are illustrated in FIG. 23, each formed from 3 precursors 70.

Turning now to FIGs. 16-20, in accordance with another aspect of the invention, various cutting devices and associated methods are provided that can be used to remove material from a CMP pad 118 in a manner that creates a smooth and even surface on the CMP pad. In accordance with one embodiment, the invention provides a CMP pad conditioner (shown by arbitrary example 112 in FIG. 20) that can include a base (e.g., 114 in FIG. 20) and a plurality of cutting elements 116 extending from the base. The cutting elements 116 shown in FIG. 20 are shown in one exemplary orientation showing one manner of spacing, placement, relative size, etc., of the cutting elements. Other embodiments can include a variety of differing sizes of cutting elements or blades, different physical layouts (e.g., spacing, angular arrangement, etc.), lengths of cutting elements or blades, etc., are also encompassed by the present invention.

As shown in FIG. 16, the cutting elements 116a, 116b, etc., can each have a cutting tip 120a, 120b, etc., that is operable to engage material of the CMP pad 118. At least some of the cutting elements can have a cutting tip oriented at a different

elevation relative to cutting tips of other cutting elements. For example, in the embodiment illustrated in FIG. 16, cutting tip 120a of cutting element 116a is oriented at a lower elevation than is cutting tip 120b of cutting element 116b (it is noted that, as used herein, the term "elevation" is used only to compare relative distances of elements, and does not limit the invention to orientations in a vertical plane).

In the aspect shown in FIG. 16, the pad 118 and the cutting elements 116 are moved relative to one another (e.g., the cutting elements can be moved in the direction indicated at 122) to remove material from the pad. As the cutting elements and pad are moved relative to one another, the leading cutting element 116a first engages the material of the pad and can remove a relatively thin layer of pad material. As the cutting elements progress over the pad material, trailing cutting element 116b engages the pad material and removes an additional thin layer of material. Thus, the pad material can be incrementally removed in thin layers until a smooth, even surface is applied to the pad.

In the embodiment shown in FIG. 11, the leading cutting element 116a includes a cutting tip 120a that is oriented at a greater elevation (relative to a base of the pad conditioner, which would be positioned above the cutting elements shown FIG. 16) than does the cutting tip 120b of immediately adjacent cutting element 116b. The embodiment of FIG. 16 also includes a pair of secondary trailing cutting elements 116c, 116d having cutting tips that are aligned at about the same elevation as cutting tip 120b. In this embodiment, the cutting tips 120a and 120b perform the work of removing thin layers of the pad material, while the secondary trailing cutting elements (116c, 116d) can perform very fine smoothing of any bumps or ridges remaining after the pass of cutting tips 120a and 120b.

In the embodiment shown in FIG. 16, the cutting elements are positioned so as to abut one another and pass over (and/or through) the pad material in rapid succession. It will be appreciated from FIG. 17 that the cutting elements can also be spaced some distance from another. This aspect of the invention can be advantageous in that the pad material may be deformed slightly by the leading cutting element, and may be given time to return to a relaxed condition prior to the succeeding trailing blade passing over the location recently cut or conditioned by the leading blade.

While not so required, in one embodiment of the invention, the cutting elements can include a cutting faces (122a, for example) that are oriented at 90 degrees or less relative to a surface 126 of the CMP pad that is formed by the cutting elements. The cutting faces of the cutting elements shown in FIGs. 16 and 17 are formed at about 90 degrees, while the cutting faces of the cutting elements shown in FIG. 18 are formed at an angle less than 90 degrees relative to the surface 126 formed on the pad material. In addition, the faces of the cutting blades can be curved or arcuate in nature

In the embodiment shown in FIGs. 16 and 17, the cutting elements include a trailing edge 130a, 130b, etc. that is angled to provide a relief area between the cutting elements and the conditioned surface 126 of the CMP pad created by the cutting elements. However, as shown in FIG. 18, the trailing edges 140a, 140b, etc. can also be formed in a substantially parallel relationship with the surface 126 created on the pad material by the cutting elements.

It will be appreciated that the number of cutting elements, and the relative elevational position of the cutting tip of each cutting element, can vary. In the embodiment illustrated in FIG. 19, three cutting elements 136a, 136b and 136c are provided, each including a different elevation. In other embodiments, the cutting tips of two or more cutting elements can share a substantially common elevation, while others are staggered upwardly or downwardly relative to this common elevation. In some embodiments, leading blades (e.g., blades that will first contact the pad material) will be at a relatively higher elevation than are trailing blades, as the trailing blades would not otherwise contact pad material remaining after the leading blade has passed. One exception to this generalization may be in the case of pad conditioners that include trailing blades that are slightly higher than an adjacent leading blade, in the case clean up of very rough surfaces created by the leading blade requires removal of protrusions created by the leading blade. In other embodiments, many of the blades may share a common elevation. The variety of differing configurations made possible by the present invention provides a great deal of flexibility in tailoring pad conditioners for specific applications.

The cutting elements or blades can be formed in a variety of manners. One

embodiment includes forming the cutting elements from a polycrystalline diamond compact or a polycrystalline cubic boron nitride compact (individual cutting elements can be formed from the compacts and attached to the base, or the base and the cutting elements can be formed from an integral piece of the compact).

In another aspect, the cutting elements can be formed by creating a sintered alumina plate having the basic shape of the cutting elements extending therefrom. A layer of DLC can be coated over this resulting patterned surface. Also, CVDD can be coated over a patterned surface of ceramic. In addition, a sintered SiC plate (with molten silicon used to infiltrate the pores) can be used. In another embodiment, sintered silicon nitride (Si3N4) can be used.

In addition, other materials can be used as the cutting elements or blades, either alone or in combination with other materials, and are to be included in the scope of the disclosure herein. For example, the cutting element can comprise or consist essentially of ceramics, or other diamond or cBN films, including those deposited via chemical vapor deposition (CVD).

Non-limiting examples of ceramics that can be used as a cutting element include alumina, aluminum carbide, silica, silicon carbide, silicon nitride, zirconia, zirconium carbide, and mixtures thereof. Cutting elements can be, in one embodiment, sintered masses, partially sintered masses, and/or layers of material attached to the substrate of the tool precursor according to any method known in the art. The cutting element can, in one aspect, include a mixture, homogeneous or otherwise, of a plurality of materials, optionally including abrasive particles. In another aspect, the cutting element can include a plurality of layers of material. As a non-limiting example, the cutting element can include a ceramic overcoated with CVD diamond.

In some embodiments, the cutting elements can be generally tooth-like, individual projections. In other aspects of the invention, the cutting elements can include cutting blades. As used herein, a "cutting blade" is to be understood to refer to a cutting element that includes a length (or width, the portion referenced being the portion that cuts the pad material) greater than a height (the portion that is "sunk" below an initial surface of the pad material). The cutting blades can advantageously

be used to remove a larger percentage of pad material per pass. The cutting blades can also include varying cutting angles along the length of the cutting blades, and can include individual teeth formed thereon, or therewith. Serrations, protrusions, and the like can also be formed on or in the cutting blades, or attached thereto, to enhance the cutting ability of the teeth or blades.

The cutting elements of the present invention can be associated with the base 114 in a variety of manners. In one embodiment, the cutting elements and the base are formed from an integral piece of material, such as a polycrystalline diamond compact, a polycrystalline cubic boron nitride compact, and the like. In other aspects, the cutting elements can be bonded, welded or otherwise attached to the base.

Also, various reverse casting methods may be utilized to associate the cutting elements with the base. For example, a spacer layer may be applied to a working surface of a temporary substrate. The cutting elements can be arranged so that at least a portion of each the cutting elements is at least partially embedded in the spacer layer. In one aspect, the cutting elements can be pressed by a variety of mechanisms or means such that tips of the cutting elements come into contact with the temporary substrate. In this manner, the temporary substrate can define the final leveling configuration (e.g., contour) of the finished pad conditioner/cutting tool. As such, the temporary substrate can include varying degrees and combinations of contour, levelness, slope, steps, etc., according to the desired contours of the pad conditioner/cutting tool.

An adhesive may be optionally applied to the temporary substrate and/or the spacer layer and/or the cutting elements to facilitate proper arrangement and temporary attachment. The adhesive used on any noted surface may be any adhesive known to one skilled in the art, such as, without limitation, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a pariffin, a phenolic resin, a wax emulsion, an acrylic resin, or combinations thereof. In one aspect, the fixative is a sprayed acrylic glue.

The spacer layer may be made from any soft, deformable material with a relatively uniform thickness, and may be selected according to particular needs of manufacturing, future use, compositional considerations of tool precursors, etc.

Examples of useful materials include, but are not limited to, rubbers, plastics, waxes, graphites, clays, tapes, grafoils, metals, powders, and combinations thereof. In one aspect, the spacer layer may be a rolled sheet comprising a metal or other powder and a binder. For example, the metal may be a stainless steel powder and a polyethylene glycol binder. Various binders can be utilized, which are well known to those skilled in the art, such as, but not limited to, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a paraffin, a phenolic resin, a wax emulsions, an acrylic resin, and combinations thereof.

An at least partially uncured resin material can be applied to the spacer layer opposite of the temporary substrate. A mold, e.g. of stainless steel or otherwise, may be utilized to contain the uncured resin material during manufacture. Upon curing the resin material, a resin layer is formed, cementing at least a portion of a cutting element. Optionally, a permanent tool substrate may be coupled to the resin layer to facilitate its use in dressing a CMP pad or in other uses. In one aspect, the permanent substrate may be coupled to the resin layer by means of an appropriate adhesive. The coupling may be facilitated by roughing the contact surfaces between the permanent substrate and the resin layer. In another aspect, the permanent substrate may be associated with the resin material, and thus become coupled to the resin layer as a result of curing. The mold and the temporary substrate can subsequently be removed from the CMP pad dresser once the resin is cured. Additionally, the spacer layer can be removed from the resin layer. This may be accomplished by any means known in the art including peeling, grinding, sandblasting, scraping, rubbing, abrasion, etc. Therefore, the protrusion of the cutting elements from the resin is dependent on the amount covered or concealed by the spacer layer. Additionally, the arrangement of the cutting elements can be relatively fixed by the resin. As such, the cutting elements can be placed in a variety of configurations, thus creating a variety of configurations of a surface of an assembled tool (e.g., pad conditioner).

Each of the cutting elements can include a substantially planar trailing face (e.g., 140a, 140b in FIG. 18 and 140c in FIG. 20) that can define a workpiece contact area. A combined workpiece contact area of all of the cutting elements can comprise from between about 5% of a total area of the base to about 20% of a total area of the

base. Thus, in one aspect of the invention, if a pad dresser has a diameter of about 100 mm, and the combined contact areas of the cutting element will be about 10% of that total, then the total contact area of all cutting elements can be about 7850 mm^2. An edge-to-area ratio of each cutting element can be about 4/mm, resulting in a total edge length being about 31400 mm.

The cutting devices of the present invention can be utilized in either a wet system or a dry system. In a dry application, the cutting elements can be used to cut or plane chips from a workpiece without the presence of a liquid slurry. In a typical application, the cutting device can be mounted to a holder cushion that can be coupled to a rotatable chuck. The workpiece, for example, a silicon wafer or a CMP pad, can be coupled to a vacuum chuck that provides for rotation of the workpiece. Both the rotatable chuck and the vacuum chuck can be rotated in either a clockwise or a counterclockwise direction to remove material from the workpiece. By changing the rotation of one element relative to another, more or less material can be removed in a single rotation of the workpiece. For example, if the workpiece and cutting elements are rotated in the same direction (but at different speeds), less material will be removed than if they are rotated counter to one another.

In this typical application, a slurry can be applied that can aid in planing the workpiece surface. The slurry can be either a water slurry or a chemical slurry. In the case where a chemical slurry is used, the chemical can be selected to provide cooling or to react with the surface of the workpiece to soften the workpiece to provide a more efficient cutting process. It has been found that the wear rate of a silicon wafer can be dramatically increased by softening its surface. For example, a chemical slurry that contains an oxidizing agent (e.g. H_2O_2) may be used to form a relatively highly viscous oxide that will tend to "cling" on the wafer surface. In this case, the PCD cutting devices of the present invention need not necessarily cut the wafer, but rather can scrape the oxide off the surface of the wafer. Consequently, the sharpness of the cutting edge becomes less critical. In addition, the service life of the cutting device can be greatly extended by utilizing a slurry. For example, a PCD scraper used with a slurry may last 1000 times longer than a PCD cutter.

In addition to the structural aspects discussed above, the present invention also

provides a method of conditioning a CMP pad is provided, including: engaging material of the CMP pad with a cutting tip of at least one cutting element; moving the cutting element and the CMP pad relative to one another to thereby remove material from the CMP pad with the cutting tip of the cutting element to create an exposed layer of CMP pad material; engaging the exposed layer of CMP pad material with the cutting tip of the cutting element, or with a cutting tip of a second cutting element; and moving the cutting element engaged with the exposed layer of CMP pad material and the CMP pad relative to one another to thereby remove the exposed layer of CMP pad material.

Engaging the exposed layer of CMP pad material can comprise engaging the exposed layer with the cutting tip of the cutting element used to create the exposed layer.

Engaging the exposed layer of CMP pad material can comprise engaging the exposed layer with the cutting tip of the second cutting element.

The present invention also provides a method of conditioning a CMP pad, including: removing, with a cutting element, a thin layer of material from the CMP pad; and removing, with the same or a different cutting element, a second layer of material from the CMP, the second layer of material being revealed by removal of the thin layer of material.

Abrasive tools formed according to the methods presented herein can be used as a final abrasive tool, e.g. utilized as a CMP dresser. Alternatively, the abrasive tools can be combined, or used as an element or elements in an abrasive tool assembly to form a CMP dresser.

FIGs. 24 and 25 illustrate data associated with another aspect of the invention, in which a sharpness and spacing of cutting "teeth" of various cutting elements or precursors are varied to address issues relating to asperities formed in the pad during dressing. As will be appreciated from FIG. 24, the more "rolling" cutting teeth illustrated with an angle of about 150 degrees have been shown to provide a better abrading profile than do the slightly wavy cutting teeth at about 130 degrees, and the more sharp cutting teeth formed at about 90 degrees. The more rolling cutting teeth are advantageous in that tips of the cutting teeth are not prone to breakage during use,

and during manufacture or formation of the cutting teeth. This advantage increases the precision with which the cutting teeth can dress pads, and increases the life of the cutting teeth, and greatly decreases the cost for which the dressers can be manufactured.

The data presented in FIG. 25 illustrates the wafer profile for a WCMP with in-situ dressing of the present pad conditioner as compared to a conventional brazed diamond dressing pad. Due to the simultaneous dressing and polishing provided by the present invention, the throughput could be increased by as much as 25%.

It is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and any appended or following claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use may be made without departing from the principles and concepts set forth herein.

CLAIMS

What is claimed is:

1. An abrasive tool, comprising:

an assembly of tool precursors including at least one elongated substrate having a continuous cutting element of polycrystalline diamond, polycrystalline cubic boron nitride, or ceramic formed into a blade shape on a surface thereof; and

a setting material configured to attach the tool precursors into a single mass that forms a predetermined cutting configuration.

2. The abrasive tool of claim 1, comprising a plurality tool precursors having elongated substrates having a continuous cutting element formed into a blade shape on a surface thereof.

3. The abrasive tool of claim 2, wherein the blade shaped tool precursors are arranged in a pattern, wherein the surfaces having the cutting element are oriented into substantially a single plane.

4. The abrasive tool of claim 3, wherein the pattern is an alternating pattern with at least one blank elongated substrates or elongated substrates having a continuous cutting element formed into a non-blade shape on a surface thereof.

5. The abrasive tool of claim 1, further comprising at least one elongated substrate having a continuous cutting element formed into a plurality of asperities.

6. The abrasive tool of claim 5, wherein the plurality of asperities include pyramidal shapes.

7. The abrasive tool of claim 5, wherein the abrasive tool includes at two abrasive precursors having elongated substrates that, when placed together, form asperities having substantially pyramidal shapes.

8. The abrasive tool of claim 1, wherein the abrasive precursors having a continuous cutting element on a surface thereof are arranged such that the protruding portions of the cutting element are substantially level.

9. The abrasive tool of claim 1, wherein the cutting element is polycrystalline diamond.

10. The abrasive tool of claim 1, wherein at least one abrasive tool is used as an element in an abrasive tool assembly.

11. The abrasive tool of claim 1, wherein the assembly includes a plurality of elongated tool precursors in a substantially parallel formation.

12. The abrasive tool of claim 1, wherein a plurality of tool precursors include surfaces having an inverse profile of another tool precursor.

13. An abrasive tool, comprising:

an assembly of tool precursors, including an elongated substrate having a continuous cutting element of polycrystalline diamond polycrystalline cubic boron nitride, or a ceramic material on a surface thereof, said precursor assembly providing a tool having a working surface with a predetermined cutting configuration; and

a setting material configured to attach the tool precursors into a single mass that forms the predetermined cutting configuration.

14. The abrasive tool of claim 13, wherein the assembly includes a plurality of tool precursors having elongated substrates and having a continuous cutting element on a surface thereof.

15. The abrasive tool of claim 14, wherein at least one of the plurality of tool precursors includes a tool precursor having the continuous cutting element formed into a plurality of asperities.

16. A method of forming an abrasive tool, comprising:

providing a plurality of tool precursors, including an elongated substrate having a continuous cutting element on a surface thereof; and

securing the tool precursors together, into a tool having a working surface with a predetermined cutting configuration.

17. The method of claim 16, wherein the plurality of tool precursors includes at least one tool precursor having a continuous cutting element formed into a plurality of asperities on a surface thereof.

18. The method of claim 16, wherein the securing includes a reverse casting of the tool precursors and setting with a setting material.

19. A method of forming an abrasive tool, comprising:

ordering a plurality of tool precursors, including at least one elongated substrate having a continuous cutting element of polycrystalline diamond, cubic boron nitride, or a ceramic material formed into a blade shape on a surface thereof into a preselected design;

vertically arranging the plurality of tool precursors;

masking a portion of cutting element with a masking material;

setting the tool precursors together using a resinous setting material; and

removing the masking material to reveal a tool having a predetermined working surface.

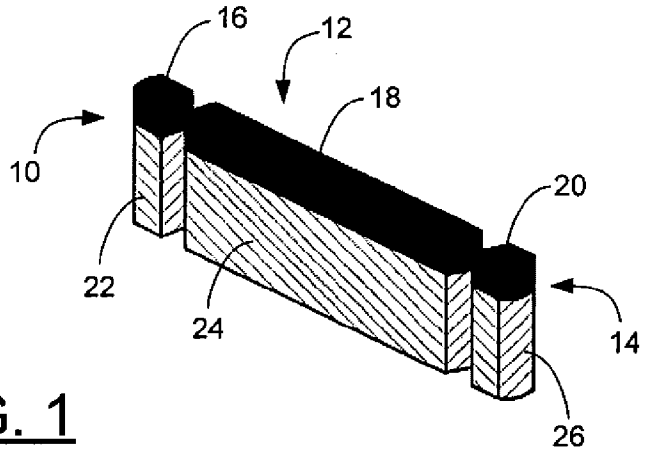


FIG. 1

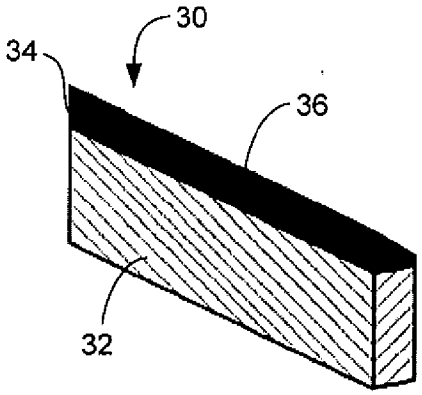


FIG. 2

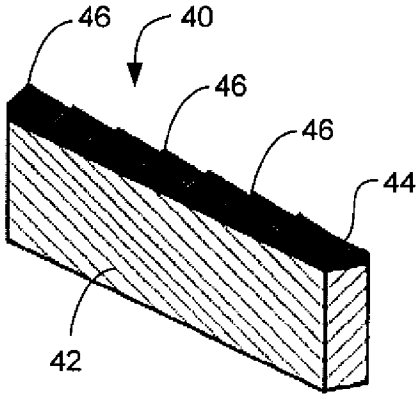


FIG. 3

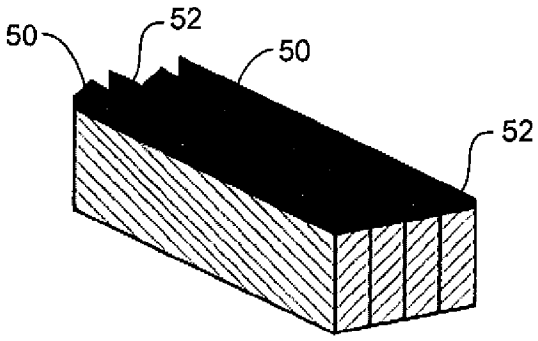


FIG. 4

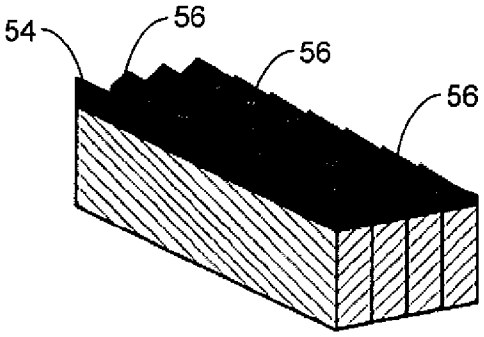


FIG. 5

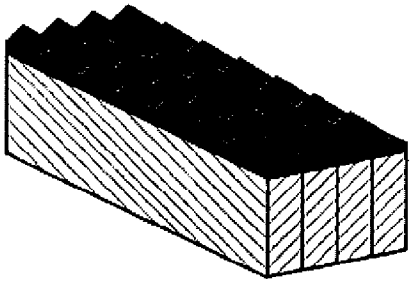


FIG. 6

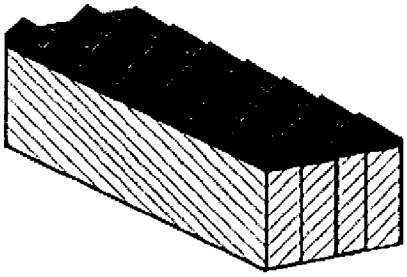


FIG. 7

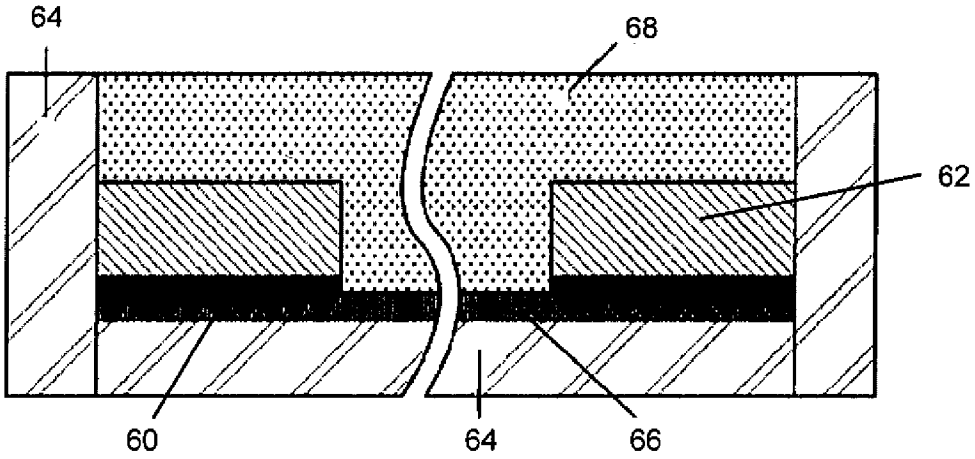


FIG. 8

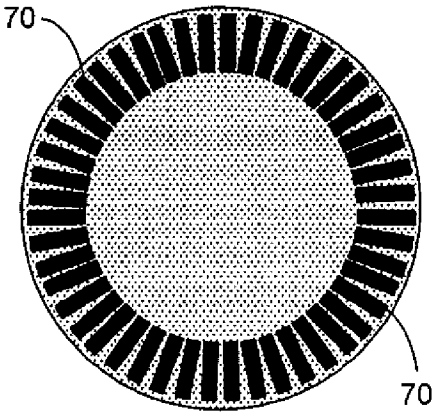


FIG. 9

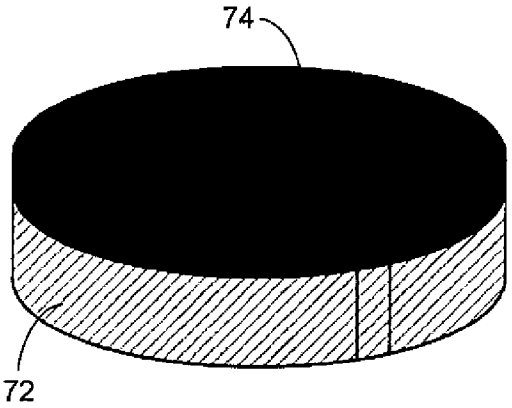


FIG. 10

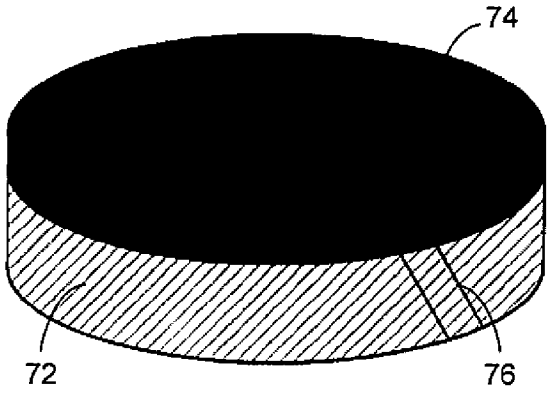


FIG. 11

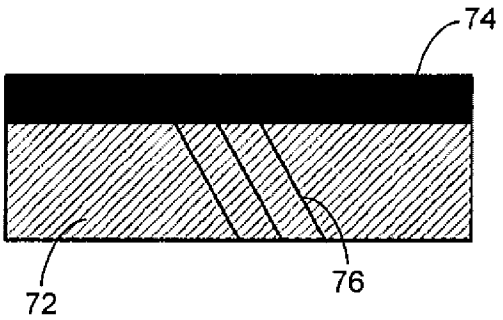


FIG. 12

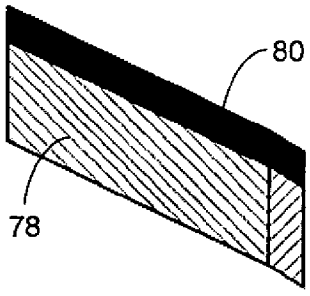


FIG. 13

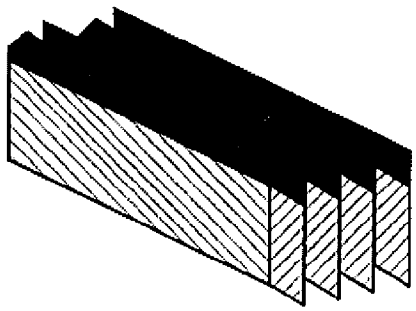


FIG. 14

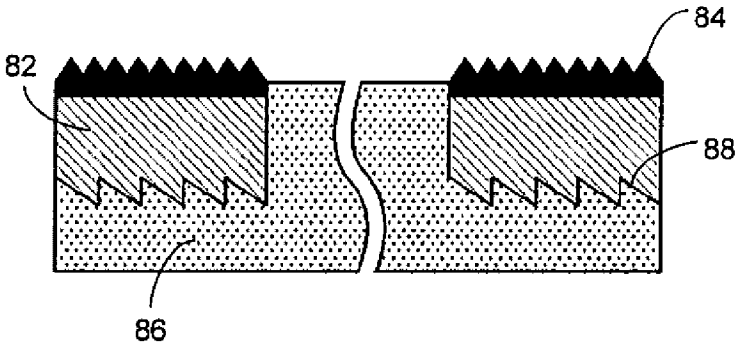


FIG. 15

FIG. 16

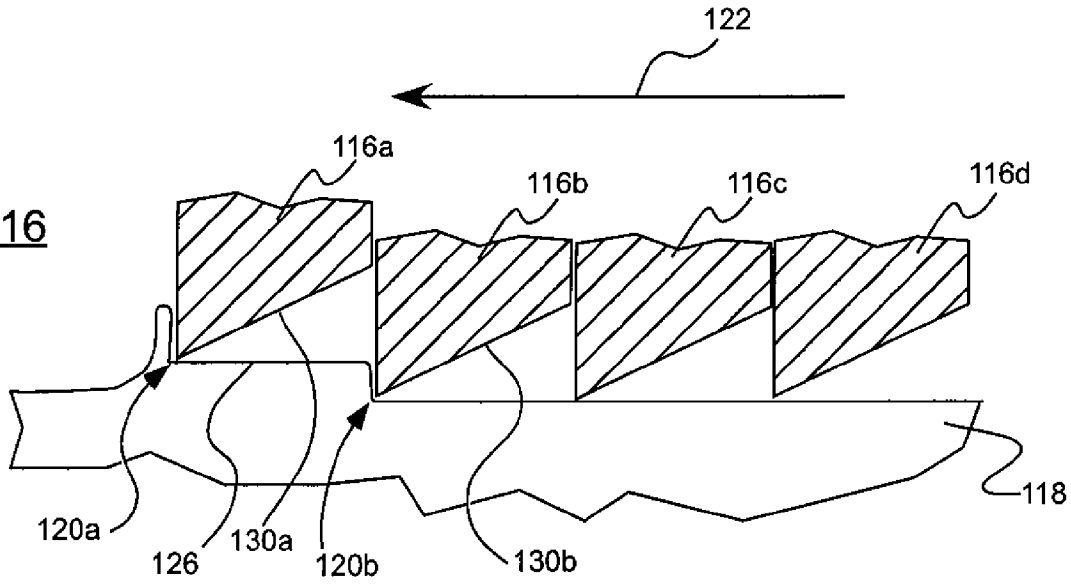


FIG. 17

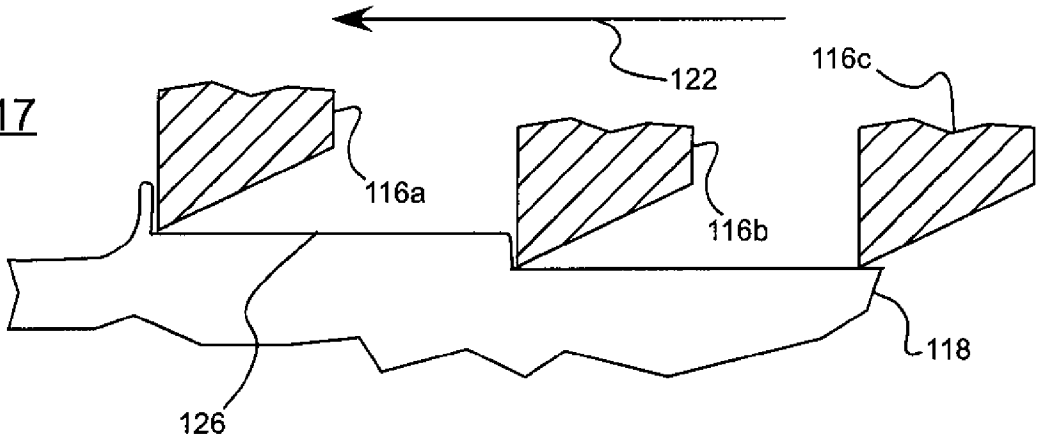
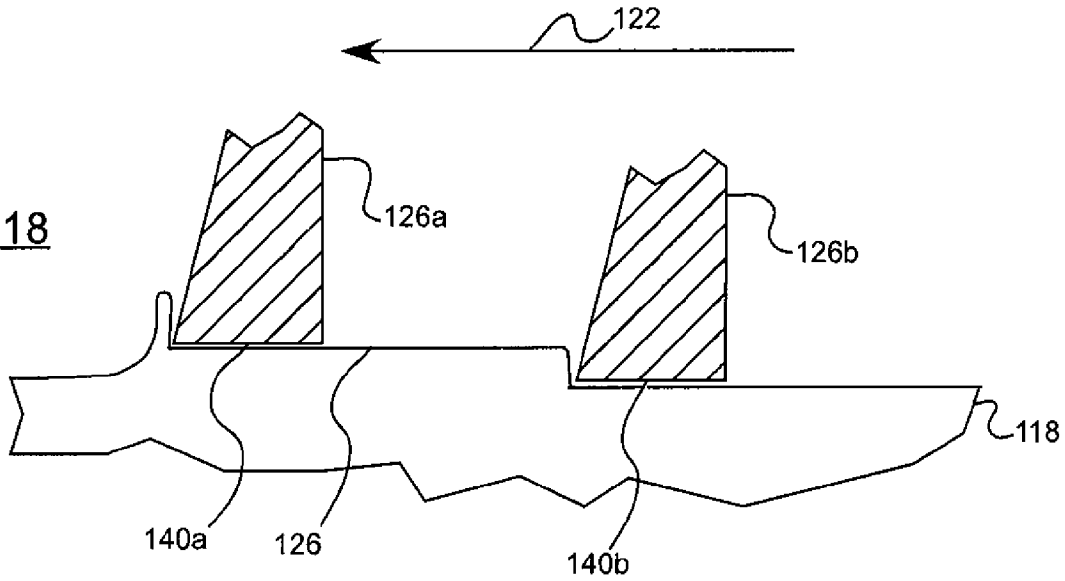


FIG. 18



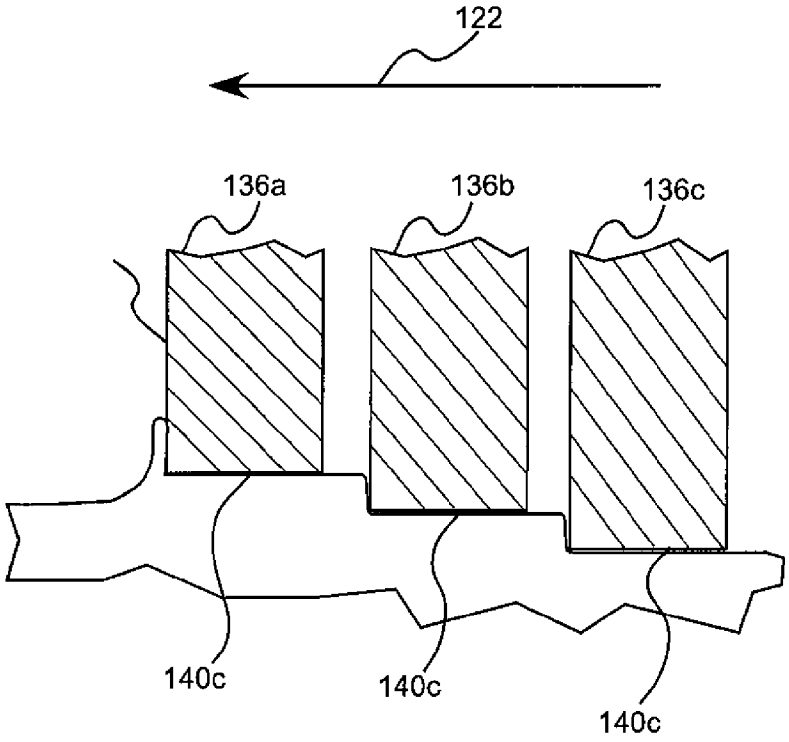


FIG. 19

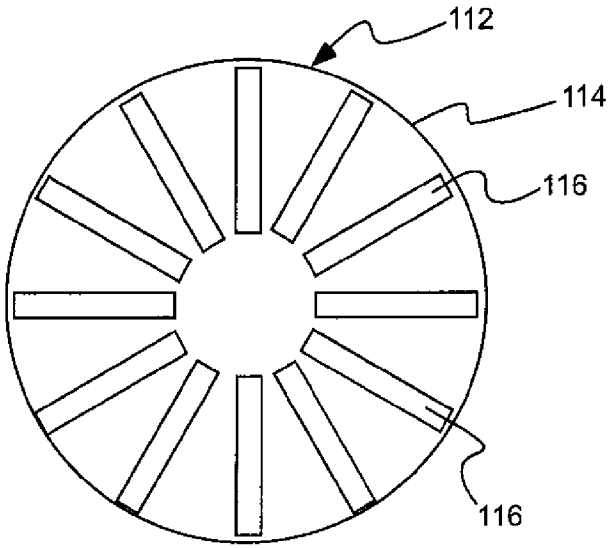


FIG. 20

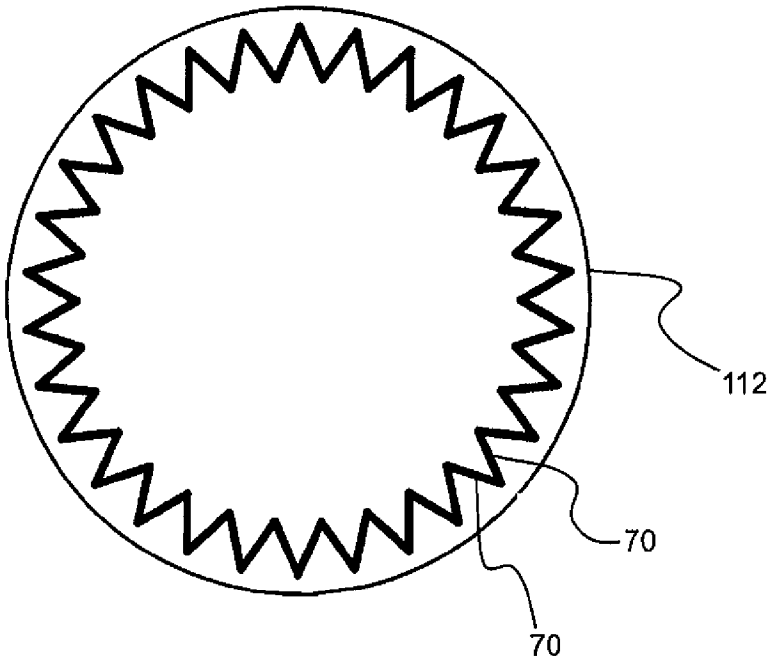


FIG. 21

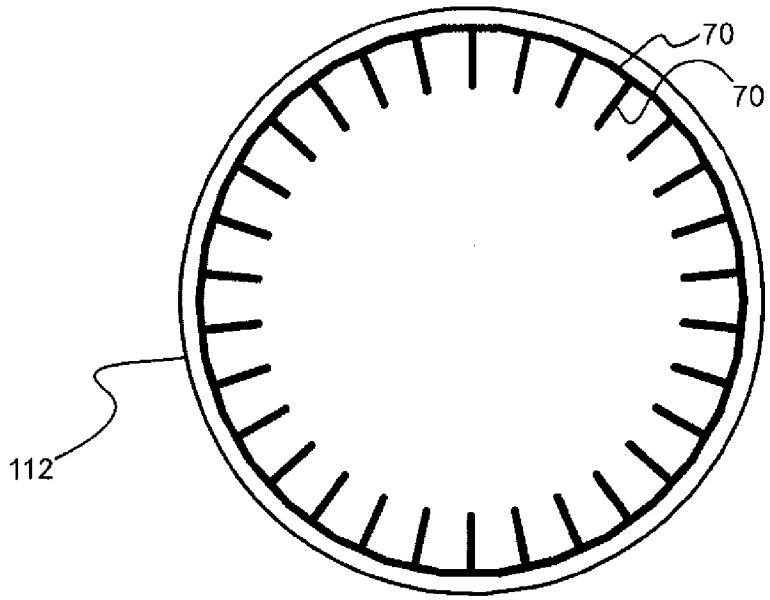


FIG. 22

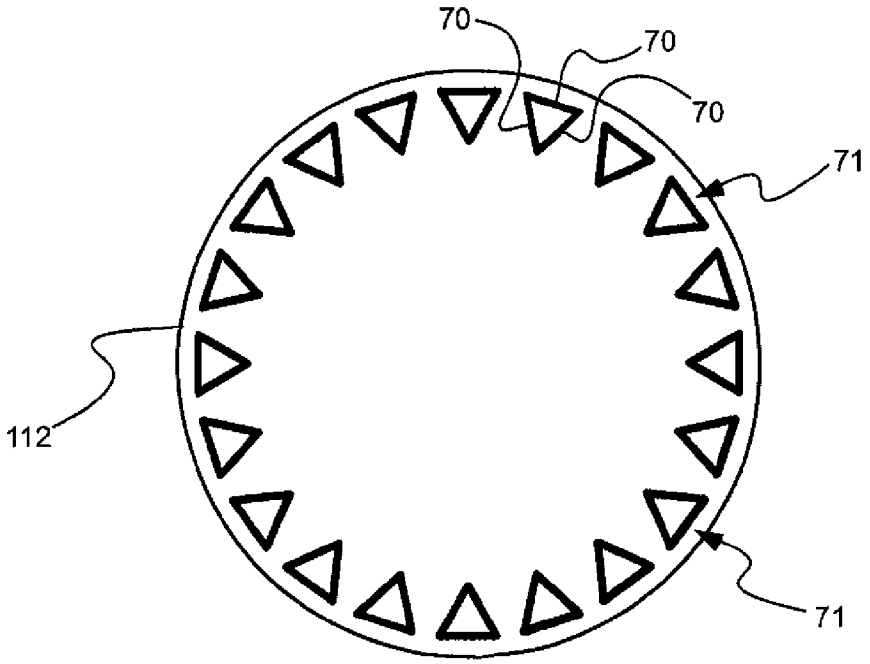


FIG. 23

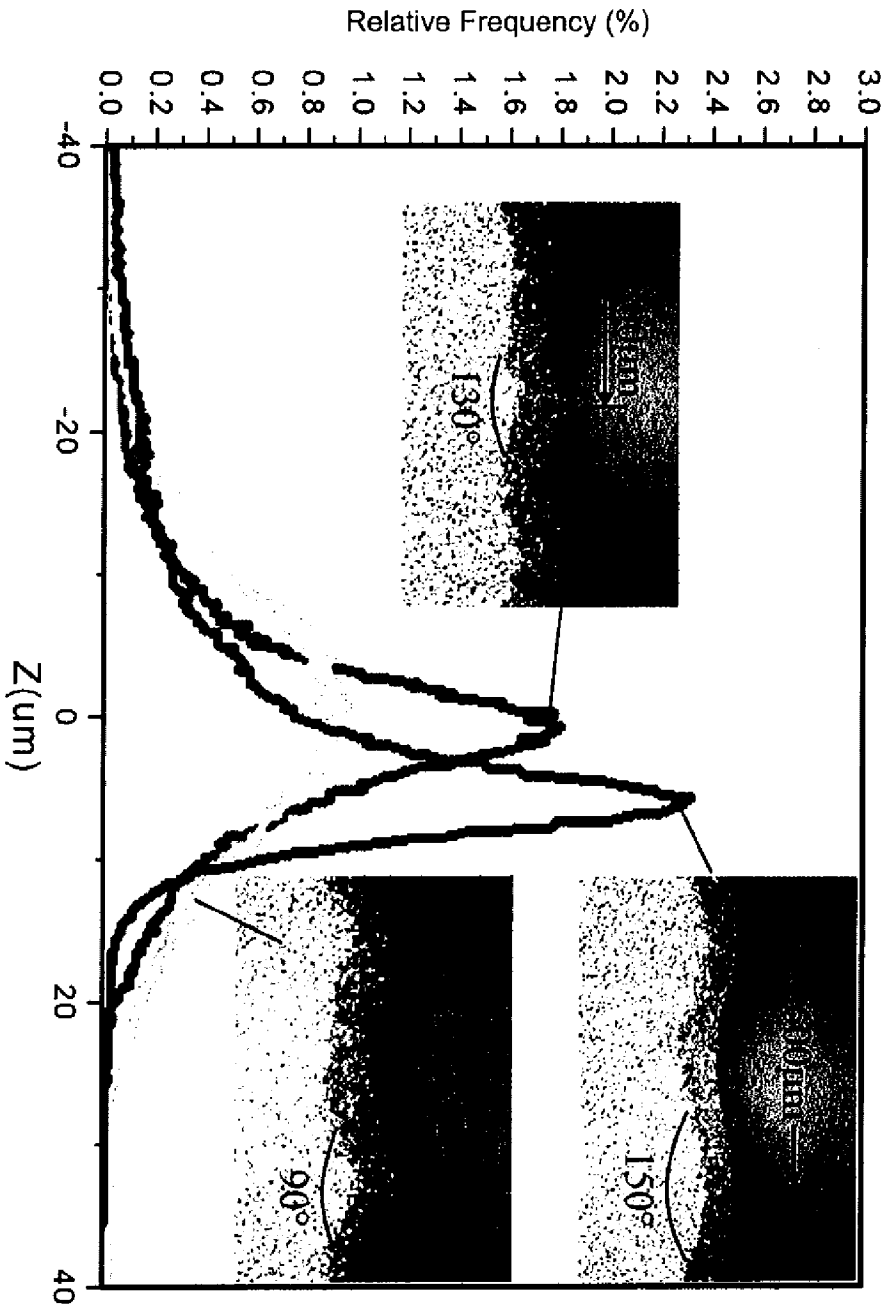

Relative Frequency (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
-40
-20
0
20
40
Z(um)
130°
90°
150°

FIG. 24

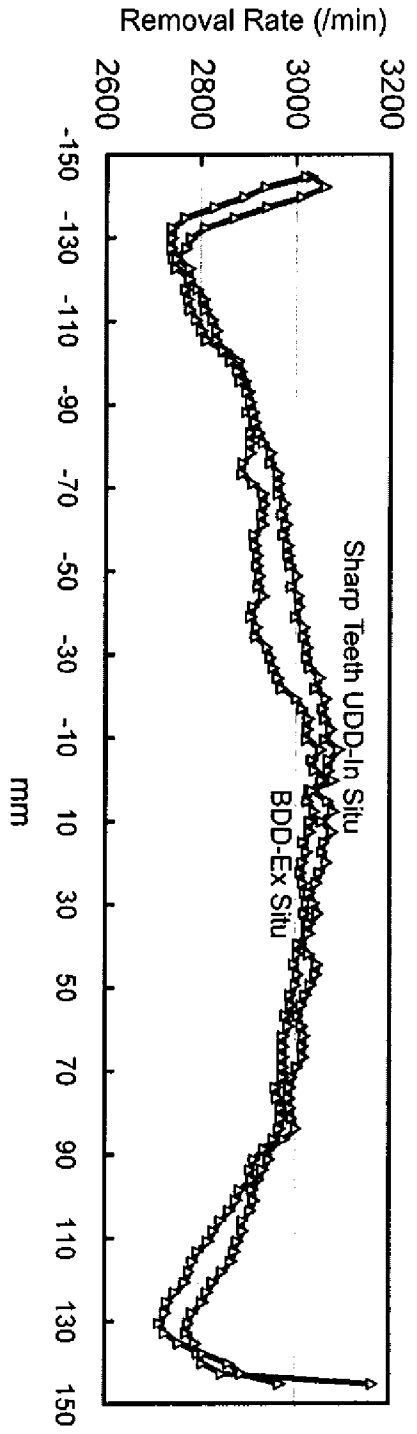

Removal Rate (/min)
2600
2800
3000
3200
-150
-130
-110
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
mm
Sharp Teeth UDD-In Situ
BDD-Ex Situ

FIG. 25

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(54) Title: SUPERABRASIVE TOOLS HAVING SUBSTANTIALLY LEVELED PARTICLE TIPS AND ASSOCIATED METHODS

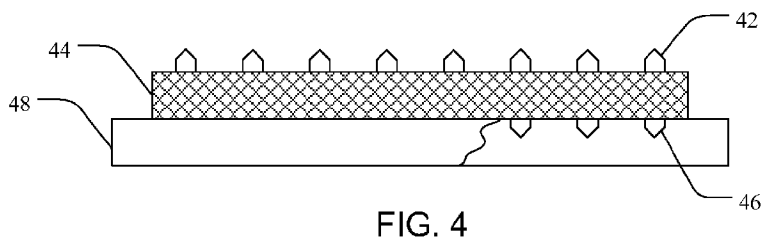


FIG. 4

(57) Abstract: Superabrasive tools and methods for making and using the same are provided. In one aspect, for example, a CMP pad dresser includes a first monolayer of superabrasive particles disposed on and coupled to one side of a metal support layer and a second monolayer of superabrasive particles disposed on and coupled to the metal support layer on an opposite side from the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer.

WO 2012/040374 A2

SUPERABRASIVE TOOLS HAVING SUBSTANTIALLY LEVELED PARTICLE TIPS AND ASSOCIATED METHODS

PRIORITY DATA

This application claims the benefit of United States Provisional Patent Application Serial Nos. 61/384,976 and 61/468,917, filed on September 21, 2010 and March 29, 2011 respectively, each of which are incorporated herein by reference.

BACKGROUND OF THE INVENTION

The semiconductor industry currently spends in excess of one billion U.S. dollars each year manufacturing silicon wafers that must exhibit very flat and smooth surfaces. Known techniques to manufacture smooth and even-surfaced silicon wafers are plentiful. The most common of these involves the process known as Chemical Mechanical Polishing (CMP) which includes the use of a polishing pad in combination with an abrasive slurry. Of central importance in all CMP processes is the attainment of high performance levels in aspects such as uniformity of polished wafer, smoothness of the IC circuitry, removal rate for productivity, longevity of consumables for CMP economics, etc.

SUMMARY OF THE INVENTION

The present disclosure provides superabrasive tools and methods for making and using the same. In one aspect, for example, a CMP pad dresser is provided. Such a dresser includes a first monolayer of superabrasive particles disposed on and coupled to one side of a metal support layer and a second monolayer of superabrasive particles disposed on and coupled to the metal support layer on an opposite side from the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer. In another aspect, the superabrasive particles of the second monolayer are positioned to have the same distribution as the superabrasive particles of the first monolayer. In yet another aspect, a rigid support can be coupled to the second monolayer of superabrasive particles opposite the first monolayer.

Various materials are contemplated for use as superabrasive particles in the first monolayer and/or the second monolayer, and any known superabrasive particle

material is considered to be within the present scope. Non-limiting examples of superabrasive particle materials include diamond materials, nitride materials, ceramics, and the like, including combinations thereof. In one specific aspect, the superabrasive particles include a diamond material. In another specific aspect, the superabrasive particles include a cubic boron nitride material.

The present disclosure additionally provides methods of making CMP pad dressers. In one aspect, a method of making a CMP pad dresser can include disposing a first monolayer of superabrasive particles on a metal support layer, and disposing a second monolayer of superabrasive particles on the metal support layer on a side opposite the first monolayer, where the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer. The method further includes bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the metal support layer such that symmetrical forces due to the substantially similar distribution between the first monolayer and the second monolayer precludes substantial warping of the metal support layer.

The superabrasive particles of the first monolayer and/or the second monolayer can be coupled to the metal support layer using a variety of contemplated techniques. It is understood that any technique for coupling superabrasive particles to a support is considered to be within the present scope. Non-limiting examples can include brazing, pressurized heating, sintering, electroplating, polymeric binding, and the like, including combinations thereof. In one specific aspect, at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles is coupled to the metal support layer with a braze alloy. In another aspect, both the first monolayer of superabrasive particles and the second monolayer of superabrasive particles are coupled to the metal support layer with a braze alloy. In yet another aspect, the bonding of at least one of the first monolayer or the second monolayer is under heat and pressure. In a further aspect, the heat and pressure bonds at least one of the first monolayer or the second monolayer directly to the metal support layer. In another aspect, the bonding of at least one of the first monolayer and the second monolayer further includes disposing a sintering compound on the metal support layer in contact with at least one of the first monolayer or the second monolayer, and sintering the sintering compound to bond the at least one of the first

monolayer or the second monolayer to the metal support layer. In one specific aspect the method can also include infiltrating the sintering compound with a braze material during bonding.

In one aspect, the method can further include coupling the second monolayer of superabrasive particles to a rigid support. Various techniques for coupling the rigid support to the second monolayer are contemplated, and any known technique is considered to be within the present scope. Non-limiting aspects of such techniques include hot pressing, brazing, sintering, soldering, electroplating, polymeric binding, and combinations thereof. In one specific aspect, the coupling of the second monolayer of superabrasive particles to the rigid support is accomplished by polymeric bonding.

The present disclosure additionally provides methods of inimizing warpage of a CMP pad dresser during manufacture. In one aspect, such a method can include substantially equalizing warping forces on opposing sides of a metal support layer during bonding of a plurality of superabrasive particles thereto, where warpage of the support layer is minimized during bonding due to the equalized forces on opposing sides. In one specific aspect, substantially equalizing forces includes arranging the plurality of superabrasive particles on opposing sides of the support layer such that the plurality of superabrasive particles has substantially the same distribution on either side of the support layer to substantially equalize warping forces during bonding.

There has thus been outlined, rather broadly, various features of the invention so that the detailed description thereof that follows may be better understood, and so that the present contribution to the art may be better appreciated. Other features of the present invention will become clearer from the following detailed description of the invention, taken with the accompanying claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention;

FIG. 2 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention;

FIG. 3 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention; and

FIG. 4 is a schematic side view of a CMP pad dresser in accordance with an embodiment of the present invention.

It will be understood that the above figures are merely for illustrative purposes in furthering an understanding of the invention. Further, the figures are not drawn to scale, thus dimensions, particle sizes, and other aspects may, and generally are, exaggerated to make illustrations thereof clearer. Therefore, departure can be made from the specific dimensions and aspects shown in the figures in order to produce the heat spreaders of the present invention.

DETAILED DESCRIPTION

Before the present invention is disclosed and described, it is to be understood that this invention is not limited to the particular structures, method steps, or materials disclosed herein, but is extended to equivalents thereof as would be recognized by those ordinarily skilled in the relevant arts. It should also be understood that terminology employed herein is used for the purpose of describing particular embodiments only and is not intended to be limiting.

It must be noted that, as used in this specification and the appended claims, the singular forms "a," "an" and, "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a diamond particle" includes one or more of such particles and reference to "the layer" includes reference to one or more of such layers.

Definitions

In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

As used herein, the terms "conditioner" and "dresser" can be used interchangeably, and refer to a tool used to condition or dress a pad, such as a CMP pad.

As used herein, "superabrasive" may be used to refer to any crystalline, or polycrystalline material, or mixture of such materials which has a Mohr's hardness of about 8 or greater. In some aspects, the Mohr's hardness may be about 9.5 or greater. Such materials include but are not limited to diamond, polycrystalline diamond

(PCD), cubic boron nitride (cBN), polycrystalline cubic boron nitride (PcBN), corundum and sapphire, as well as other superabrasive materials known to those skilled in the art. Superabrasive materials may be incorporated into aspects of the present disclosure in a variety of forms including particles, grits, films, layers, pieces, segments, etc.

As used herein, "particle" refers to a particulate form of a material. Such particles may take a variety of shapes, including round, oblong, square, euhedral, etc., can be either single crystal or polycrystalline, and can have a number of mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes. All mesh sizes referred to herein are U.S. mesh unless otherwise indicated. Further, mesh sizes are generally understood to indicate an average mesh size of a given collection of particles since each particle within a particular "mesh size" may actually vary over a small distribution of sizes.

As used herein, the process of "brazing" is intended to refer to the creation of chemical bonds between the atoms of the superabrasive particles/materials and the braze material. Further, "chemical bond" means a covalent bond, such as a carbide or boride bond, rather than mechanical or weaker inter-atom attractive forces. Thus, when "brazing" is used in connection with superabrasive particles a true chemical bond is being formed. However, when "brazing" is used in connection with metal to metal bonding the term is used in the more traditional sense of a metallurgical bond. Therefore, brazing of a superabrasive segment to a tool body does not necessarily require the presence of a carbide former.

As used herein, "sintering" refers to the joining of two or more individual particles to form a continuous solid mass. The process of sintering involves the consolidation of particles to at least partially eliminate voids between particles. Sintering of diamond particles generally is facilitated by ultrahigh pressures and the presence of a carbon solvent as a diamond sintering aid.

The term "metallic" refers to both metals and metalloids. Metals include those compounds typically considered metals found within the transition metals, alkali and alkali earth metals. Examples of metals are Ag, Au, Cu, Al, and Fe. Metalloids include specifically Si, B, Ge, Sb, As, and Te. Metallic materials also include alloys or mixtures that include metallic materials. Such alloys or mixtures may further include additional additives. In the present invention, carbide formers and carbon

wetting agents may be included as alloys or mixtures, but are not anticipated to be the only metallic component. Examples of such carbide formers are Sc, Y, Ti, Zr, Hf, V, Nb, Cr, Mo, Mn, Ta, W, and Tc. Examples of carbon wetting agents are Co, Ni, Mn, and Cr.

As used herein, "infiltrating" refers to when a material is heated to its melting point and then flows as a liquid through the interstitial voids between particles.

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained.

The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. For example, a composition that is "substantially free of" particles would either completely lack particles, or so nearly completely lack particles that the effect would be the same as if it completely lacked particles. In other words, a composition that is "substantially free of" an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.

As used herein, the term "about" is used to provide flexibility to a numerical range endpoint by providing that a given value may be "a little above" or "a little below" the endpoint.

As used herein, a plurality of items, structural elements, compositional elements, and/or materials may be presented in a common list for convenience. However, these lists should be construed as though each member of the list is individually identified as a separate and unique member. Thus, no individual member of such list should be construed as a de facto equivalent of any other member of the same list solely based on their presentation in a common group without indications to the contrary.

Concentrations, amounts, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc., as well as 1, 2, 3, 4, and 5, individually. This same principle applies to ranges reciting only one numerical value as a minimum or a maximum. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present disclosure generally provides superabrasive tools and methods for the making and use thereof. In one aspect, such superabrasive tools can include CMP pad dressers that can be utilized in conditioning (e.g., smoothing, polishing, dressing) a CMP pad. CMP pad dressers according to aspects the present disclosure can be advantageously utilized, for example, in dressing CMP pads that are used in polishing, finishing or otherwise affecting semiconductor materials. These dressers can be made such that they have superabrasive particles with substantially leveled tips. Traditional CMP pad dresser manufacturing methods, even many of those describing techniques for leveling superabrasive particle tips prior to fixation, generally contain significant variation in tip height across the surface of the dresser. Often, the superabrasive particles are affixed to the CMP pad dresser support in a manner that disrupts any leveling that has occurred. For example, fixation techniques that utilize high heat and/or pressure can cause warping of the dresser support as the dresser cools. Thus, unless steps are taken to avoid such warpage, superabrasive particles are not maintained in their leveled state following cooling of the dresser. This can be particularly problematic with brazing techniques.

Accordingly, minimizing the warpage of the metal support layer can maintain a greater degree of leveling of superabrasive particle tips in the finished tool. When heat and/or pressure are used to make a superabrasive tool, warpage of the metal support layer can cause great variations in tip height level, even for those particles that were leveled prior to heating and/or applying pressure. By distributing the warpage forces equally or substantially equally on both sides of the metal support layer through the arrangement of the superabrasive particles, these forces effectively cancel each other with respect to the degree of warping occurring in the metal support layer, thus also minimizing the relative height movement of the superabrasive particles relative to one another.

The present CMP pad dressers include a layer of superabrasive particles having substantially leveled tips across the working surface of the finished CMP pad dresser. A CMP pad dresser having such substantially leveled tip arrangements can have a low scratch rate because superabrasive particles are less likely to pull out of the matrix layer due to their more uniform protrusion distribution compared to traditional dressers. Additionally, the more uniform protrusion distributions of such a

dressers allows the conditioning of CMP pads in such a manner as to facilitate good polishing rates while at the same time extending the effective working life of the dresser. These benefits can be affected by, for example, uniform asperity spacing and size distribution in the CMP pad.

In one aspect of the present disclosure, superabrasive tip leveling can be accomplished by manufacturing the CMP pad dresser in such a way that the effects of warpage are minimized. For example, in one aspect a CMP pad dresser can be made in at least a two stage process, where the first stage is performed in a manner that minimizes perturbations of the leveled tips in a process that would normally significantly move the superabrasive tips out of a leveled arrangement, such as, for example, by brazing. The second stage of the process can further enhance the leveling of superabrasive particle tips across the CMP pad dresser.

Various exemplary configurations of CMP pad dressers having substantially leveled tips are contemplated. In one aspect, for example, a CMP pad dresser can include a first monolayer of superabrasive particles disposed on and coupled to one side of a metal support layer and a second monolayer of superabrasive particles disposed on and coupled to the metal support layer on an opposite side from the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer. In one aspect, a rigid support is coupled to the second monolayer of superabrasive particles opposite the first monolayer to provide support to the dresser. The disposition of a single superabrasive particle layer on each side of the metal support layer can moderate the thermal shrinkage from a high temperature process such as brazing that would otherwise buckle a distribution of diamond on one side. By applying a superabrasive layer to each side of the metal support layer, warping forces such as thermal movement and pressure can be equalized or substantially equalized on both sides. As such, the warpage of the metal or support layer can be minimized. In other words, the forces responsible for warping are applied substantially equally to each side of the metal support layer and can thus cancel one another out, thus minimizing warpage that can otherwise occur.

In one aspect, as is shown in FIG. 1 for example, a first monolayer of superabrasive particles 12 is arranged on a surface of a metal support layer 14. A second monolayer of superabrasive particles 16 is arranged on the metal support layer

14 on a side that is opposite to the first monolayer. As is discussed further below, in some cases the first and second monolayers of superabrasive particles can be arranged such that corresponding superabrasive particles across the metal support layer are in substantial alignment, as is shown in FIG. 1. In other cases, the superabrasive particles of the first and second monolayers can be arranged in a substantially similar distribution, but may or may not be substantially aligned with one another across the metal support layer.

A variety of materials are contemplated for use as superabrasive particles. Any superabrasive known that can be utilized in a CMP pad dresser should be considered to be within the present scope. Non-limiting examples of such materials include diamond materials, nitride materials, ceramics, and the like. In one aspect, the superabrasive particles include diamond materials. Such diamond materials can include natural or synthetic diamond, single crystal, polycrystalline, and the like. In another aspect, the superabrasive particles include cubic boron nitride materials. Additionally, various diamond particles sizes can be used, including mesh sizes such as 10/20, 30/40, 80/90, 90/100, 100/120, 120/140, 140/170, 170/200, 200/230, 230/270, 270/325, and 325/400.

The metal support layer can be any material capable of supporting the diamond monolayer during tool formation. Such materials can include, without limitation, metal materials, metal alloy materials, braze alloy materials, ceramic materials, composites, and the like, including combinations thereof. It should be noted that the metal support layer can be of a variety of configurations. In one aspect, for example, a metal support layer can be a solid metal such as a metal plate or a metal foil. In another aspect, a metal support layer can be a pressed powder. For example, a metal powder can be placed in a mold and cold pressed to form a metal support layer.

Additionally, the metal support layer can be any thickness capable of supporting the superabrasive particles. For example, in one aspect the metal support layer can be greater than about 10 mm thick. In another aspect, the metal support layer can be from about 2 mm thick to about 10 mm thick. In another aspect, the metal support layer can be from about 1 μm to about 200 μm thick. In yet another aspect, the metal support layer can be from about 1 μm to about 100 μm thick. In a

further aspect, the metal support layer can be from about 100 μm to about 3 mm. In a yet further aspect, the metal support layer can be from about 500 μm to about 2 mm.

In some aspects, the superabrasive particles of either or both of the monolayers can be arranged into a predetermined pattern. Such a pattern can be a uniformly distributed pattern or a non-uniformly distributed pattern. Additionally, a variety of techniques are contemplated to facilitate the arrangement of superabrasive particles into a predetermined pattern. Predetermined is understood to mean a non-random pattern that has been determined prior to arranging the superabrasive particles. In one aspect, a predetermined pattern can also apply to a predetermined spacing between particles. Non-limiting examples of such techniques include arrangement by a template, arrangement using spots of adhesives, arrangement on a first substrate followed by a pattern specific transfer from the first substrate to the metal support layer, and the like, including combinations thereof. The superabrasive particles from either of the monolayers can be temporarily held in position in the predetermined pattern using a variety of techniques, including, without limitation, adhesives, dimpled locations on the metal support matrix, a supporting compound such as, for example, a wax, and the like, including combinations thereof. In one specific aspect, the superabrasive particles can be temporarily coupled to the metal support layer using an adhesive that then volatilizes away and is eliminated during construction of the dresser.

The disposition of a monolayer of superabrasive particles on each side of the metal layer thus moderates the thermal shrinkage from the brazing temperature that would otherwise buckle a distribution of superabrasive particles arranged on just one side. By applying a monolayer to each side of the metal support layer, warping forces such as thermal movement and pressure can be equalized or substantially equalized on both sides. As such, the warpage of the metal support layer can be minimized. In other words, the forces responsible for warping are applied substantially equally to each side of the metal layer and can thus at least partially cancel one another out, thus minimizing warpage that can otherwise occur. In some aspects, the superabrasive particles making up the monolayers on each side of the metal layer can have matching configurations, patterns, or orientations to one another. In this way there can be a substantially matching spatial arrangement of superabrasive particles on each side of the metal layer. In another aspect, the configurations, patterns, or orientations can be

different or varied from one another, or may be partially matching. In yet another aspect, the patterned placement of the superabrasive particles on one side of the metal support layer can be substantially aligned with the pattern of superabrasive particles on the other side of the metal layer so that particle locations match one another. In some aspects, there can be a direct correspondence between the spatial positioning of superabrasive particles on one side of the metal support layer and the spatial positioning of superabrasive particles on the other side of the metal support layer. In another aspect, the patterns of superabrasive particles may match or substantially match one another, but may be offset on opposite sides of the metal support layer so that particle locations do not match one another.

In another aspect, as is shown in FIG. 2, a first monolayer of superabrasive particles 22 is arranged on a surface of a metal support layer 24. A second monolayer of superabrasive particles 26 is arranged on the metal support layer 24 on a side that is opposite to the first monolayer. A bonding material 28 secures the first monolayer and the second monolayer to the metal support layer 24. The bonding material can be any material capable of securing the first and second monolayer to the metal support layer. In some aspect, the bonding material can be the same for securing the first monolayer and the second monolayer, while in other aspects the bonding material can be different for securing the first monolayer and the second monolayer.

The bonding material can be any material capable of securing superabrasive particles therein. Non-limiting examples of bonding materials include metal brazes, metal braze alloys, organic matrix materials, sintered materials, electroplated materials, and the like, including combinations thereof.

In one aspect, for example, the superabrasive particles can be brazed to the metal support layer, and thus the bonding material can be a metal braze or metal braze alloy. Metal brazing techniques are known in the art. A green braze material can be applied to the metal support layer on or around the superabrasive particles. The metal braze can be applied in any know configuration, including braze sheets, powders, pastes, sprays, and the like, including combinations thereof. Once applied to the metal support layer, the braze can be heated and melted to coat at least a portion of the metal support layer and to bond the superabrasive particles. The heating temperature can vary depending on the braze material used, but in one aspect can be from about 700°C to about 1200°C. The superabrasive particles in the first and

second monolayer are thus arranged such that thermal forces exerted on the metal support layer during heating and cooling are substantially equalize in order to minimize warping.

In one non-limiting example, the superabrasive particles can be bonded to the metal support layer by brazing with a nickel-based alloy, with or without chromium. In another example, the brazing can include pressing the superabrasive particles with a flat ceramic material that cannot be bonded to the braze in order to level the superabrasive particle tips. Various braze alloys are contemplated, including non-limiting examples such as BNi_2, BNi_7, and the like.

Additionally, in one aspect at least one of the first and second monolayers of superabrasive particles can be coupled to the metal support layer by an electrodeposition process, and thus the bonding material can be an electrodeposited metal material. In one aspect, a monolayer of superabrasive particles can be disposed on the metal support layer which is then placed into an ionic solution containing metal ions. An electrical current is introduced into the ionic solution such that a metal layer is electroplated onto the metal substrate to secure the superabrasive particles. Thus by this method, the superabrasive particles are coupled to the metal support layer. As an example of a suitable method for positioning and retaining superabrasive materials prior to and during the electrodeposition process, a mold can be used that includes an insulating material that can effectively prevent the accumulation of electrodeposited material on the molding surface. Superabrasive particles can thus be held on the molding surface of the mold during electrodeposition. As such, the accumulation of electrodeposited material can be prevented from occurring on the particle tips and the working surface of the pad conditioner substrate. Such techniques are described in U.S. Patent Application Serial No. 11/292,938, filed December 2, 2005, which is hereby incorporated herein by reference.

In another aspect, the superabrasive particles can be bonded to the metal support layer by sintering, and thus the bonding material can include a sintering material. For example, the bonding of the superabrasive particles to the metal support layer can include disposing a sintering compound on the metal support layer in contact with at least one of the first monolayer and the second monolayer and sintering the sintering compound to bond the superabrasive particles to the metal support layer. Suitable sintering methods will be readily appreciated by one of

ordinary skill in the art having possession of this disclosure. Basically, a sintering compound is applied around the superabrasive particles and in contact with the metal support layer. The sintering compound can be any known sintering material that can be used to secure superabrasive particles to a substrate. Non-limiting examples of such materials can include metal and metal alloy powders, ceramic powders, and the like. One specific non-limiting example of a sintering compound is cobalt powder. Once the sintering compound has been applied around the superabrasive particles and to the metal support substrate, heat and in some cases pressure can be applied to cause sintering to occur. In some aspects, a braze or braze alloy can be infiltrated into the sintering compound during bonding to further strengthen the bonding material matrix.

In another aspect, as is shown in FIG. 3, heat and pressure can be applied to bond the first monolayer of superabrasive particles 32 and/or the second monolayer of superabrasive particles 36 directly into the metal support layer 34. Thus, upon the application of heat and pressure, the metal support layer 34 is softened or partially melted. The superabrasive particles in one or more of the monolayers are then pressed into the metal support layer. A planar leveling surface can be used to apply pressure to the monolayer and thus maintain the level nature of the superabrasive particle tips as the superabrasive particles are pressed into the metal support layer. Upon cooling, the distribution of superabrasive particles on either side of the metal support layer at least partially equalizes the thermal forces acting on the metal support layer, thus minimizing warping. Additionally, heat and pressures useful in making such a device can vary depending on the materials and equipment used. In one aspect, for example, the heat is from about 700° C to about 1000° C. In another aspect, the pressure is from about 10 MPa to about 50 MPa.

In yet another aspect, as is shown in FIG. 4, a CMP pad dresser can include a first monolayer of superabrasive particles 42 and a second monolayer of superabrasive particles 46 coupled to a metal support layer 44. The superabrasive particles can be coupled to the metal support layer directly or via a bonding material. The second monolayer of superabrasive particles 46 is coupled to a rigid support 48. A portion of the rigid support 48 is shown removed in FIG. 4 to expose the second monolayer. The rigid support 48 can facilitate handling and use of the CMP pad dresser. By bonding the superabrasive particles of the second monolayer to the rigid

support, the first monolayer of superabrasive particles remains exposed for CMP pad conditioning operations.

The rigid support can be made from any material compatible with the abrading or dressing process. Such materials can include polymeric materials, metal materials, ceramic materials, glasses, composites, and the like. In one aspect, the rigid support can be a polymeric material and the second monolayer of superabrasive particles can be embedded therein using heat, pressure, adhesives, etc. In some aspects, the rigid support can be a non-polymeric material such as a metal layer. In such cases, the superabrasive particles can be bonded to the rigid support by adhesive attachment, soldering, brazing, electroplating, and the like. For brazing techniques, care can be taken to minimize or eliminate warpage in the metal layer during the heating and cooling process. In another aspect, one or more magnetic elements can be placed into the rigid support to attract and hold the CMP pad dresser in place, thus forming a temporary attachment. An optional locking mechanism can be utilized to further immobilize the CMP pad dresser to the rigid support during use. In some aspects the rigid support can include surface features to hold the dresser in place during rotational movement against a CMP pad. The rigid support can have approximately the same diameter as the metal support layer, a larger diameter than the metal support layer, or, in some cases, a smaller diameter than the metal support layer.

Various polymeric materials are contemplated for use as a rigid support. Examples of suitable materials include, without limitation, amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof. In one specific aspect, the polymeric material can be an epoxy resin. In another aspect, the polymeric material can be a polyimide resin. In yet another aspect, the polymeric material can be a polyurethane resin.

When an polymeric material is utilized, methods of curing the polymeric material can be a variety of processes known to one skilled in the art that cause a phase transition in the polymeric material from at least a pliable state to at least a rigid state. Curing can occur, without limitation, by exposing the polymeric material to

energy in the form of heat, electromagnetic radiation, such as ultraviolet, infrared, and microwave radiation, particle bombardment, such as an electron beam, organic catalysts, inorganic catalysts, or any other curing method known to one skilled in the art.

In one aspect of the present invention, the polymeric material can be a thermoplastic material. Thermoplastic materials can be reversibly hardened and softened by cooling and heating respectively. In another aspect, the polymeric material layer may be a thermosetting material. Thermosetting materials cannot be reversibly hardened and softened as with the thermoplastic materials. In other words, once curing has occurred, the process can be essentially irreversible, if desired.

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of a superabrasive material to facilitate the retention of the superabrasive particles in the polymeric material via chemical bonding. A wide variety of organic and organometallic compounds is known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive materials and the polymeric material, thus increasing the bonding between the second monolayer of superabrasive particles and the polymeric material. In this way, the organometallic coupling agent can serve as a bridge to form bonds between the polymeric material and the surface of the superabrasive material. In one aspect, the organometallic coupling agent can be a titanate, zirconate, silane, or mixture thereof. The amount of organometallic coupling agent used can depend upon the coupling agent and on the surface area of the superabrasive material. In one aspect, 0.05% to 10% by weight of the polymeric material layer can be sufficient.

In another aspect of the present disclosure, a method of making a CMP pad dresser can include disposing a first monolayer of superabrasive particles on a metal support layer, and disposing a second monolayer of superabrasive particles on the metal support layer on a side opposite the first monolayer. The superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer. The method can further include bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the metal support layer such that symmetrical

forces due to the substantially similar distribution between the first monolayer and the second monolayer precludes substantial warping of the metal support layer.

In yet another aspect, disposing at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles can include adhering a plurality of superabrasive particles to an adhesive transfer sheet in a predetermined pattern established by apertures in a template, and removing the template from the adhesive transfer sheet such that the plurality of superabrasive particles remain adhered to the adhesive transfer sheet in the predetermined pattern. The plurality of superabrasive particles is then transferred with the adhesive transfer sheet to the metal support layer, and the adhesive transfer sheet is removed from the plurality of superabrasive particles to form at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles.

In a further aspect of the present disclosure, a method of minimizing warpage of a CMP pad dresser during manufacture can include substantially equalizing warping forces on opposing sides of a metal support layer during bonding of a plurality of superabrasive particles thereto, wherein warpage of the support layer is minimized during bonding due to the equalized forces on opposing sides. In one aspect, substantially equalizing forces includes arranging the plurality of superabrasive particles on opposing sides of the support layer such that the plurality of superabrasive particles has substantially the same distribution on either side of the support layer to substantially equalize warping forces during bonding.

It is noted that, while the above disclosure refers primarily to CMP pad dressers, other precision grinding and/or abrading tools are considered to be within the present scope. As such, the techniques and teaching disclosed herein can additionally be applied to such tools.

The following examples present various methods for making the heat spreaders of the present invention. Such examples are illustrative only, and no limitation on the present invention is meant thereby.

Examples

Example 1

A thin metal layer (e.g. Cu 100 microns thick) has an adhesive (e.g. 3M manufacture, 25 microns, fugitive, i.e. can vaporize to leave no residue carbon behind) on each side. Ti coated diamond particles (e.g. about 50 microns) are spread on both sides create a diamond particle monolayer on each side. Excess diamond particles are removed. The layer is placed in a graphite mold that is covered with a thin layer of Cu powder. An additional layer of Cu powder is applied on top of the layer. The assembly is then hot pressed (e.g. 900 C for 20 minutes) under vacuum or in an inert atmosphere to form a disk having diamond particles protruding from both sides. Due to the presence of Ti coating, Cu can bond the diamond particles firmly. The flatness of the disk is maintained by the flat mold surface.

Example 2

Same as with Example 1, with the exception that the thin metal Cu layer has a braze alloy layer (e.g. Cu-Sn-Ti or Ag-Cu-Ti) coupled to each side. Uncoated diamond particles are then arranged on the exposed sides of the braze alloy layers with the adhesive. The assembly is then heated to melt the braze in a vacuum furnace, resulting in a copper layer covered with diamond particles on both sides.

Example 3

The diamond-attached layer of Example 2 is suspended in an electrolyte of $CuSO_4$ solution with connection to a cathode. The anode is a copper electrode. After passing current through the electrolyte, Cu will be plated on the copper layer and in the gaps between the diamond particles to strengthen the bonding of the diamond particles to the Cu metal layer.

Example 4

Same as Example 2, with the exception that that the Cu layer is replaced with a thin Ni layer, and the braze layers are Ni-Cr-B-Si (BNi2, e.g. Nichrobraze LM made by Wall Colmonoy), and the diamond particles (e.g. 150 microns) are arranged in a grid pattern (e.g. pitch of 500 microns intervals).

Example 5

The article of Example 4 is pressed against a flat substrate (108 mm in diameter by 6.5 mm in thickness) and heated with a thermal plastic adhesive in between (e.g. 150 C for 10 minutes). The result is a tool such as a CMP pad conditioner having a flat surface. A layer on each side moderates the thermal shrinkage from the brazing temperature (e.g. 1020 C for 10 minutes) that would buckle an asymmetrical distribution of diamond on one side.

Of course, it is to be understood that the above-described arrangements are only illustrative of the application of the principles of the present invention. Numerous modifications and alternative arrangements may be devised by those skilled in the art without departing from the spirit and scope of the present invention and the appended claims are intended to cover such modifications and arrangements. Thus, while the present invention has been described above with particularity and detail in connection with what is presently deemed to be the most practical and preferred embodiments of the invention, it will be apparent to those of ordinary skill in the art that numerous modifications, including, but not limited to, variations in size, materials, shape, form, function and manner of operation, assembly and use may be made without departing from the principles and concepts set forth herein.

CLAIMS

What is claimed is:

1. A CMP pad dresser, comprising:

a first monolayer of superabrasive particles disposed on and coupled to one side of a metal support layer; and

a second monolayer of superabrasive particles disposed on and coupled to the metal support layer on an opposite side from the first monolayer, wherein the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer.

2. The dresser of claim 1, wherein the superabrasive particles in the first monolayer include a member selected from the group consisting of diamond materials, nitride materials, ceramics, or a combination thereof.

3. The dresser of claim 1, wherein the superabrasive particles in the first monolayer are a diamond material.

4. The dresser of claim 1, wherein the superabrasive particles in the first monolayer are a cubic boron nitride material.

5. The dresser of claim 1, wherein the superabrasive particles in the second monolayer include a member selected from the group consisting of diamond materials, nitride materials, ceramics, or a combination thereof.

6. The dresser of claim 1, wherein the superabrasive particles in the second monolayer are a diamond material.

7. The dresser of claim 1, wherein the superabrasive particles in the second monolayer are a cubic boron nitride material.

8. The dresser of claim 1, further comprising a rigid support coupled to the second monolayer of superabrasive particles opposite the first monolayer.

9. The dresser of claim 1, wherein at least one of the first monolayer of superabrasive particles or the second monolayer of superabrasive particles is coupled to the metal support layer with a braze alloy.

10. The dresser of claim 1, wherein both the first monolayer of superabrasive particles and the second monolayer of superabrasive particles are coupled to the metal support layer with a braze alloy.

11. The dresser of claim 1, wherein the superabrasive particles of the second monolayer are positioned to have the same distribution as the superabrasive particles of the first monolayer.

12. A method of making a CMP pad dresser, comprising:

disposing a first monolayer of superabrasive particles on a metal support layer;

disposing a second monolayer of superabrasive particles on the metal support layer on a side opposite the first monolayer, wherein the superabrasive particles of the second monolayer are positioned to have substantially the same distribution as the superabrasive particles of the first monolayer; and

bonding the first monolayer of superabrasive particles and the second monolayer of superabrasive particles to the metal support layer such that symmetrical forces due to the substantially similar distribution between the first monolayer and the second monolayer precludes substantial warping of the metal support layer.

13. The method of claim 12, wherein the bonding of at least one of the first monolayer or the second monolayer is by brazing with a braze alloy.

14. The method of claim 12, wherein the bonding of at least one of the first monolayer or the second monolayer is under heat and pressure.

15. The method of claim 14, wherein the bonding of at least one of the first monolayer and the second monolayer further includes:

disposing a sintering compound on the metal support layer in contact with at least one of the first monolayer or the second monolayer; and

sintering the sintering compound to bond the at least one of the first monolayer or the second monolayer to the metal support layer.

16. The method of claim 15, further comprising infiltrating the sintering compound with a braze material during bonding.

17. The method of claim 14, wherein the heat and pressure bonds at least one of the first monolayer or the second monolayer directly to the metal support layer.

18. The method of claim 12, wherein the superabrasive particles of the second monolayer are positioned to align with the superabrasive particles of the first monolayer.

19. The method of claim 12, further comprising coupling the second monolayer of superabrasive particles to a rigid support.

20. The method of claim 19, wherein the coupling of the second monolayer of superabrasive particles to the rigid support is accomplished by a technique selected from the group consisting of hot pressing, brazing, sintering, soldering, electroplating, polymeric bonding, and combinations thereof.

21. The method of claim 19, wherein the coupling of the second monolayer of superabrasive particles to the rigid support is accomplished by polymeric bonding.

22. A method of minimizing warpage of a CMP pad dresser during manufacture, comprising:

substantially equalizing warping forces on opposing sides of a metal support layer during bonding of a plurality of superabrasive particles thereto, wherein warpage of the support layer is minimized during bonding due to the equalized forces on opposing sides.

23. The method of claim 22, wherein substantially equalizing forces includes arranging the plurality of superabrasive particles on opposing sides of the support layer such that the plurality of superabrasive particles has substantially the same distribution on either side of the support layer to substantially equalize warping forces during bonding.

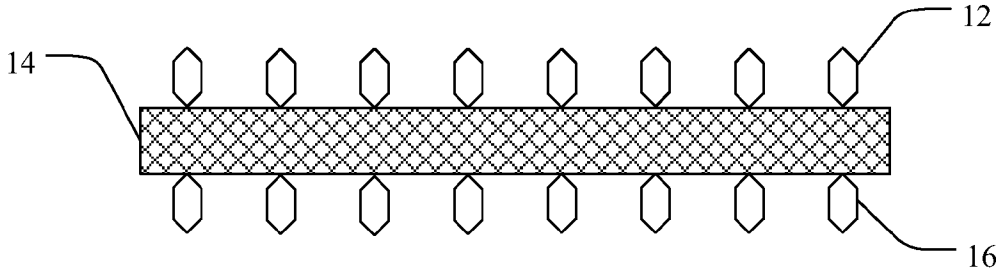


FIG. 1

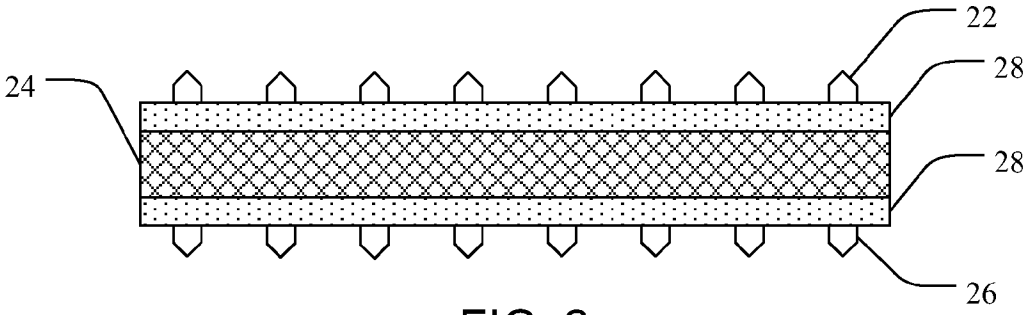


FIG. 2

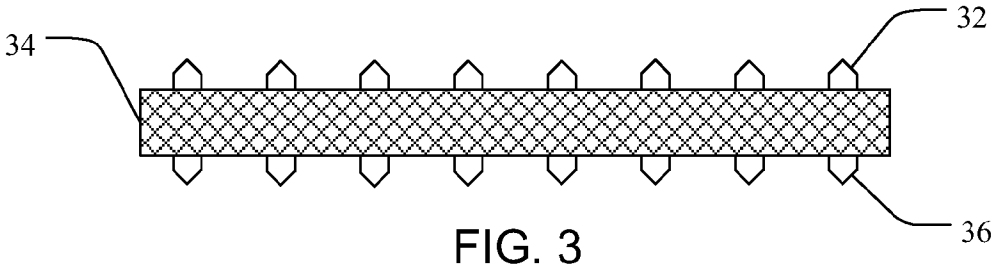


FIG. 3

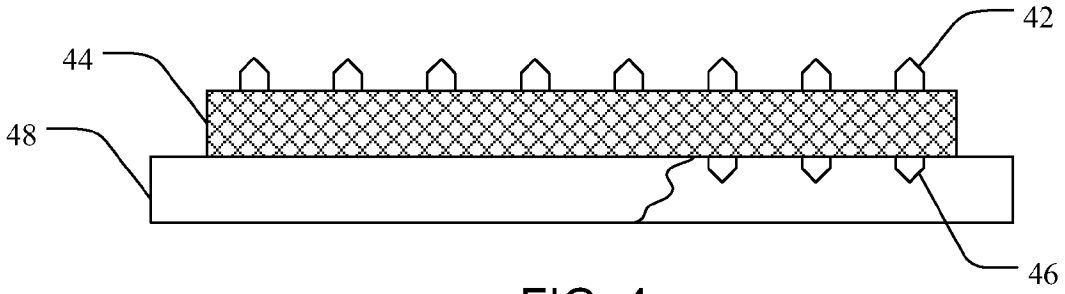


FIG. 4

PATENT COOPERATION TREATY

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INTERNATIONAL SEARCHING AUTHORITY

To:
OSBORNE DAVID W.

THORPE NORTH & WESTERN, LLP PO BOX 1219
SANDY UT 84091-1219 USA

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WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

Date of mailing *(day/month/year)*	**23 MAY 2011 (23.05.2011)**
Applicant's or agent's file reference 00802-24462.NP.CIP.	**FOR FURTHER ACTION** See paragraph 2 below

International application No.	International filing date *(day/month/year)*	Priority date *(day/month/year)*
PCT/US2007/024165	**16 NOVEMBER 2007 (16.11.2007)**	16 NOVEMBER 2006 (16.11.2006)

International Patent Classification (IPC) or both national classification and IPC

B24D 7/06(2006.01)i, H01L 21/304(2006.01)i, B24D 18/00(2006.01)i, B24D 3/02(2006.01)i

Applicant

SUNG CHIEN-MIN

1. This opinion contains indications relating to the following items:

- ☒ Box No. I Basis of the opinion
- ☐ Box No. II Priority
- ☐ Box No. III Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
- ☐ Box No. IV Lack of unity of invention
- ☒ Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
- ☐ Box No. VI Certain documents cited
- ☐ Box No. VII Certain defects in the international application
- ☐ Box No. VIII Certain observations on the international application

2. **FURTHER ACTION**

If a demand for international preliminary examination is made, this opinion will be considered to be a written opinion of the International Preliminary Examining Authority ("IPEA") except that this does not apply where the applicant chooses an Authority other than this one to be the IPEA and the chosen IPEA has notified the International Bureau under Rule 66.1bis(b) that written opinions of this International Searching Authority will not be so considered.

If this opinion is, as provided above, considered to be a written opinion of the IPEA, the applicant is invited to submit to the IPEA a written reply together, where appropriate, with amendments, before the expiration of 3 months from the date of mailing of Form PCT/ISA/220 or before the expiration of 22 months from the priority date, whichever expires later.
For further options, see Form PCT/ISA/220.

3. For further details, see notes to Form PCT/ISA/220.

Name and mailing address of the ISA/KR	Date of completion of this opinion	Authorized officer
Korean Intellectual Property Office Government Complex-Daejeon, 189 Cheongsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	23 MAY 2011 (23.05.2011)	KIM, DONG JIN Telephone No.82-42-481-5415

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2007/024165

Box No. I Basis of this opinion

1. With regard to the **language**, this opinion has been established on the basis of :

   ☒ the international application in the language in which it was filed

   ☐ a translation of the international application into _____ , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))

2. ☐ This opinion has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43*bis*.1(a))

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, this opinion has been established on the basis of:

   a. type of material

   ☐ a sequence listing

   ☐ table(s) related to the sequence listing

   b. format of material

   ☐ on paper

   ☐ in electronic form

   c. time of filing/furnishing

   ☐ contained in the international application as filed.

   ☐ filed together with the international application in electronic form.

   ☐ furnished subsequently to this Authority for the purposes of search.

4. ☐ In addition, in the case that more than one version or copy of a sequence listing and/or table relating thereto has been filed or furnished, the required statements that the information in the subsequent or additioanl copies is identical to that in the application as filed or does not go beyond the application as filed, as appropriate, were furnished.

5. Additional comments:

Box No. V Reasoned statement under Rule 43bis.1(a)(i) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Claims	9, 10, 12-14, 21-45	YES
	Claims	1-8, 11, 15-20	NO
Inventive step (IS)	Claims	9, 10, 14, 23-24, 31-40, 43-45	YES
	Claims	1-8, 11-13, 15-22, 25-30, 41, 42	NO
Industrial applicability (IA)	Claims	1-45	YES
	Claims	NONE	NO

2. Citations and explanations :

Reference is made to the following documents:

D1: JP 2004-025401 A (AIRTEC JAPAN:KK et al.) 29 January 2004
D2: US 6319108 B1 (ADEFRIS; NEGUS B. et al.) 20 November 2001
D3: US 2006-0135050 A1 (JOHN PETERSEN et al.) 22 June 2006

1. Novelty and Inventive Step

1.1 Claims 1-10

1.1.1 Claim 1

D1, which is considered to be the closest prior art to the subject matter of claim 1, discloses a diamond grinding wheel comprising a abrasive chip and an abrasive element. Accordingly, claim 1 is substantially the same as D1. Therefore, claim 1 lacks novelty under PCT Article 33(2).

1.1.2 Claim 2

The cutting tip of claim 2 is already disclosed in document D1(see figure 4). Therefore, claim 2 lacks novelty under PCT Article 33(2).

1.1.3 Claims 3-8

The additional feature of claims 3-8 is already disclosed in document D1(see figure 1). Therefore, claims 3-8 lack novelty under PCT Article 33(2).

1.1.4 Claims 9 and 10

The cutting device of claim 9 differs from the disclosures of D1-D3 in that it includes the cutting elements distributed on the cutting device in alternating orientations. The cutting device of claim 10 differs from the disclosures of D1-D3 in that it includes the secondary cutting element. Therefore, claims 9 and 10 meet the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

1.2 Claims 11-24

1.2.1 Claim 11

D1, which is considered to be the closest prior art to the subject matter of claim 11, discloses abrasive element and abrasive tip. Accordingly, claim 11 is substantially the same as D1. Therefore, claim 11 lacks novelty under PCT Article 33(2).

1.2.2 Claim 12

D2, which is considered to be the closest prior art to the subject matter of claim 12, discloses uniformly distributed cutting element. Accordingly, claim 12 is substantially correspond as D1 and D2. Therefore, claim 12 lacks inventive step under PCT Article 33(3).

Continued on Supplemental Box

Supplemental Box

In case **the space in any of the preceding boxes is not sufficient.**
Continuation of :

Box V

1.2.3 Claim 13
The cutting device of claim 13 dependent on claim 11 is not disclosed in D1, but was generally known in the art at the time of filing this application. Accordingly, claim 13 does not involve an inventive step under PCT Article 33(3).

1.2.4 Claim 14
The cutting device of claim 14 differs from the disclosures of D1-D3 in that it includes the cutting depth of less than about 20 microns when used to abrade a workpiece. Therefore, claim 14 meets the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

1.2.5 Claim 15
The cutting device of claim 15 dependent on claim 11 is already disclosed in document D1(see figure 4). Therefore, claim 15 lacks novelty under PCT Article 33(2).

1.2.6 Claims 16-20
The additional feature of claims 16-21 is already disclosed in document D1(see figure 1). Therefore, claims 16-21 lack novelty under PCT Article 33(2).

1.2.7 Claims 21-22
The cutting device of claims 21 and 22 dependent on claim 11 is not disclosed in D1, but was generally known in the art at the time of filing this application. Accordingly, claims 21 and 22 do not involve an inventive step under PCT Article 33(3).

1.2.8 Claims 23-24
The cutting device of claim 23 differs from the disclosures of D1-D3 in that it includes the distance of from about 100 microns to about 800 microns. The cutting device of claim 24 differs from the disclosures of D1-D3 in that it includes the distance of about 500 microns. Therefore, claims 23 and 24 meet the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

1.3 Claims 25-30, 41 and 42
The cutting device of claims 25-30, 41 an 42 dependent on claims 1 or 11 is not disclosed in D1, but was generally known in the art at the time of filing this application. Accordingly, claims 25-30, 41 and 42 do not involve an inventive step under PCT Article 33(3).

1.4 Claims 31-40, 43-45
The method of forming a cutting device of claim 31 differs from the disclosures of D1-D3 in that it includes a arranging on the substrate a plurality of individual polycrystalline cutting elements, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration. And it is not obvious to a person skilled in the art by the documents, taken alone or in combination. Therefore, claims 32-40 and 43-45 meet the requirements of PCT Article 33(2) and (3) with respect to novelty and inventive step.

2. Industrial Applicability
Claims 1-45 are industrially applicable under PCT Article 33(4).

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference	**FOR FURTHER ACTION**	see Form PCT/ISA/220 as well as, where applicable, item 5 below.
3356-32820.PCT1		
International application No.	International filing date *(day/month/year)*	(Earliest) Priority Date *(day/month/year)*
PCT/US2011/052626	**21 SEPTEMBER 2011 (21.09.2011)**	21 SEPTEMBER 2010 (21.09.2010)

Applicant

SUNG CHIEN-MIN et al

This International search report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This international search report consists of a total of **3** sheets.

☐ It is also accompanied by a copy of each prior art document cited in this report.

1. **Basis of the report**
   a. With regard to the **language**, the international search was carried out on the basis of :
      ☒ the international application in the language in which it was filed
      ☐ a translation of the international application into _____ , which is the language of a translation furnished for the purposes of international search (Rules 12.3(a) and 23.1(b))
   b. ☐ This international search report has been established taking into account the **rectification of an obvious mistake** authorized by or notified to this Authority under Rule 91 (Rule 43.6*bis*(a)).
   c. ☐ With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, see Box No. I.
2. ☐ **Certain claims were found unsearchable** (See Box No. II)
3. ☐ **Unity of invention is lacking** (See Box No. III)
4. With regard to the **title,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established by this Authority to read as follows:
5. With regard to the **abstract,**
   ☒ the text is approved as submitted by the applicant.
   ☐ the text has been established, according to Rule 38.2, by this Authority as it appears in Box No. IV. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.
6. With regard to the drawings,
   a. the figure of the **drawings** to be published with the abstract is Figure No. **1**
      ☒ as suggested by the applicant.
      ☐ as selected by this Authority, because the applicant failed to suggest a figure.
      ☐ as selected by this Authority, because this figure better characterizes the invention.
   b. ☐ none of the figure is to be published with the abstract.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/052626

A. CLASSIFICATION OF SUBJECT MATTER

H01L 23/34(2006.01)i, H05K 7/20(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H01L 23/34; H01L 23/36; H01L 23/06; H01L 29/06; H01L 21/31

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: thermally, reduce, heat, spreader, diamond, mono-layer, metal, expansion, coefficient, thin, matrix, material, bonding.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2010-0102442 A1 (CHIEN-MIN SUNG) 29 April 2010 See abstract, paragraph [0065]-[0080], claims 1,2,6,26-30,36 and figures 2-5b.	1-19
A	US 05008737 A (ROBERT D. BURNHAM et al.) 16 April 1991 See abstract, column 6, line 4-line 50, claims 1,3,4,6,8 and figure 1.	1-19
A	US 2007-0232074 A1 (KRAMADHATI RAVI et al.) 04 October 2007 See abstract, paragraph [0019]-[0027], claims 1,5,6 and figures 1A-1F.	1-19
A	US 7067903 B2 (TAKESHI TACHIBANA et al.) 27 June 2006 See abstract, column 6, line 20-35, column 8, line 30-48, claims 1-4 and figures 5A-7B.	1-19

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
01 MAY 2012 (01.05.2012)	**02 MAY 2012 (02.05.2012)**
Name and mailing address of the ISA/KR Korean Intellectual Property Office Government Complex-Daejeon, 189 Cheongsa-ro, Seo-gu, Daejeon 302-701, Republic of Korea Facsimile No. 82-42-472-7140	Authorized officer KIM, Jung Jin Telephone No. 82-42-481-5962

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0102442 A1	29.04.2010	US 2011-0056672 A1	10.03.2011
		US 7791188 B2	07.09.2010
US 05008737A	16.04.1991	EP 0364155 A3	10.10.1990
		JP 02-170452 A	02.07.1990
		US 05130771 A	14.07.1992
US 2007-0232074 A1	04.10.2007	None	
US 7067903 B2	27.06.2006	CN 1499620 C0	02.04.2008
		JP 2004-158726 A	03.06.2004
		JP 2004-158727 A	03.06.2004
		TW 239606 A	11.09.2005
		US 2004-0238946 A1	02.12.2004

Electronic Patent Application Fee Transmittal

Application Number:	13479148
Filing Date:	23-May-2012
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Warren Archibald
Attorney Docket Number:	02074-24012.NP

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Miscellaneous:				
Request for Continued Examination	2801	1	600	600
		Total in USD ($)		**600**

Electronic Acknowledgement Receipt

EFS ID:	20981684
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	16-DEC-2014
Filing Date:	23-MAY-2012
Time Stamp:	18:07:10
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$600
RAM confirmation Number	5240
Deposit Account	
Authorized User	
The Director of the USPTO is hereby authorized to charge indicated fees and credit any overpayment as follows:	

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Request for Continued Examination (RCE)	RCEtransmittal.pdf	697392 a25921721a26b4a072c84946356afb1ab4cd550d	no	3
Warnings:					
Information:					
2	Transmittal Letter	IDStransmittal.PDF	79501 f89a5570d9d48e1851c0d568f81ee2dc02b56c88	no	4
Warnings:					
Information:					
3	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	136231 f481cd1d53d38f5e599a113808bd65e613b7e954	no	2
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	96132 3a8b589c29443353686ef13add03d07fe5812f0a	no	2
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
5	Foreign Reference	EP1075898A2.pdf	1325134 d5ea068bc02e8a8f88ffdcff1bc768f558aec418	no	28
Warnings:					
Information:					
6	Foreign Reference	GB2366804A.pdf	790441 696da841eae064f6a2f5ec023b19981bcbdc6176	no	27
Warnings:					
Information:					
7	Foreign Reference	WO9531006A1.pdf	1767289 1909d991b02ad5d57a319d3b4726990fd2d9e74f	no	47
Warnings:					
Information:					

8	Foreign Reference	WO2006039413A2.pdf	1110779 e1fd136aa4453d610d9c967f2dc1e4011662086b	no	20
Warnings:					
Information:					
9	Foreign Reference	WO2009043058A3.pdf	152607 bc22572969f8b54ad5bb9d505f4f462db2504270	no	4
Warnings:					
Information:					
10	Foreign Reference	WO2009064677A2.pdf	1704000 9f05662445ddbaf29d9cafdb015ca7c74e0e5eea	no	43
Warnings:					
Information:					
11	Foreign Reference	WO2012040374A2.pdf	1244966 b1cceef42aad84873aec313480570d861e519cca	no	26
Warnings:					
Information:					
12	Other Reference-Patent/App/Search documents	PCTUS2007024165searchMay232011.pdf	185219 c18d595c271c59d17763e46bf1a72f2e1948c44d	no	4
Warnings:					
Information:					
13	Other Reference-Patent/App/Search documents	PCTUS2011052626searchMay222012.pdf	129829 4aec3185b082f48cff535145d2ce293d912477c17	no	3
Warnings:					
Information:					
14	Fee Worksheet (SB06)	fee-info.pdf	30773 b35949d83af2249ce0770d39121e6c37c1191bb2	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	9450293	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

PTO/SB/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2002/0014041	02/2002	Baldonai et al.	
		2002/0164928	11/07/2002	Toles	
		2003/0092357	05/2003	Yoon et al.	
		2004/0023610	02/05/2004	Hu et al.	
		2005/0032469	02/10/2005	Duescher	
		2005/0095959	05/05/2005	Sung	
		2005/0118939	06/02/2005	Duescher	
		2005/0227590	10/13/2005	Sung	
		2007/0232074	10/04/2007	Krmadhati et al.	
		2009/0073774	04/06/2006	Sung	
		2009/0123705	05/14/2009	Sung	
		2011/0293905	12/01/2011	Sung	
		2012/0192499	08/02/2012	Sung	
		2012/0260582 A1	10/18/2012	Sung	
		2012/0302146 A1	11/29/2012	Sung	
		3706650	12/19/1972	Eisner	
		3664662	05/23/1972	Linz	
		4151154	04/1979	Berger	
		4405411	09/20/1983	Inoue et al.	
		4737162	04/1988	Grazen	
		4863573	09/05/1989	Moore et al.	
		5224469	05/01/2001	Ohmori et al.	
		5868806	02/09/1999	Nishio et al.	
		6159087	12/2000	Briang et al.	
		6200360	03/2001	Imai et al.	
		6312324	11/06/2001	Mitsui et al.	
		6416878	07/09/2002	An	
		6769969	08/03/2004	Duescher	
		6837979	01/04/2005	Uzho et al.	
		7067903	06/27/2006	Takeshi et al.	
		7651368	01/26/2010	Kendall et al.	
		7762872	07/27/2010	Sung	
		8393934	03/17/2013	Sung	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		EP 1075898	02/14/2001	Mitsubishi		
		GB 2366804	03/02/2002	Kinik Company		
		WO 95/31006	11/16/1995	Siliconix Incorporated		
		WO 2006/039413	04/13/2006	Sung		
		WO 2009/043058	04/02/2009	Sung et al.		
		WO 2009/064677	05/22/2009	Sung		
		WO 2012/040374 A2	03/29/2012	Rite Dia Corporation		

PTO/SB/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

Examiner Signature		Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1]Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

This collection of information is required by 37 CFR 1.97 and 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450**.

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet		of	

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		Colmonoy Technical Data Sheet; no. DSP-A; 1993	
		Endecott's Specifications; 2004	
		Kennametal Specification for DMHPM002 Hot Press Matrix N-50 12/06/2001	
		Material Safety Data Sheet (MSDS), Wall Colmonoy Corporation; prepared 07/20/1989	
		Material Safety Data Sheet (MSDS); Kennametal; issued 06/11/2004	
		SUNG et al.; The Eastern Wind of Diamond Symthesis; New Diamond and Frontier Carpon Technology; 2003; pages 47-61; vol. 13, no. 1	
		SUNG et al; Mechanism of the Solvent-Assisted Graphite to Diamond Transition Under High Pressure: Implications for the Selection of Catalysts, High Temperatures-High Pressure; 1995/1996; pages 523-546; vol. 27/28	
		Syndite, CTM302; Announcement, Elementsix Advancing Diamond; 01/14/2003; http://www.e6.com/en/resourches/announcementsheets/CTM302.pdf; as accessed on 12/16/2008	

Examiner Signature		Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an

PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

				Complete if Known	
				Application Number	13/479,148
				Filing Date	5/23/2012
				First Named Inventor	Chien-Min Sung
				Art Unit	3723
				Examiner Name	George Nguyen
Sheet		of		Attorney Docket Number	02074-24012.NP

application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	21026167
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	19-DEC-2014
Filing Date:	23-MAY-2012
Time Stamp:	20:04:31
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	79603 bbbe8ed7d962eab5e6f8dca363d7038dfa33d41e	no	4

Warnings:	
Information:	

2	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	90034 f6c1b51ea97a53b9ab4d4889e1dacf31ac3ee542	no	2
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Non Patent Literature	ColmonoyTech.pdf	180716 5bfb491c6cabe0968d3837bd1a7868dc4f72c908	no	2
Warnings:					
Information:					
4	Non Patent Literature	EndecottSpec.pdf	96774 f79f45fcb9f5866904793c5e568fc27d263cfa7d	no	2
Warnings:					
Information:					
5	Non Patent Literature	KennametalSpec.pdf	43461 6fd07489d780182228d3ea500d7daa4a827167cb	no	2
Warnings:					
Information:					
6	Non Patent Literature	MSDColmonoy.pdf	162485 b6b4dd1a3aa5cfa1c4bf098aa2c9e3b967238eb1	no	3
Warnings:					
Information:					
7	Non Patent Literature	MSDKennametal.pdf	274753 be60be85945395b1ec87affddec0b7f044b92351	no	6
Warnings:					
Information:					
8	Non Patent Literature	SungEastern.pdf	2142977 8d81f1acc54ae312d2118afe9c35c490c791c285	no	15
Warnings:					
Information:					
9	Non Patent Literature	SungMechanism.pdf	5771374 d35aee3f71fdc4ddb41eb3168e7552965d6e87f5	no	24
Warnings:					
Information:					
10	Non Patent Literature	Syndite.pdf	743045 233f3c94e1bdadd55bfd28ca93c8066efb78cc2f	no	2

Warnings:	
Information:	
Total Files Size (in bytes):	9585222

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New Applications Under 35 U.S.C. 111
If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371
If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: George Nguyen FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: December 19, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

Pursuant to the duty of disclosure under 37 C.F.R. §§ 1.56, 1.97 and 1.98, the Applicant requests consideration of this Information Disclosure Statement, which is being submitted in accordance with:

☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☒ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☐ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

While no representation is made that any of these references may be "prior art" within the meaning of that term in accordance with 37 C.F.R. §§ 102 or 103, the enclosed list of references is disclosed so as to comply with the duty of disclosure set forth in 37 C.F.R. § 1.56.

Moreover, while no representation is made that a specific search of office files or patent office records has been conducted or that no better art exists, the undersigned attorney of record believes that the references listed, together with any other references which may have been previously submitted or listed, are the closest to the claimed invention (taken in its entirety) of which the undersigned is presently aware, and no art which is closer to the claimed invention (taken in its entirety) has been knowingly withheld.

☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 19th day of December, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
Customer No. 20,551
P.O. Box 1219
Sandy, Utah 84091-1219
Telephone: (801) 566-6633

PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 13/644,790; filing date 10/04/2012; Chien-Min Sung; office action dated 12/24/2014	

Examiner Signature		Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 (1-800-786-9199) and select option 2.

Electronic Acknowledgement Receipt

EFS ID:	21161992
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	08-JAN-2015
Filing Date:	23-MAY-2012
Time Stamp:	18:31:06
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	80517 2232881b0d6d679db1f12a5c27daf07499f5170c	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	77810 d322252cd4d600c51c34344cdb419ed94ff812ed	no	1

Warnings:	
Information:	
This is not an USPTO supplied IDS fillable form	
Total Files Size (in bytes):	158327

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New Applications Under 35 U.S.C. 111

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National Stage of an International Application under 35 U.S.C. 371

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New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: George Nguyen FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/479,148 FILED: 5/23/2012 CONF. NO.: 7248 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: January 8, 2015 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

SUPPLEMENTAL INFORMATION DISCLOSURE STATEMENT UNDER 37 C.F.R. §§ 1.56, 1.97 and 1.98

Mail Stop Amendment
Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Dear Sir/Madam:

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☒ 37 C.F.R. § 1.97(b)(1) or (3), within three months of the filing date of the application, or before a first office action on the merits, whichever occurs last;

☐ 37 C.F.R. § 1.97(c), after a first office action on the merits, but before a Final Office Action or a Notice of Allowance, whichever occurs first, and is accompanied by **EITHER** a statement in accordance with 37 C.F.R. § 1.97(e), **OR** the fee set forth in 37 C.F.R. § 1.17(p); or

☐ 37 C.F.R. § 1.97(d), after a Final Office Action or Notice of Allowance, whichever occurs first, but on or before payment of the issue fee, and is accompanied by **BOTH** a statement in

accordance with 37 C.F.R. § 1.97(e), **AND** the fee set forth in 37 C.F.R. § 1.17(p).

☒ 37 C.F.R. § 1.704(d), within 30 days of receipt of a first citation in any communication from a patent office in a counterpart foreign or international application or from the Office, in accordance with 37 C.F.R. § 1.97 and 1.98.

SUBMISSIONS

Please find enclosed, pursuant to 37 C.F.R. §§ 1.97 and 1.98:

☒ Form **PTO/SB/08A** and/or **PTO/SB/08B** listing the references submitted for consideration, which contains a list of all patents, publications and all other items that have come to the attention of one or more of the individuals designated in 37 C.F.R. § 1.56(c).

☐ Legible copies of the listed non-patent documents, unpublished U.S. applications and foreign documents or their relevant portions are included.

☐ All English translations of each non-English reference, if any, within the possession, custody, control or availability of anyone designated in 37 C.F.R. § 1.56(c) (see 37 C.F.R. §1.98 are included.

☐ For all listed references that are not either in the English language, or accompanied by a translation into English, a concise explanation of relevance as required under 37 C.F.R. § 1.98(a)(3) is enclosed attached to each.

Copies of references listed on the enclosed PTO/SB/08A and/or PTO/SB/08B are **not** enclosed:

☐ because, under 37 C.F.R. § 1.98.(d), they were previously cited by or submitted to the Office in application number _____, which is relied upon for an earlier filing date under 37 C.F.R. § 1.20.

☐ because they are substantially cumulative of an enclosed reference.

STATEMENT IN ACCORDANCE WITH 37 C.F.R. § 1.97(e)

☐ I hereby certify that each item contained in the information disclosure statement was first cited in a communication from a foreign patent office in a counterpart foreign application not more than three months prior to the filing of the information disclosure statement.

☐ I hereby certify that no item contained in the information disclosure statement was cited in a communication from a foreign patent office in a counterpart foreign application, and, to the knowledge of the person signing the certification after making reasonable inquiry, no item of information contained in the information disclosure statement was known to any individual designated in §1.56(c) more than three months prior to the filing of the information disclosure statement.

REMARKS

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☐ Check No. ____ in the amount of $ ____(amount in § 1.17(p)) constituting the submission fee set forth in 37 C.F.R. § 1.17(p) is enclosed.

In the event that 37 C.F.R. § 1.97(c) applies and the Examiner is not satisfied that the Statement

meets the requirements of 37 C.F.R. § 1.97(e), or in any other event remediable by a fee, please credit any over payment or charge any additional fees to Deposit Account No. 20-0100 of the undersigned.

Dated this 8th day of January, 2015.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

THORPE NORTH & WESTERN, LLP
Customer No. 20,551
P.O. Box 1219
Sandy, Utah 84091-1219
Telephone: (801) 566-6633

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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NOTICE OF ALLOWANCE AND FEE(S) DUE

20551 7590 01/12/2015

THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

EXAMINER
NGUYEN, GEORGE BINH MINH

ART UNIT	PAPER NUMBER
3723	

DATE MAILED: 01/12/2015

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

TITLE OF INVENTION: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	04/13/2015

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE DOES NOT REFLECT A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE IN THIS APPLICATION. IF AN ISSUE FEE HAS PREVIOUSLY BEEN PAID IN THIS APPLICATION (AS SHOWN ABOVE), THE RETURN OF PART B OF THIS FORM WILL BE CONSIDERED A REQUEST TO REAPPLY THE PREVIOUSLY PAID ISSUE FEE TOWARD THE ISSUE FEE NOW DUE.

HOW TO REPLY TO THIS NOTICE:

I. Review the ENTITY STATUS shown above. If the ENTITY STATUS is shown as SMALL or MICRO, verify whether entitlement to that entity status still applies.

If the ENTITY STATUS is the same as shown above, pay the TOTAL FEE(S) DUE shown above.

If the ENTITY STATUS is changed from that shown above, on PART B - FEE(S) TRANSMITTAL, complete section number 5 titled "Change in Entity Status (from status indicated above)".

For purposes of this notice, small entity fees are 1/2 the amount of undiscounted fees, and micro entity fees are 1/2 the amount of small entity fees.

II. PART B - FEE(S) TRANSMITTAL, or its equivalent, must be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted. If an equivalent of Part B is filed, a request to reapply a previously paid issue fee must be clearly made, and delays in processing may occur due to the difficulty in recognizing the paper as an equivalent of Part B.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Mail Stop ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Use Block 1 for any change of address)

20551 7590 01/12/2015
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

TITLE OF INVENTION: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	04/13/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, GEORGE BINH MINH	3723	451-443000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
- ❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
- ❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ❑ Individual ❑ Corporation or other private group entity ❑ Government

4a. The following fee(s) are submitted:
- ❑ Issue Fee
- ❑ Publication Fee (No small entity discount permitted)
- ❑ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
- ❑ A check is enclosed.
- ❑ Payment by credit card. Form PTO-2038 is attached.
- ❑ The director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
- ❑ Applicant certifying micro entity status. See 37 CFR 1.29 — NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
- ❑ Applicant asserting small entity status. See 37 CFR 1.27 — NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
- ❑ Applicant changing to regular undiscounted fee status. — NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature _____ Date _____

Typed or printed name _____ Registration No. _____

PTOL-85 Part B (10-13) Approved for use through 10/31/2013. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

Ex. 1003, Page 1310

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

20551 7590 01/12/2015

THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

EXAMINER	
NGUYEN, GEORGE BINH MINH	
ART UNIT	PAPER NUMBER
3723	

DATE MAILED: 01/12/2015

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(Applications filed on or after May 29, 2000)

The Office has discontinued providing a Patent Term Adjustment (PTA) calculation with the Notice of Allowance.

Section 1(h)(2) of the AIA Technical Corrections Act amended 35 U.S.C. 154(b)(3)(B)(i) to eliminate the requirement that the Office provide a patent term adjustment determination with the notice of allowance. See Revisions to Patent Term Adjustment, 78 Fed. Reg. 19416, 19417 (Apr. 1, 2013). Therefore, the Office is no longer providing an initial patent term adjustment determination with the notice of allowance. The Office will continue to provide a patent term adjustment determination with the Issue Notification Letter that is mailed to applicant approximately three weeks prior to the issue date of the patent, and will include the patent term adjustment on the patent. Any request for reconsideration of the patent term adjustment determination (or reinstatement of patent term adjustment) should follow the process outlined in 37 CFR 1.705.

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at 1-(888)-786-0101 or (571)-272-4200.

OMB Clearance and PRA Burden Statement for PTOL-85 Part B

The Paperwork Reduction Act (PRA) of 1995 requires Federal agencies to obtain Office of Management and Budget approval before requesting most types of information from the public. When OMB approves an agency request to collect information from the public, OMB (i) provides a valid OMB Control Number and expiration date for the agency to display on the instrument that will be used to collect the information and (ii) requires the agency to inform the public about the OMB Control Number's legal significance in accordance with 5 CFR 1320.5(b).

The information collected by PTOL-85 Part B is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, Virginia 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, Virginia 22313-1450. Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

Privacy Act Statement

The Privacy Act of 1974 (P.L. 93-579) requires that you be given certain information in connection with your submission of the attached form related to a patent application or patent. Accordingly, pursuant to the requirements of the Act, please be advised that: (1) the general authority for the collection of this information is 35 U.S.C. 2(b)(2); (2) furnishing of the information solicited is voluntary; and (3) the principal purpose for which the information is used by the U.S. Patent and Trademark Office is to process and/or examine your submission related to a patent application or patent. If you do not furnish the requested information, the U.S. Patent and Trademark Office may not be able to process and/or examine your submission, which may result in termination of proceedings or abandonment of the application or expiration of the patent.

The information provided by you in this form will be subject to the following routine uses:

1. The information on this form will be treated confidentially to the extent allowed under the Freedom of Information Act (5 U.S.C. 552) and the Privacy Act (5 U.S.C 552a). Records from this system of records may be disclosed to the Department of Justice to determine whether disclosure of these records is required by the Freedom of Information Act.
2. A record from this system of records may be disclosed, as a routine use, in the course of presenting evidence to a court, magistrate, or administrative tribunal, including disclosures to opposing counsel in the course of settlement negotiations.
3. A record in this system of records may be disclosed, as a routine use, to a Member of Congress submitting a request involving an individual, to whom the record pertains, when the individual has requested assistance from the Member with respect to the subject matter of the record.
4. A record in this system of records may be disclosed, as a routine use, to a contractor of the Agency having need for the information in order to perform a contract. Recipients of information shall be required to comply with the requirements of the Privacy Act of 1974, as amended, pursuant to 5 U.S.C. 552a(m).
5. A record related to an International Application filed under the Patent Cooperation Treaty in this system of records may be disclosed, as a routine use, to the International Bureau of the World Intellectual Property Organization, pursuant to the Patent Cooperation Treaty.
6. A record in this system of records may be disclosed, as a routine use, to another federal agency for purposes of National Security review (35 U.S.C. 181) and for review pursuant to the Atomic Energy Act (42 U.S.C. 218(c)).
7. A record from this system of records may be disclosed, as a routine use, to the Administrator, General Services, or his/her designee, during an inspection of records conducted by GSA as part of that agency's responsibility to recommend improvements in records management practices and programs, under authority of 44 U.S.C. 2904 and 2906. Such disclosure shall be made in accordance with the GSA regulations governing inspection of records for this purpose, and any other relevant (i.e., GSA or Commerce) directive. Such disclosure shall not be used to make determinations about individuals.
8. A record from this system of records may be disclosed, as a routine use, to the public after either publication of the application pursuant to 35 U.S.C. 122(b) or issuance of a patent pursuant to 35 U.S.C. 151. Further, a record may be disclosed, subject to the limitations of 37 CFR 1.14, as a routine use, to the public if the record was filed in an application which became abandoned or in which the proceedings were terminated and which application is referenced by either a published application, an application open to public inspection or an issued patent.
9. A record from this system of records may be disclosed, as a routine use, to a Federal, State, or local law enforcement agency, if the USPTO becomes aware of a violation or potential violation of law or regulation.

Notice of Allowability	Application No. 13/479,148	Applicant(s) SUNG, CHIEN-MIN	
	Examiner GEORGE NGUYEN	Art Unit 3723	AIA (First Inventor to File) Status No

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☒ This communication is responsive to *the RCE filed on December 16, 2014*.
   ☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on_____.
2. ☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.
3. ☒ The allowed claim(s) is/are *7-13 and 28*. As a result of the allowed claim(s), you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov .
4. ☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

   Certified copies:

   a) ☐ All b) ☐ Some *c) ☐ None of the:
   1. ☐ Certified copies of the priority documents have been received.
   2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
   3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application.
THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.

5. ☐ CORRECTED DRAWINGS (as "replacement sheets") must be submitted.
   ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No./Mail Date _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the front (not the back) of each sheet. Replacement sheet(s) should be labeled as such in the header according to 37 CFR 1.121(d).
6. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1. ☐ Notice of References Cited (PTO-892)
2. ☒ Information Disclosure Statements (PTO/SB/08), Paper No./Mail Date 12/16/2014; 12/19/2014; 11/06/2012
3. ☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
4. ☐ Interview Summary (PTO-413), Paper No./Mail Date _____ .
5. ☐ Examiner's Amendment/Comment
6. ☐ Examiner's Statement of Reasons for Allowance
7. ☐ Other _____.

/GEORGE NGUYEN/
Primary Examiner, Art Unit 3723

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
L1	33	("20020014041" | "20020164928" | "20030092357" | "20040023610" | "20050095959" | "20050118939" | "20050227590" | "20070232074" | "20090073774" | "20090123705" | "20110293905" | "20120192499" | "20120260582" | "20120302146" | "3664662" | "3706650" | "4151154" | "4405411" | "4737162" | "4863573" | "5224469" | "5868806" | "6159087" | "6200360" | "6312324" | "6416878" | "6769969" | "6837979" | "7067903" | "7651368" | "7762872" | "8393934").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/12/18 13:50
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S26	608	451/443.ccls.	USPAT	OR	OFF	2014/02/24 11:31
S27	331	451/444.ccls.	USPAT	OR	OFF	2014/02/24 11:34
S28	912	451/548.ccls.	USPAT	OR	OFF	2014/02/24 11:37
S29	1838	b24b53/12.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:40
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S41	113033	"451"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:43
S42	8	S40 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:43
S43	14761	"51"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:52
S44	3	S40 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:53
S45	1212	tip adj (level leveling leveled)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:54
S46	8	S45 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:54
S47	59	protrusion adj difference	US-PGPUB;	OR	OFF	2014/05/07

			USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB			13:42
S48	4102	heat near2 pressure near2 bonding	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 13:59
S49	9	S48 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:00
S50	263	sintering adj compound	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:05
S51	3	S50 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:06
S52	4	S50 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 14:06
S53	1160	adhesive near2 transfer near2 sheet	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 15:46
S54	12	S53 and S43	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 15:46
S55	971	aperture near2 template	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT;	OR	OFF	2014/05/07 16:09

			IBM_TDB			
S56	0	S53 with S55	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:10
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S59	53542	hot adj pressing	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:18
S60	14766	"51"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:18
S61	581	S59 and S60	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:18
S62	126	warping adj (reducing reduction minimizing mininized)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:51
S63	0	S62 and S60	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	OFF	2014/05/09 08:51

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S64	113048	"451"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:51
S65	0	S62 and S64	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:52
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S68	9	("20040238946" | "5919084" | "6159286" | "7791188").PN.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/12/02 14:05
S69	4	("20080014845" | "20090094902" | "20110104989" | "20130225052").PN.	US-PGPUB; USPAT; USOCR	OR	OFF	2014/12/02 14:09
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S71	1	"8777699".pn.	USPAT	OR	OFF	2014/12/02 14:22
S72	632	451/443.ccls.	USPAT	OR	OFF	2014/12/02 14:27
S73	339	451/444.ccls.	USPAT	OR	OFF	2014/12/02 14:29
S74	918	451/548.ccls.	USPAT	OR	OFF	2014/12/02 14:29
S75	451	b24b53/12.cpc.	USPAT	OR	OFF	2014/12/02 14:31
S76	860	b24b53/017.cpc.	USPAT	OR	OFF	2014/12/02 14:32
S77	1466	51/295.ccls.	USPAT	OR	OFF	2014/12/02 14:33
S78	3044	51/309.ccls.	USPAT	OR	OFF	2014/12/02 14:34

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S21	608	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S22	53464	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S23	1	S21 same S22	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S30	635	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38
S31	55259	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38
S32	19881	(superabrasive abrasive) adj particles	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:39
S33	1	S30 same S31 same S32	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:39

12/18/2014 2:00:41 PM
C:\Users\gnguyen\Documents\EAST\Workspaces\13479148.wsp

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	Art Unit
	GEORGE NGUYEN	3723

CPC- SEARCHED		
Symbol	Date	Examiner
B24b53/12;53/017	5/9/2014	GN
Updated search above	12/2/2014	GN

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
451	443,444,548,56,	5/9/2014	GN
51	295,309	5/9/2014	GN
	updated search above	12/2/2014	GN

SEARCH NOTES		
Search Notes	Date	Examiner
Inventor search	5/9/2014	GN
Considered IDS submitted with RCE filed on 12/16/2014	12/18/2014	GN

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner
	Please see East search history	12/2/2014	GN

	/GEORGE NGUYEN/ Primary Examiner.Art Unit 3723

PTO/SB/08B (08-03)
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		Colmonoy Technical Data Sheet; no. DSP-A; 1993	
		Endecott's Specifications; 2004	
		Kennametal Specification for DMHPM002 Hot Press Matrix N-50 12/06/2001	
		Material Safety Data Sheet (MSDS), Wall Colmonoy Corporation; prepared 07/20/1989	
		Material Safety Data Sheet (MSDS); Kennametal; issued 06/11/2004	
		SUNG et al.; The Eastern Wind of Diamond Symthesis; New Diamond and Frontier Carpon Technology; 2003; pages 47-61; vol. 13, no. 1	
		SUNG et al; Mechanism of the Solvent-Assisted Graphite to Diamond Transition Under High Pressure: Implications for the Selection of Catalysts, High Temperatures-High Pressure; 1995/1996; pages 523-546; vol. 27/28	
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Examiner Signature	/George Nguyen/ (12/24/2014)	Date Considered	

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				Application Number	13/479,148
				Filing Date	5/23/2012
				First Named Inventor	Chien-Min Sung
				Art Unit	3723
				Examiner Name	George Nguyen
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		2008/0076338	03/2008	Andrews et al.	
		2010/0015898	01/2010	An et al.	

FOREIGN PATENT DOCUMENTS						
Examiner	Cite	Foreign Patent Document	Publication	Name of Patentee or	Pages, Columns, Lines, Where	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /G.N./

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

Initials*	No.[1]	Country Code[3]- Number[4] – Kind Code[5] (if known)	Date MM-DD-YYYY	Applicant of Cited Document	Relevant Passages or Relevant Figures Appear	T[6]

Examiner Signature	/George Nguyen/ (12/24/2014)	Date Considered	

*EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant. [1]Applicant's unique citation designation number (optional). [2] See Kinds Codes of USPTO Patent Documents at www.uspto.gov or MPEP 901.04. [3] Enter Office that issued the document, by the two-letter code (WIPO Standard ST.3). [4] For Japanese patent documents, indication of the year of the reign of the Emperor must precede the serial number of the patent document. [5] Kind of document by the appropriate symbols as indicated on the document under WIPO Standard ST.16 if possible. [6] Applicant is to place a check mark here if English language Translation is attached.

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Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		Colmonoy Technical Data Sheet; no. DSP-A; 1993	
		Endecott's Specifications; 2004	
		Kennametal Specification for DMHPM002 Hot Press Matrix N-50 12/06/2001	
		Material Safety Data Sheet (MSDS), Wall Colmonoy Corporation; prepared 07/20/1989	
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		Syndite, CTM302; Announcement, Elementsix Advancing Diamond; 01/14/2003; http://www.e6.com/en/resourches/announcementsheets/CTM302.pdf; as accessed on 12/16/2008	
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		US Application 09/447,620; filing date 11/22/1999; Chien-Min Sung	
		US Application 11/512,755; filing date 08/29/2006; Chien-Min Sung	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet | | of | |

Complete if Known	
Application Number	13/416,201
Filing Date	3/9/2012
First Named Inventor	Chien-Min Sung
Art Unit	1731
Examiner Name	
Attorney Docket Number	00802-T5100.CIP9

		US Application 13/239,198; filing date 09/21/2011; Chien-Min Sung	
		US Application 13/416,201; filing date 03/09/2012; Chien-Min Sung	
		US Application 13/479,148; filing date 05/23/2012; Chien-Min Sung	
		YASINAGA et al; Advances in Abrasive Technology, III; Soc. Of Grinding Engineers (SGE) in Japan; 2000	
		PCT Application PCT/US2011/052627; filing date 09/21/2011; Chien-Min Sung; International Search Report mailed 05/11/2012	
		U.S. Application 13/362,917; filed 01/31/2012; Chien-Min Sung; office action dated 06/14/2012	
		U.S. Application 12/168,110; filed 07/05/2008; Chien-Min Sung; office action dated 05/14/2012	
		US Application 12/059,422; filed 03/30/2008; Chien-Min Sung; office action dated 08/22/2012	
		US Application 12/255,823; filed 10/21/2008; Chien-Min Sung; notice of allowance dated 09/21/2012	
		US Application 12/168,110; filed 07/05/2008; Chien-Min Sung; notice of allowance dated 09/28/2012	

Examiner Signature	/George Nguyen/ (12/24/2014)	Date Considered	

*Examiner: Initial if reference considered, whether or not citation is in conformance with MPEP 609. Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

[1]Applicant's unique citation designation number (optional). [2]Applicant is to place a check mark here if English language Translation is attached. This collection of information is required by 37 CFR 1.98. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentially is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 2 hours to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **Send to: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

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Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2002/0014041	02/2002	Baldonai et al.	
		2002/0164928	11/07/2002	Toles	
		2003/0092357	05/2003	Yoon et al.	
		2004/0023610	02/05/2004	Hu et al.	
		2005/0032469	02/10/2005	Duescher	
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		2005/0118939	06/02/2005	Duescher	
		2005/0227590	10/13/2005	Sung	
		2007/0232074	10/04/2007	Krmadhati et al.	
		2009/0073774	04/06/2006	Sung	
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		2011/0293905	12/01/2011	Sung	
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		6769969	08/03/2004	Duescher	
		6837979	01/04/2005	Uzho et al.	
		7067903	06/27/2006	Takeshi et al.	
		7651368	01/26/2010	Kendall et al.	
		7762872	07/27/2010	Sung	
		8393934	03/17/2013	Sung	

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Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		EP 1075898	02/14/2001	Mitsubishi		
		GB 2366804	03/02/2002	Kinik Company		
		WO 95/31006	11/16/1995	Siliconix Incorporated		
		WO 2006/039413	04/13/2006	Sung		
		WO 2009/043058	04/02/2009	Sung et al.		
		WO 2009/064677	05/22/2009	Sung		
		WO 2012/040374 A2	03/29/2012	Rite Dia Corporation		

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /G.N./

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Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

Examiner Signature	/George Nguyen/ (12/18/2014)	Date Considered	

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Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		PCT Application PCT/US2007/024165; filed 11/16/2007; Chien-Min Sung; Internaitonal Search Report mailed 05/23/2011	
		PCT Application PCT/US2011/052626; filing date 09/21/2011; Chien-Min Sung; International Search Report mailed 05/02/2012	
		US Application 12/255,823; filing date 10/22/2005; Chien-Min Sung; office action issued 03/07/2012	
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		US Application 12/267,172; filing date 01/31/2012; Chien-Min Sung; office action issued 07/09/2012	
		US Application 12/715,583; filing date 03/02/2010; Chien-Min Sung; office action issued 03/21/2012	
		US Application 12/715,583;; filling date 03/02/2010; Chien-Min Sung; office action issued 08/09/2012	
		US Application 12/715,583; filing date 03/02/2010; Chien-Min Sung; office action issued 10/25/2011	
		US Application 12/328,338; filed 12/04/2008; Chien-Min Sung; office action issued 05/10/2011	
		US Application 13/021,350; filing date 02/04/2011; Chien-Min Sung; office action issued 08/31/2011	
		US Application 13/021,350; filed 02/04/2011; Chien-Min Sung; office action issued 02/07/2012	
		US Application 13/113/779; filing date 05/23/2011; Chien-Min Sung; office action dated 10/09/2014	
		US Application 13/153,176; filing date 06/03/2011; Chien-Min Sung; office action dated 10/10/2014	
		US Application 13/407,634; filing date 02/28/2012; Chien-Min Sung; office action dated 10/29/2014	

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Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

		US Application 13/802,112; filing date 03/13/2013; Chien-Min Sung; office action dated 11/06/2014	

Examiner Signature	/George Nguyen/ (12/18/2014)	Date Considered	

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Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	**Art Unit**
	GEORGE NGUYEN	3723

CPC						
Symbol					**Type**	**Version**
H01L	/	21	/	304	F	2013-01-01

CPC Combination Sets								
Symbol					**Type**	**Set**	**Ranking**	**Version**

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	8	
/GEORGE NGUYEN/ Primary Examiner, Art Unit 3723	12/02/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	**Art Unit**
	GEORGE NGUYEN	3723

US ORIGINAL CLASSIFICATION		INTERNATIONAL CLASSIFICATION										
CLASS	SUBCLASS	CLAIMED					NON-CLAIMED					
451	443	B	2	4	B	53 / 12						
CROSS REFERENCE(S)												
CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)											
451	444	548										

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	8	
/GEORGE NGUYEN/ Primary Examiner, Art Unit 3723	12/02/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

Issue Classification	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13479148	SUNG, CHIEN-MIN
	Examiner	**Art Unit**
	GEORGE NGUYEN	3723

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☒ T.D. ☐ R.1.47

Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original	Final	Original
-	1	-	17												
-	2	-	18												
-	3	-	19												
-	4	-	20												
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4	9	-	25												
1	10	-	26												
5	11	-	27												
6	12	8	28												
7	13														
-	14														
-	15														
-	16														

NONE		**Total Claims Allowed:**	
(Assistant Examiner)	(Date)	8	
/GEORGE NGUYEN/ Primary Examiner, Art Unit 3723	12/02/2014	O.G. Print Claim(s)	O.G. Print Figure
(Primary Examiner)	(Date)	1	5

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Mail Stop ISSUE FEE**
Commissioner for Patents
P.O. Box 1450
Alexandria, Virginia 22313-1450
or Fax (571)-273-2885

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 5 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

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20551
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

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I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Mail Stop ISSUE FEE address above, or being facsimile transmitted to the USPTO (571) 273-2885, on the date indicated below.

Nicole Solomon	(Depositor's name)
/Nicole Solomon/	(Signature)
January 19, 2015	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	7248

TITLE OF INVENTION: CMP Pad Dresser Having Leveled Tips and Associated Methods

APPLN. TYPE	ENTITY STATUS	ISSUE FEE DUE	PUBLICATION FEE DUE	PREV. PAID ISSUE FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	SMALL	$480	$0	$0	$480	03/09/2015

EXAMINER	ART UNIT	CLASS-SUBCLASS
NGUYEN, GEORGE BINH MINH	3723	451-443000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).
☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.
☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list
(1) The names of up to 3 registered patent attorneys or agents OR, alternatively,
(2) The name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.
1 THORPE NORTH & WESTERN LLP
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. If an assignee is identified below, the document has been filed for recordation as set forth in 37 CFR 3.11. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) : ☐ Individual ☐ Corporation or other private group entity ☐ Government

4a. The following fee(s) are submitted:
☑ Issue Fee
☐ Publication Fee (No small entity discount permitted)
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s): **(Please first reapply any previously paid issue fee shown above)**
☐ A check is enclosed.
☑ Payment by credit card. Form PTO-2038 is attached.
☑ The Director is hereby authorized to charge the required fee(s), any deficiency, or credits any overpayment, to Deposit Account Number 20-0100 (enclose an extra copy of this form).

5. **Change in Entity Status** (from status indicated above)
☐ Applicant certifying micro entity status. See 37 CFR 1.29
NOTE: Absent a valid certification of Micro Entity Status (see forms PTO/SB/15A and 15B), issue fee payment in the micro entity amount will not be accepted at the risk of application abandonment.
☐ Applicant asserting small entity status. See 37 CFR 1.27
NOTE: If the application was previously under micro entity status, checking this box will be taken to be a notification of loss of entitlement to micro entity status.
☐ Applicant changing to regular undiscounted fee status.
NOTE: Checking this box will be taken to be a notification of loss of entitlement to small or micro entity status, as applicable.

NOTE: This form must be signed in accordance with 37 CFR 1.31 and 1.33. See 37 CFR 1.4 for signature requirements and certifications.

Authorized Signature /David W. Osborne/ Date January 19, 2015

Typed or printed name David W. Osborne Registration No. 44989

Electronic Patent Application Fee Transmittal

Application Number:	13479148
Filing Date:	23-May-2012
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Nicole Solomon
Attorney Docket Number:	02074-24012.NP

Filed as Small Entity

Filing Fees for Utility under 35 USC 111(a)

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Pages:				
Claims:				
Miscellaneous-Filing:				
Petition:				
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Utility Appl Issue Fee	2501	1	480	480

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Extension-of-Time:				
Miscellaneous:				
			Total in USD ($)	**480**

Electronic Acknowledgement Receipt

EFS ID:	21244495
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Nicole Solomon
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP
Receipt Date:	19-JAN-2015
Filing Date:	23-MAY-2012
Time Stamp:	19:50:28
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$480
RAM confirmation Number	11604
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Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Issue Fee Payment (PTO-85B)	02074-24012-NP-Issue-Fee.pdf	104605 f48f1aee0df49a96ca9668583e8101e90d88e2f2	no	1
Warnings:					
Information:					
2	Fee Worksheet (SB06)	fee-info.pdf	30732 d7806fd6ea7cecec6714a88c4364454582a88682	no	2
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Application Number	13/479,148
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First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	George Nguyen
Attorney Docket Number	02074-24012.NP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 13/644,790; filing date 10/04/2012; Chien-Min Sung; office action dated 12/24/2014	

Examiner Signature	/George Nguyen/ (02/05/2015)	Date Considered	

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Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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First Named Inventor	Chien-Min Sung
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Art Unit	1731
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Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

Change(s) applied to document, /M.I.G./ 2/10/2015

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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /G.N./

PTO/SB/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/479,148
Filing Date	5/23/2012
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP

U.S. PATENT DOCUMENTS					
Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2001/0003884	06/2001	Wei et al.	
		2001/0009844	07/2001	Cho et al.	
		2002/0042200	04/11/2002	Fawcett	
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		2009/0283089	~~11/19/2011~~	Sung	November 19, 2009

Change(s) applied to document,
/M.I.G./
2/10/2015

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /G.N./

PTO/SB/08A (08-03)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

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First Named Inventor	Chien-Min Sung
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U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 6159286	12/2000	Sung	
		US 5919084	07/1999	Powell, et al.	
		US 2004/0238946	12/2004	Tachibana, et al.	
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		US 7791188	~~12/2008~~	Sung	September 7, 2010
Change(s) applied to document, /M.I.G./ 2/10/2015					

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
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ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /G.N./

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UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER FOR PATENTS
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NO.	ISSUE DATE	PATENT NO.	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/479,148	03/10/2015	8974270	02074-24012.NP	7248

20551 7590 02/18/2015

THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

ISSUE NOTIFICATION

The projected patent number and issue date are specified above.

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The Patent Term Adjustment is 199 day(s). Any patent to issue from the above-identified application will include an indication of the adjustment on the front page.

If a Continued Prosecution Application (CPA) was filed in the above-identified application, the filing date that determines Patent Term Adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) WEB site (http://pair.uspto.gov).

Any questions regarding the Patent Term Extension or Adjustment determination should be directed to the Office of Patent Legal Administration at (571)-272-7702. Questions relating to issue and publication fee payments should be directed to the Application Assistance Unit (AAU) of the Office of Data Management (ODM) at (571)-272-4200.

APPLICANT(s) (Please see PAIR WEB site http://pair.uspto.gov for additional applicants):

Chien-Min Sung, Tansui, TAIWAN;

The United States represents the largest, most dynamic marketplace in the world and is an unparalleled location for business investment, innovation, and commercialization of new technologies. The USA offers tremendous resources and advantages for those who invest and manufacture goods here. Through SelectUSA, our nation works to encourage and facilitate business investment. To learn more about why the USA is the best country in the world to develop technology, manufacture products, and grow your business, visit SelectUSA.gov.

PTO/AIA/81A (02-15)
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PATENT - POWER OF ATTORNEY OR REVOCATION OF POWER OF ATTORNEY WITH A NEW POWER OF ATTORNEY AND CHANGE OF CORRESPONDENCE ADDRESS

Patent Number	8,974,270
Issue Date	March 10, 2015
First Named Inventor	Chien-Min SUNG
Title	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
Attorney Docket No.	

I hereby revoke all previous powers of attorney given in the above-identified patent.

☐ A Power of Attorney is submitted herewith.

OR

☒ I hereby appoint Practitioner(s) associated with the Customer Number identified in the box at right as my/our attorney(s) or agent(s) with respect to the patent identified above, and to transact all business in the United States Patent and Trademark Office connected therewith: 134688

OR

☐ I hereby appoint Practitioner(s) named below as my/our attorney(s) or agent(s) with respect to the patent identified above, and to transact all business in the United States Patent and Trademark Office connected therewith:

Practitioner(s) Name	Registration Number

Please recognize or change the correspondence address for the above-identified patent to:

☒ The address associated with the above-identified Customer Number.

OR

☐ The address associated with the Customer Number identified in the box at right:

OR

☐ Firm or Individual Name					
Address					
City		State		Zip	
Country					
Telephone		Email			

I am the:

☒ Applicant.

OR

☐ Patent owner.

Statement under 37 CFR 3.73(c) (Form PTO/AIA/96) submitted herewith or filed on _____

SIGNATURE of Applicant or Patent Owner

Signature	Chien-Min Sung	Date	2021/8/18
Name	Dr. Chien-Min SUNG	Telephone	886-1333986291?
Title and Company			

NOTE: Signatures of all the applicants or patent owners of the entire interest or their representative(s) are required. If more than one signature is required, submit multiple forms, check the box below, and identify the total number of forms submitted in the blank below.

☐ A total of _____ forms are submitted.

This collection of information is required by 37 CFR 1.41, 1.32, and 1.33. The information is required to obtain or retain a benefit by the public, which is to update (and by the USPTO to process) the file of a patent or reexamination proceeding. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 3 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

If you need assistance in completing the form, call 1-800-PTO-9199 and select option 2.

PTO/AIA/96 (08-12)
Approved for use through 11/30/2020. OMB 0651-0031
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STATEMENT UNDER 37 CFR 3.73(c)

Applicant/Patent Owner: Chien-Min SUNG

Application No./Patent No.: 8,974,270 Filed/Issue Date: March 10, 2015

Titled: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

Chien-Min SUNG, a individual

(Name of Assignee) (Type of Assignee, e.g., corporation, partnership, university, government agency, etc.)

states that, for the patent application/patent identified above, it is (choose **one** of options 1, 2, 3 or 4 below):

1. ☑ The assignee of the entire right, title, and interest.

2. ☐ An assignee of less than the entire right, title, and interest (check applicable box):

   ☐ The extent (by percentage) of its ownership interest is _____%. Additional Statement(s) by the owners holding the balance of the interest must be submitted to account for 100% of the ownership interest.

   ☐ There are unspecified percentages of ownership. The other parties, including inventors, who together own the entire right, title and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

3. ☐ The assignee of an undivided interest in the entirety (a complete assignment from one of the joint inventors was made). The other parties, including inventors, who together own the entire right, title, and interest are:

   Additional Statement(s) by the owner(s) holding the balance of the interest must be submitted to account for the entire right, title, and interest.

4. ☐ The recipient, via a court proceeding or the like (*e.g.*, bankruptcy, probate), of an undivided interest in the entirety (a complete transfer of ownership interest was made). The certified document(s) showing the transfer is attached.

The interest identified in option 1, 2 or 3 above (not option 4) is evidenced by either (choose **one** of options A or B below):

A. ☐ An assignment from the inventor(s) of the patent application/patent identified above. The assignment was recorded in the United States Patent and Trademark Office at Reel _____, Frame _____, or for which a copy thereof is attached.

B. ☑ A chain of title from the inventor(s), of the patent application/patent identified above, to the current assignee as follows:

1. From: Chien-Min SUNG To: KINIK Company

   The document was recorded in the United States Patent and Trademark Office at

   Reel 033566, Frame 0479, or for which a copy thereof is attached.

2. From: KINIK Company To: Chien-Min SUNG

   The document was recorded in the United States Patent and Trademark Office at

   Reel _____, Frame _____, or for which a copy thereof is attached.

This collection of information is required by 37 CFR 3.73(b). The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.11 and 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, P.O. Box 1450, Alexandria, VA 22313-1450. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. **SEND TO: Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450.**

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STATEMENT UNDER 37 CFR 3.73(c)

3. From: _____ To: _____

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Reel _____, Frame _____, or for which a copy thereof is attached.

4. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

5. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

6. From: _____ To: _____

The document was recorded in the United States Patent and Trademark Office at

Reel _____, Frame _____, or for which a copy thereof is attached.

☐ Additional documents in the chain of title are listed on a supplemental sheet(s).

☐ As required by 37 CFR 3.73(c)(1)(i), the documentary evidence of the chain of title from the original owner to the assignee was, or concurrently is being, submitted for recordation pursuant to 37 CFR 3.11.

[NOTE: A separate copy (i.e., a true copy of the original assignment document(s)) must be submitted to Assignment Division in accordance with 37 CFR Part 3, to record the assignment in the records of the USPTO. See MPEP 302.08]

The undersigned (whose title is supplied below) is authorized to act on behalf of the assignee.

/James M. Lennon/	2021-08-19
Signature	Date
James M. Lennon	56815
Printed or Typed Name	Title or Registration Number

U.S. PATENT ASSIGNMENT

To the extent that KINIK COMPANY ("Assignor"), a corporation organized and existing under the laws of Republic of China (R.O.C.), with a place of business at No. 64 Zhongshan Road, Yingge District, New Taipei City 23942, Taiwan (R.O.C.), is the owner of the following (i) and (ii), or to the extent Assignor owns, controls or has the right to practice, license, or enforce any such patent or patents at any time: (i) United States Patent listed in Schedule A; (ii) any continuations, divisional, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsection (i) (together the "Assigned Patents").

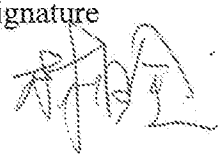
WHEREAS, Dr. Chien-Min Sung ("Assignee") is the rightful owner of the Assigned Patents but is desirous of acquiring complete and clear title in and to the Assigned Patents to the extent that Assignee does not already own such title in and to the Assigned Patents.

WHEREAS, Assignor has asserted certain ownership of its right, title, and interest in and to the Assigned Patents but has now disclaimed that Assignor has such right, title, and interest in and to the Assigned Patents subject to and without prejudice to any of the rights and interests of each of the Parties pursuant to the terms of the Settlement Transcript prepared by the Intellectual Property Court of Taiwan and agreed and executed by the Parties on 13 August 2021 before the judge of the said court (the "Settlement Transcript").

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest, if any, in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, to the extent Assignor is the owner of or asserts certain ownership of any right, title and/or interest in the Assigned Patents, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature	Signature
Dr. Chien-Min Sung	
Name	Name Po Chun Lin
Date:	Date: Aug/13/2021

SCHEDULE A

9868100

9724802

8777699

9138862

8974270

Electronic Acknowledgement Receipt

EFS ID:	43554211
Application Number:	13479148
International Application Number:	
Confirmation Number:	7248
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	James Michael Lennon/Jennifer Picini
Filer Authorized By:	James Michael Lennon
Attorney Docket Number:	02074-24012.NP
Receipt Date:	19-AUG-2021
Filing Date:	23-MAY-2012
Time Stamp:	15:56:04
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Power of Attorney	8974270-POA-signed.pdf	528082 ddebcb088c049b15c76da57c2bbd835912a575e7	no	1

Warnings:

Information:					
2	Assignee showing of ownership per 37 CFR 3.73	8974270-373c-statement.pdf	104743 97b7a9b73a7e38f88cabab38d5f3b8d135aa1310	no	2
Warnings:					
Information:					
3	Miscellaneous Incoming Letter	Assignment-Kinik-to-Sung.pdf	2172382 d39afb19dbeecf15c7054343429dd21b2c9dc08e	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	2805207	

This Acknowledgement Receipt evidences receipt on the noted date by the USPTO of the indicated documents, characterized by the applicant, and including page counts, where applicable. It serves as evidence of receipt similar to a Post Card, as described in MPEP 503.

New Applications Under 35 U.S.C. 111

If a new application is being filed and the application includes the necessary components for a filing date (see 37 CFR 1.53(b)-(d) and MPEP 506), a Filing Receipt (37 CFR 1.54) will be issued in due course and the date shown on this Acknowledgement Receipt will establish the filing date of the application.

National Stage of an International Application under 35 U.S.C. 371

If a timely submission to enter the national stage of an international application is compliant with the conditions of 35 U.S.C. 371 and other applicable requirements a Form PCT/DO/EO/903 indicating acceptance of the application as a national stage submission under 35 U.S.C. 371 will be issued in addition to the Filing Receipt, in due course.

New International Application Filed with the USPTO as a Receiving Office

If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

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APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP

CONFIRMATION NO. 7248

134688
Devlin Law Firm
1526 Gilpin Ave.
Wilmington, DE 19806

POA ACCEPTANCE LETTER

OC000000127907605

Date Mailed: 08/24/2021

NOTICE OF ACCEPTANCE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 08/19/2021.

The Power of Attorney in this application is accepted. Correspondence in this application will be mailed to the above address as provided by 37 CFR 1.33.

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/mbeyene/

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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP

CONFIRMATION NO. 7248

POWER OF ATTORNEY NOTICE

20551
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

OC000000127907556

Date Mailed: 08/24/2021

NOTICE REGARDING CHANGE OF POWER OF ATTORNEY

This is in response to the Power of Attorney filed 08/19/2021.

- The Power of Attorney to you in this application has been revoked by the assignee who has intervened as provided by 37 CFR 3.71. Future correspondence will be mailed to the new address of record(37 CFR 1.33).

Questions about the contents of this notice and the requirements it sets forth should be directed to the Office of Data Management, Application Assistance Unit, at **(571) 272-4000** or **(571) 272-4200** or **1-888-786-0101**.

/mbeyene/

UNITED STATES
PATENT AND TRADEMARK OFFICE

P.O. Box 1450
Alexandria, Virginia 22313-1450
www.uspto.gov

ACKNOWLEDGEMENT OF LOSS OF ENTITLEMENT TO ENTITY STATUS DISCOUNT

APPLICATION #	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTORNEY DOCKET #	REQUEST ID
13/479,148	05/23/2012	Chien-Min Sung	02074-24012.NP	52439

The entity status change request below filed through Patent Center on 12/07/2022 has been accepted.

Certifications

APPLICANT CHANGING TO REGULAR UNDISCOUNTED FEE STATUS

Signature

I certify, in accordance with 37 CFR 1.4(d)(4), that I am one of the signatories making the entity status change.

Signature	Name	Registration #
/James M Lennon/	James Lennon	56815

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of: Sung

Confirmation No.: 7248

Application No.: 13/479,148

Art Unit: 3723

Filing Date: May 23, 2012

For: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Notice of Loss of Entitlement to Small Entity Status

Applicant hereby submits Notice of Loss of Entitlement to Small Entity Status. Small entity status was established in good faith, and fees as a small entity were paid in good faith, but it was recently discovered that entitlement to small entity status was lost and that through error the Office was not notified of the loss of entitlement to small entity status. This was a good faith error without deceptive intent. Applicant submits that this good faith error shall be excused pursuant to 37 CFR § 1.28 as Applicant herewith is complying with the separate submission and itemization requirements of paragraphs (c)(1) and (c)(2) of 37 CFR § 1.28, and the deficiency payment requirement of paragraph (c)(2) of 37 CFR § 1.28.

The fee deficiency is calculated below and has been submitted.

Date Paid	Fee Code	Amount Paid	2022 Amount	Deficiency
9/10/2018	2551	$800	$2000	**$1200**
5/9/2022	2552	$1880	$3760	**$1880**
			Total Due	**$3080**

The Office is invited to telephone the undersigned attorney to resolve any outstanding issues.

Date: December 7, 2022

Respectfully Submitted,
/James M. Lennon/
James M. Lennon
Customer No. 134688
Devlin Law Firm LLC
1526 Gilpin Ave.
Wilmington, DE 19806

PAGE 4/5 * RCVD AT 12/7/2022 5:13:49 PM [Eastern Standard Time] * SVR:W-PTOFAX-DTS-E1/24 * DNIS:2738300 * CSID:13023534251 * ANI:3023534251 * DURATION (mm-ss):02-29

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FAX

TO:	Office of Petitions	FROM:	Jennifer Picini
FAX:	571-273-8300	FAX:	
PHONE:	571-272-3282	PHONE:	302-486-3402
SUBJECT:	Petition for Review by the Office of Petitions	DATE:	December 7, 2022

COMMENTS Documents included:
Notice of Loss of Entitlement to Small Entity Status – US 8,974,270 (1 page)
Credit Card Authorization (1 page)

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FAX COVER SHEET

To: 5712738300

From: Michelle McClain <mmcclain@devlinlawfirm.com>

Company:

Date: 12/07/2022 17:13

Fax Number: 5712738300

Pages (including cover): 5

Re: Petition for Review by Office of Petitions

Notes:

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Michelle McClain
1526 Gilpin Ave, Wilmington, DE 19806
(302) 449-9468

DEVLIN LAW FIRM LLC
INTELLECTUAL PROPERTY LAW