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.

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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.

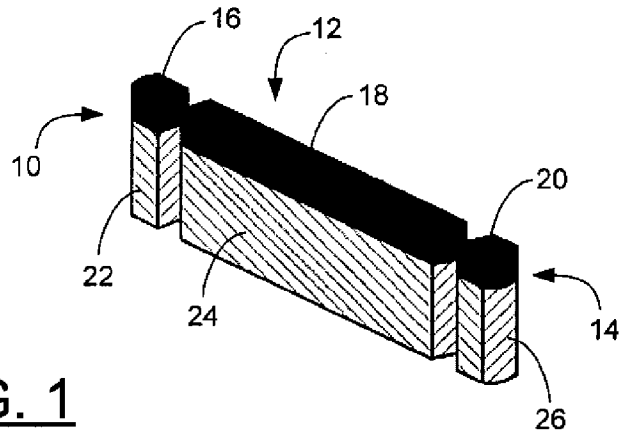


FIG. 1

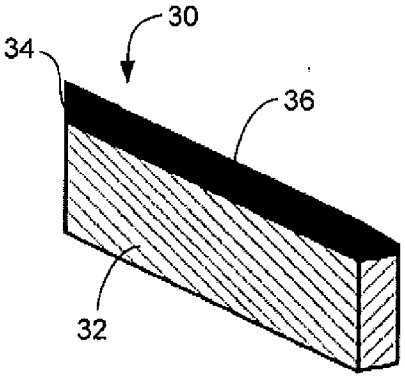


FIG. 2

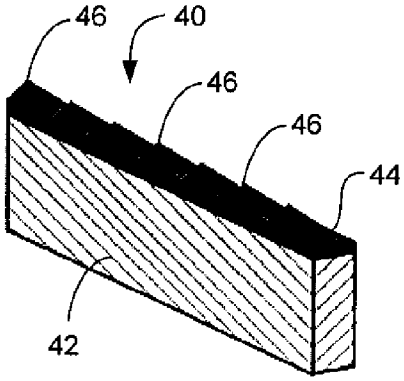


FIG. 3

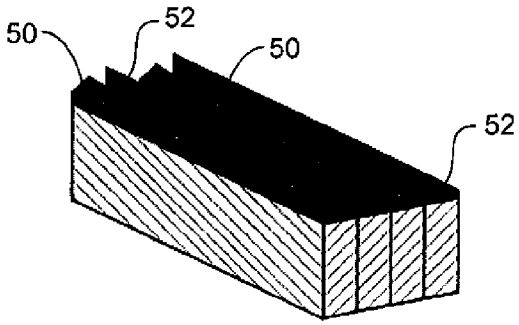


FIG. 4

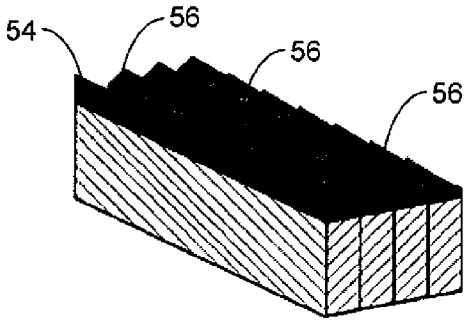


FIG. 5

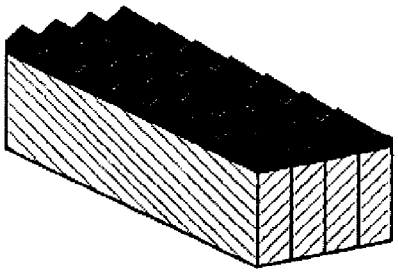


FIG. 6

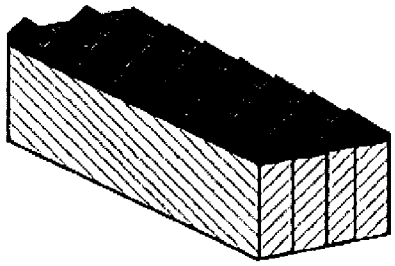


FIG. 7

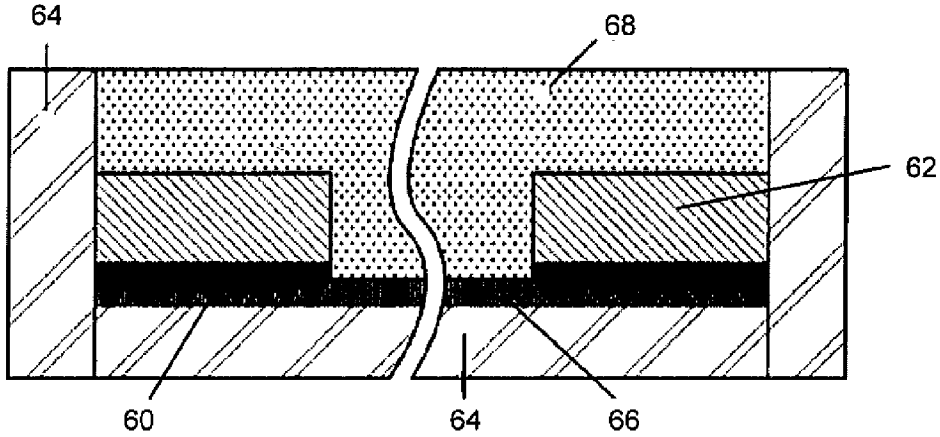


FIG. 8

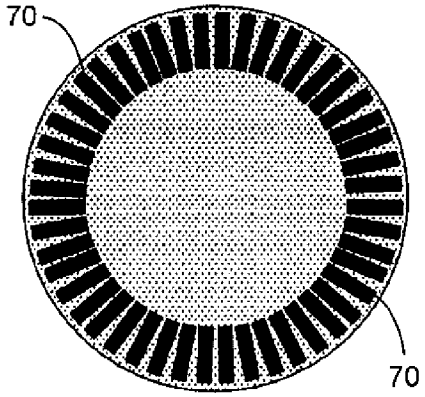


FIG. 9

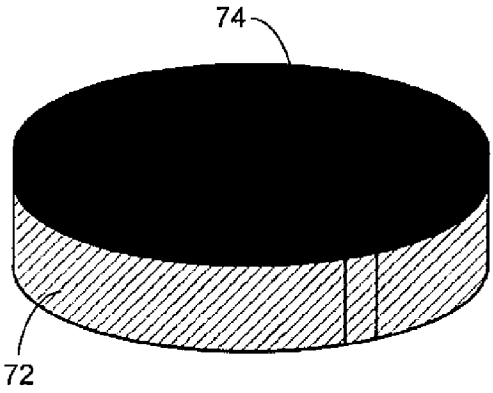


FIG. 10

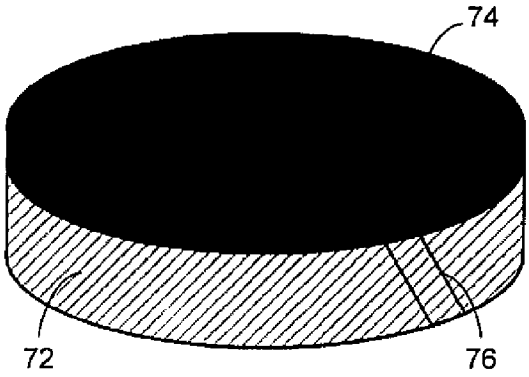


FIG. 11

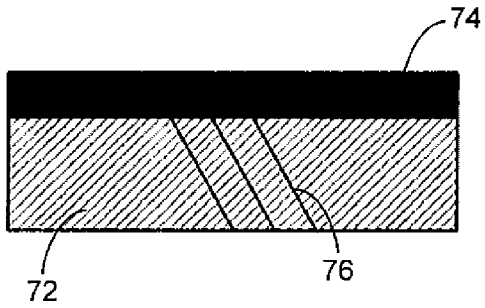


FIG. 12

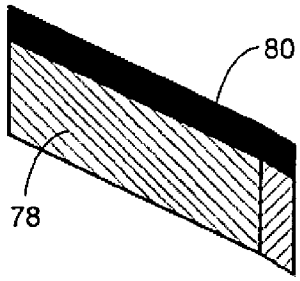


FIG. 13

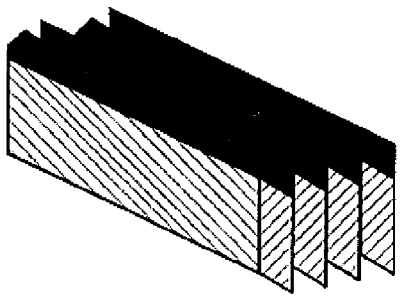


FIG. 14

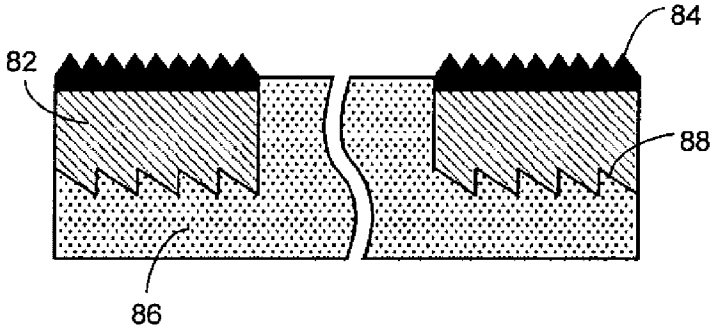


FIG. 15

FIG. 16

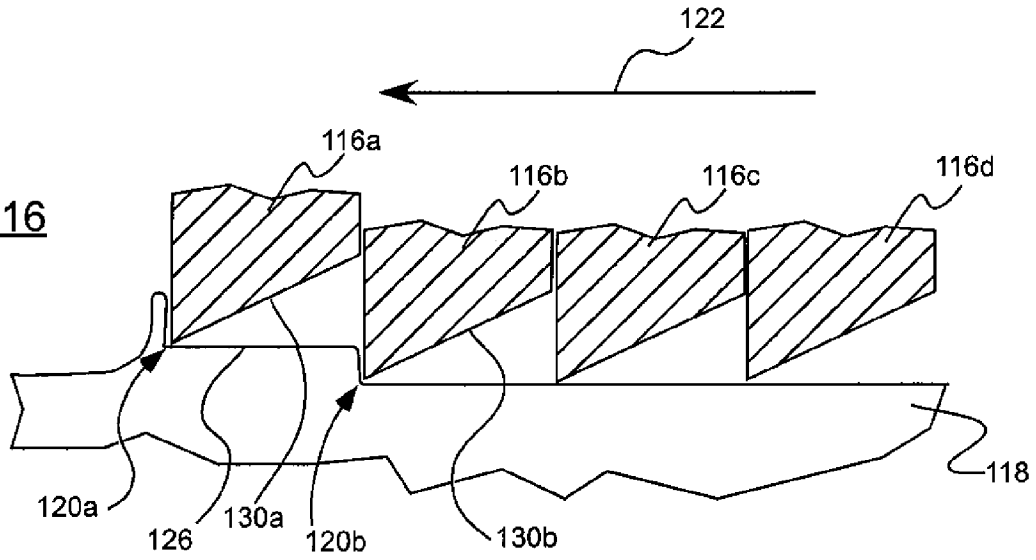


FIG. 17

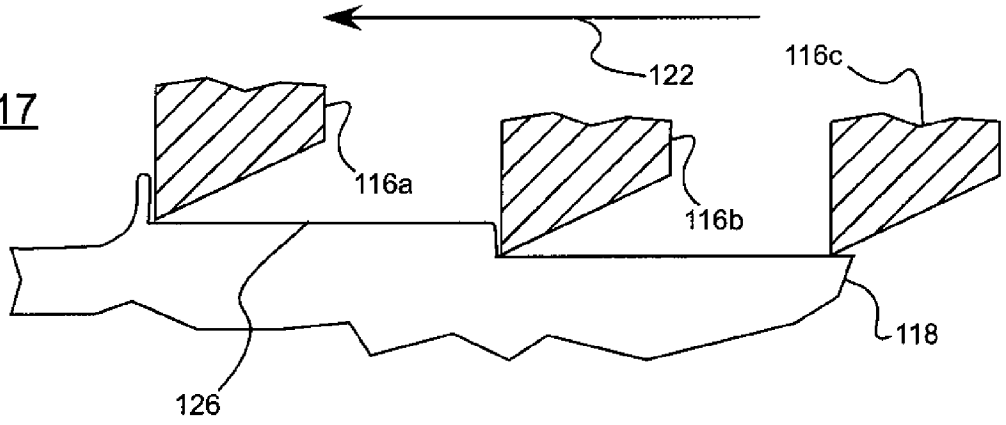
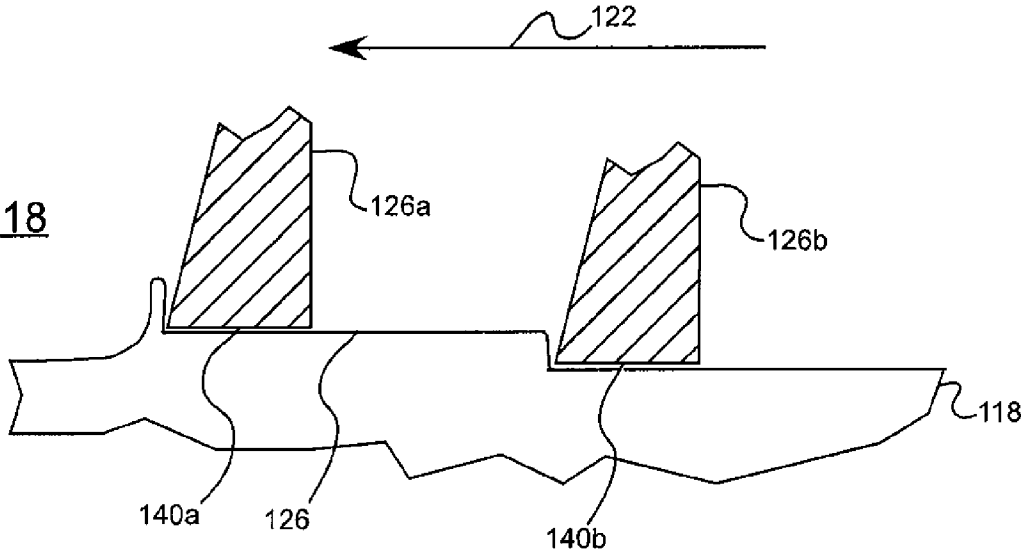


FIG. 18



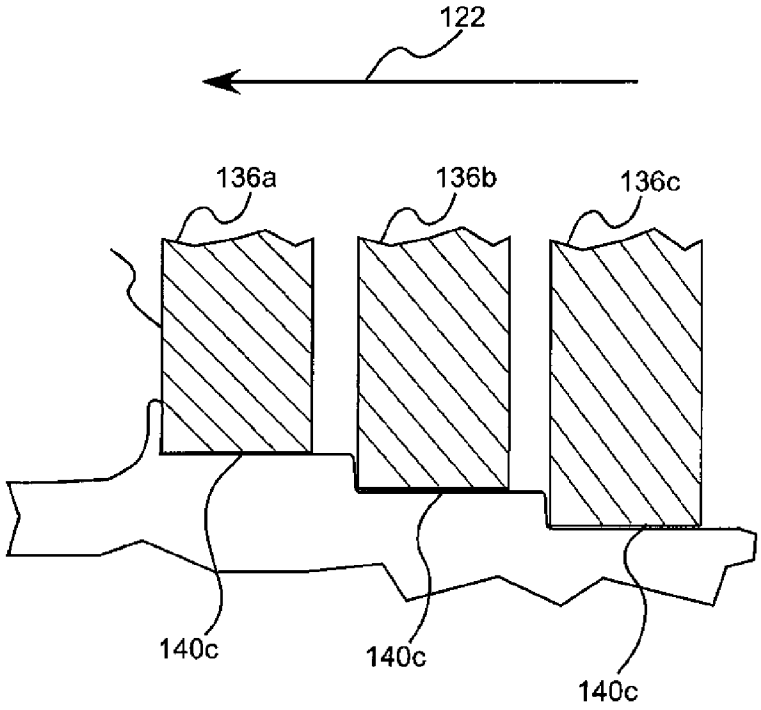


FIG. 19

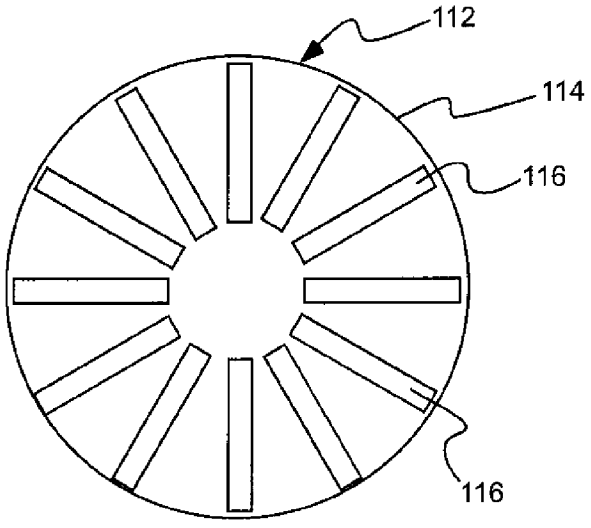


FIG. 20

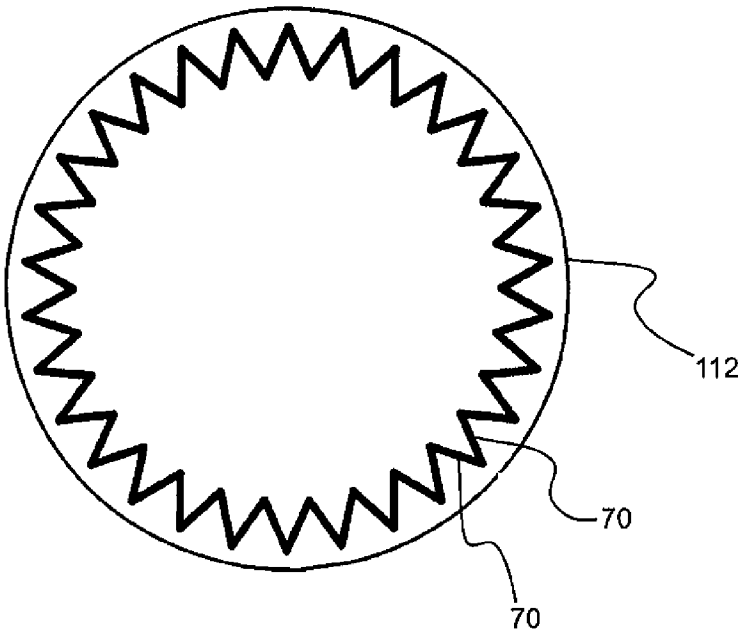


FIG. 21

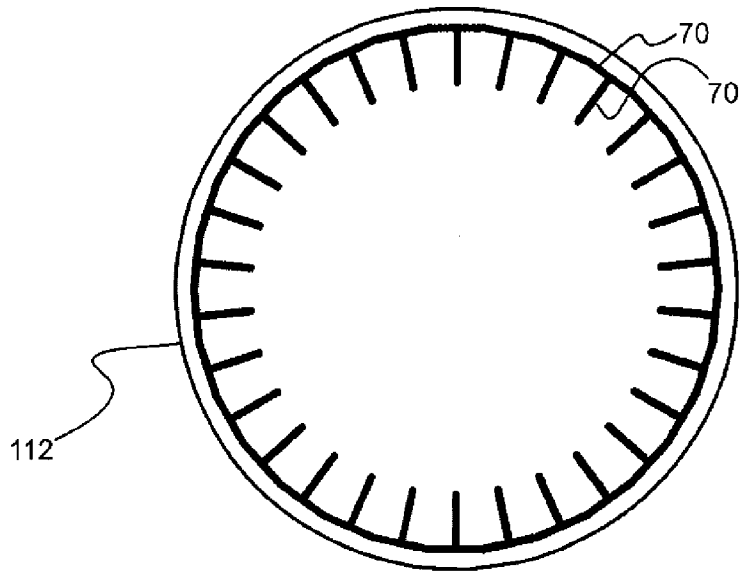


FIG. 22

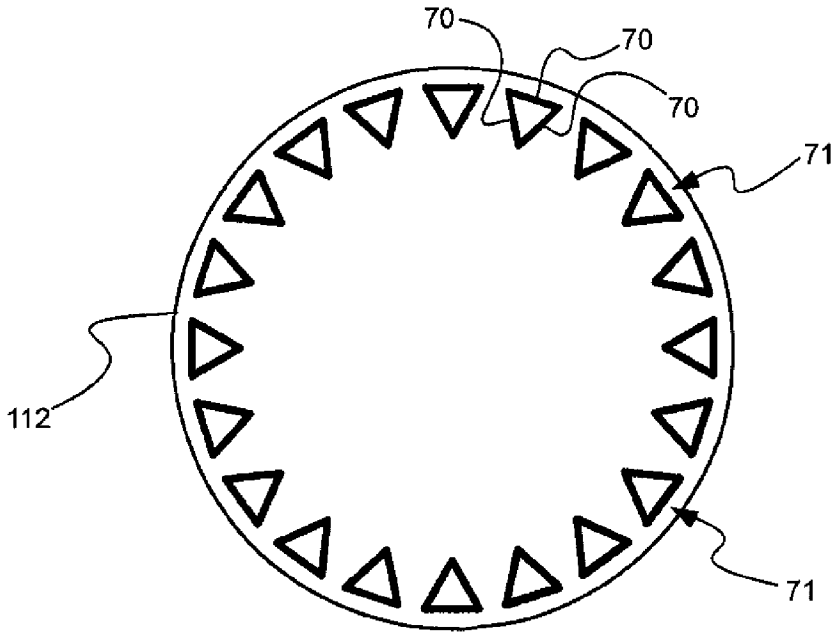


FIG. 23

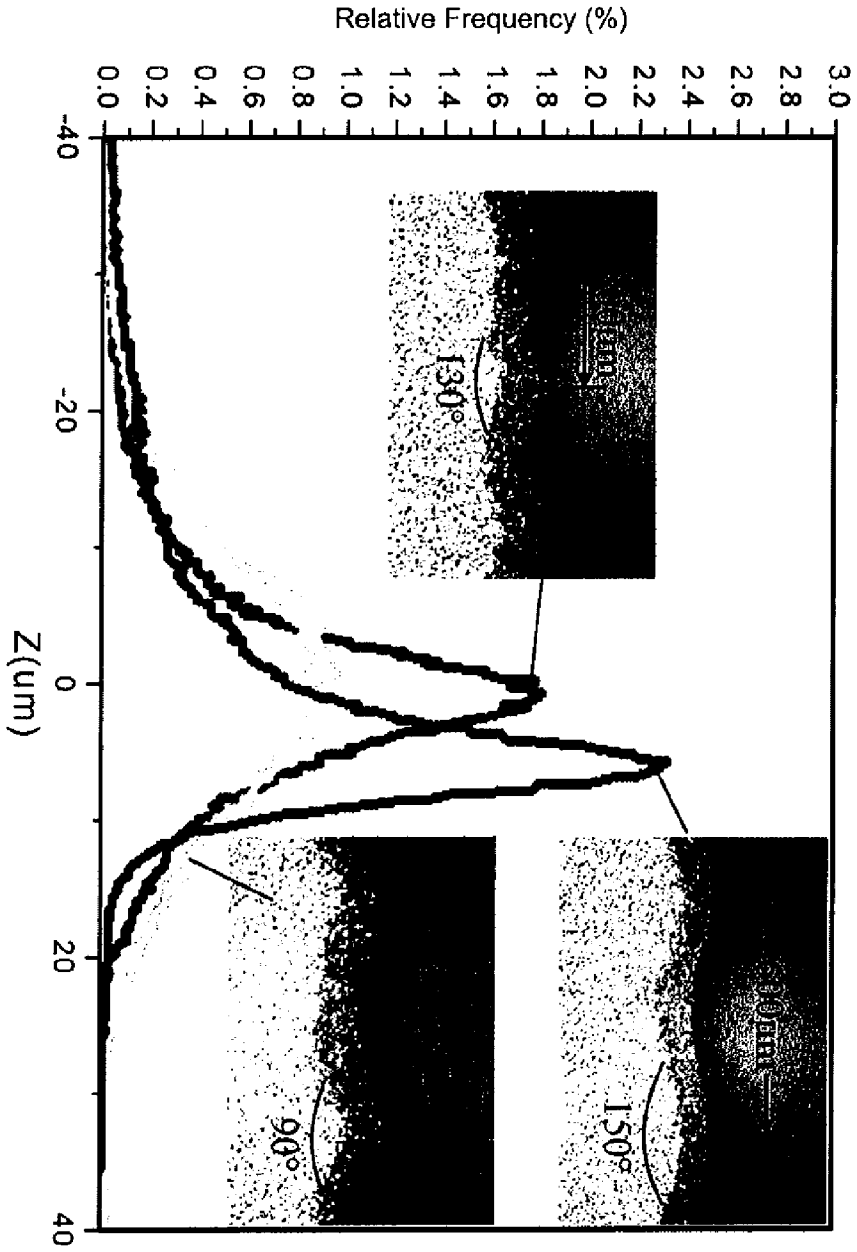

Relative Frequency (%)
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
-40
-20
0
20
40
Z(um)
130°
90°
150°

FIG. 24

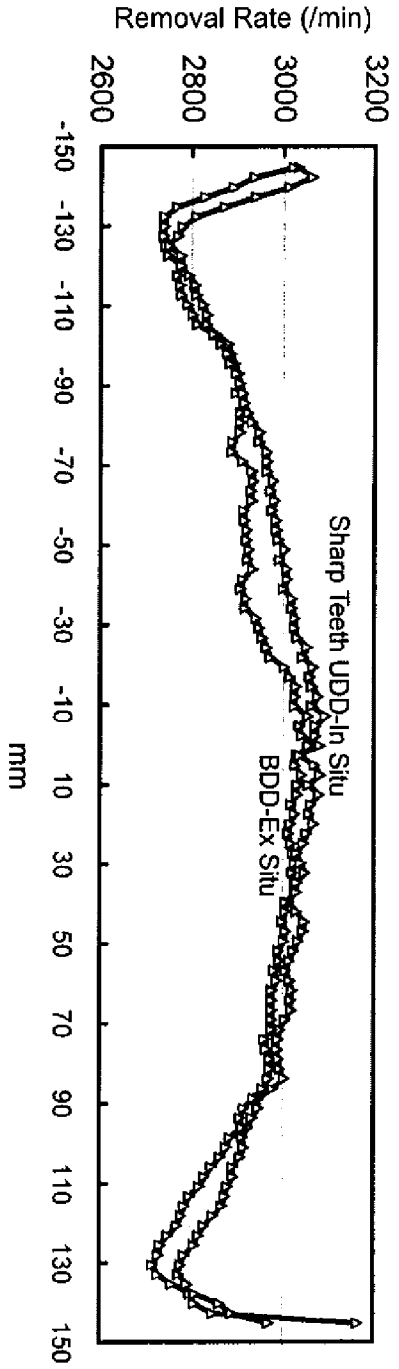

Removal Rate (/min)
2600
2800
3000
3200
-150
-130
-110
-90
-70
-50
-30
-10
10
30
50
70
90
110
130
150
mm
Sharp Teeth UDD-In Situ
BDD-Ex Situ

FIG. 25

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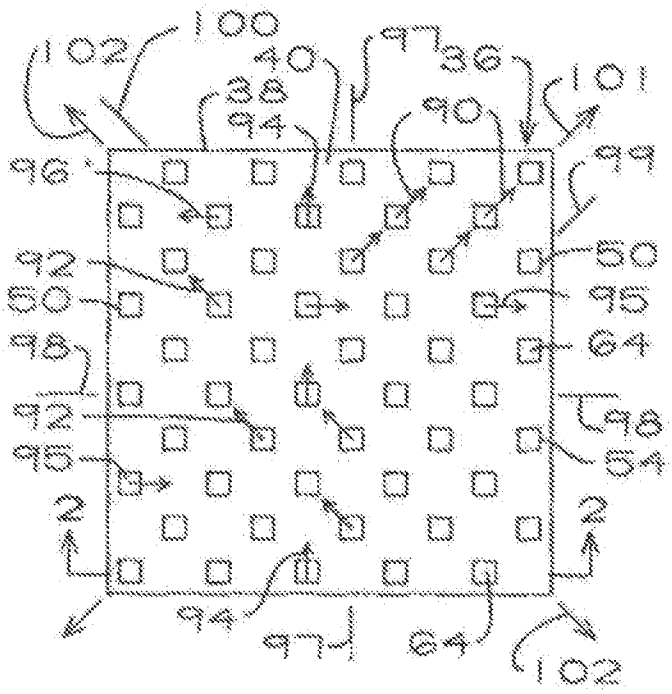
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(54) Title: ORIENTED CRYSTAL ASSEMBLIES

(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, 39, 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. 33 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 templates 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. 33), 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 substantially 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 stability 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 1,6,7,20 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.

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.

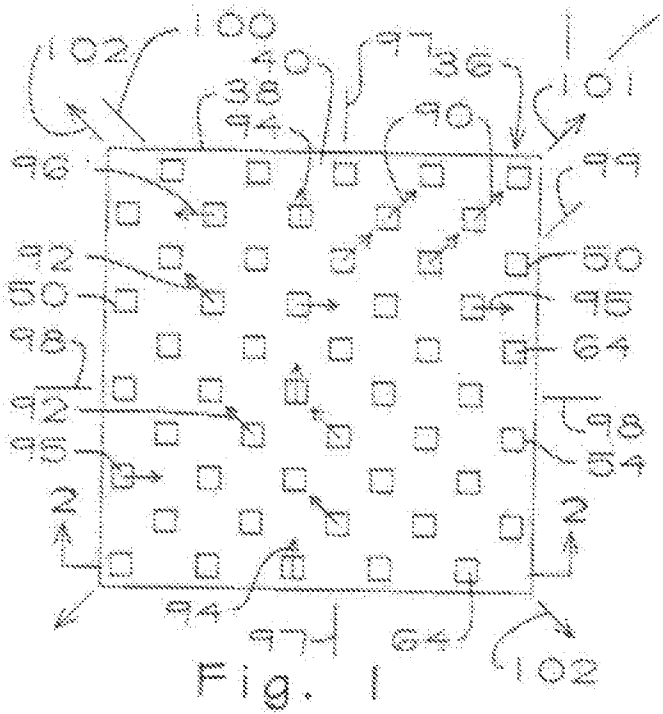


Fig. 1

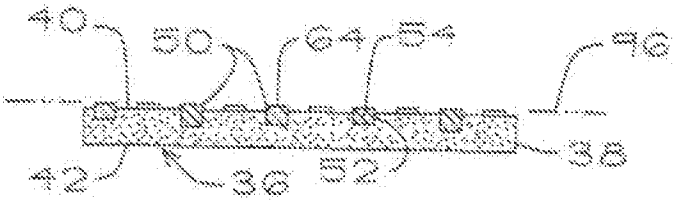


Fig. 2

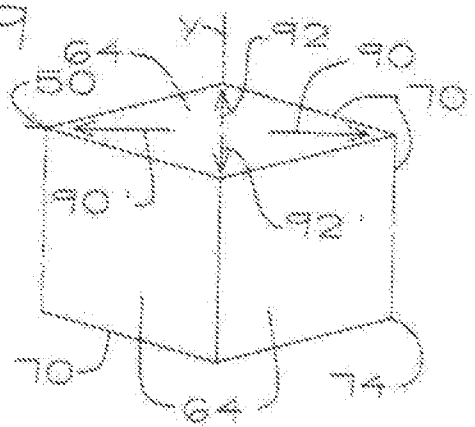


Fig. 3
PRIOR ART

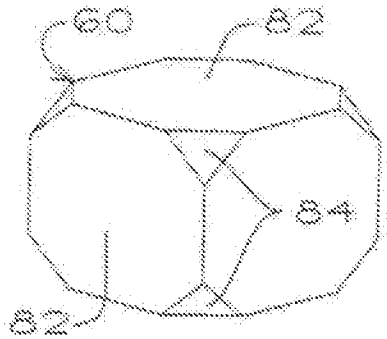


Fig. 4
PRIOR ART

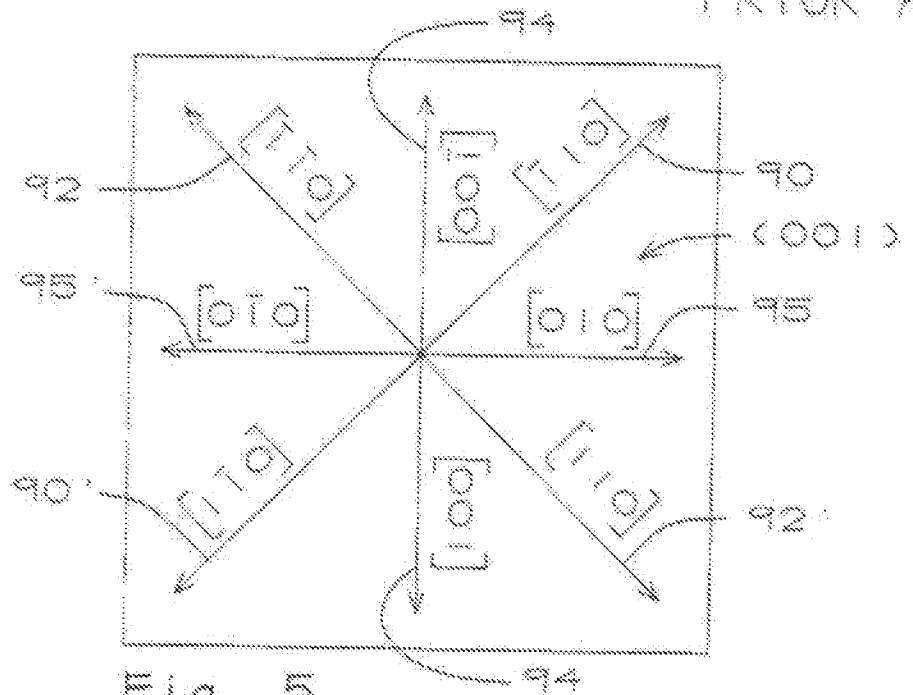


Fig. 5
PRIOR ART

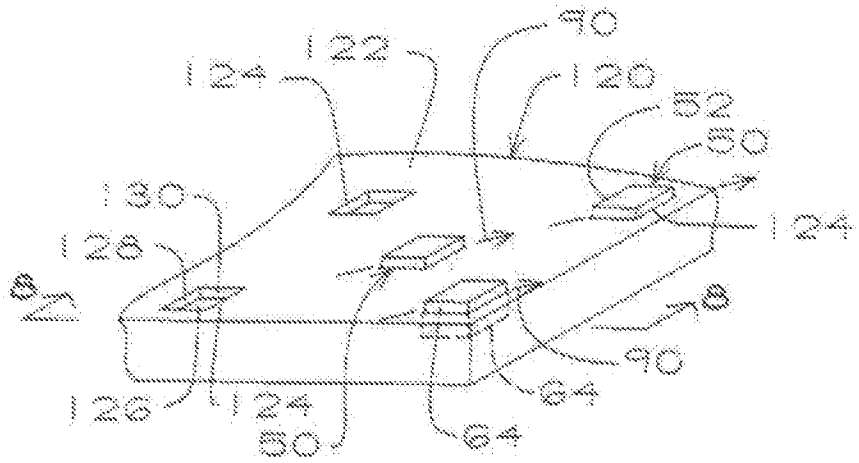


Fig. 6

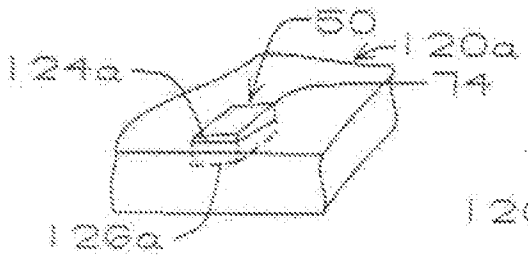


Fig. 7

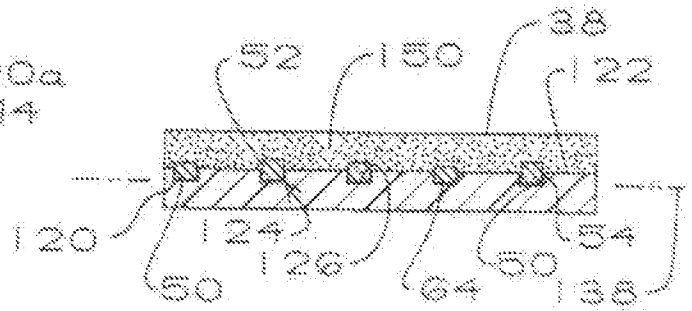


Fig. 8

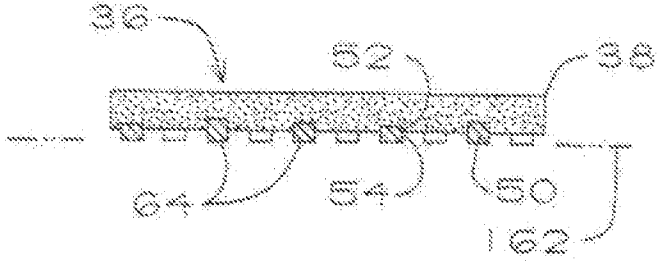


Fig. 9

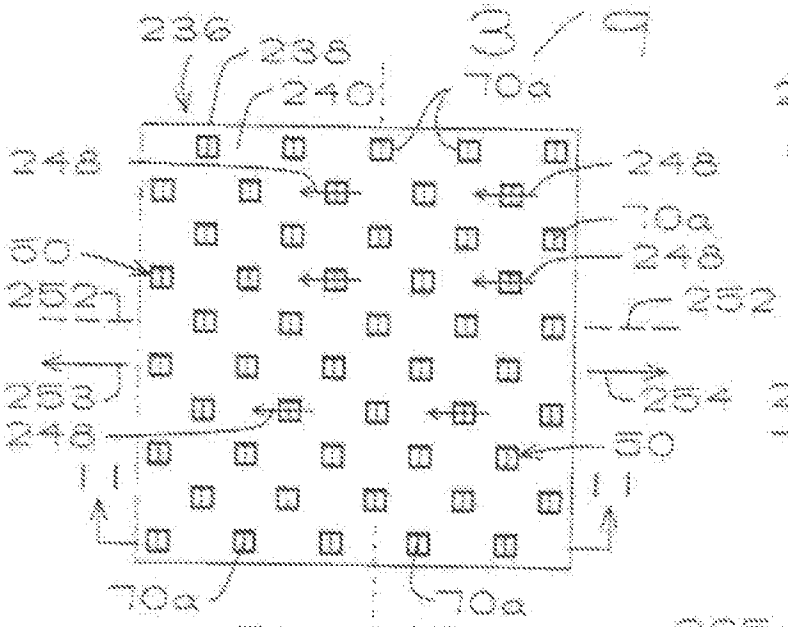


Fig. 10

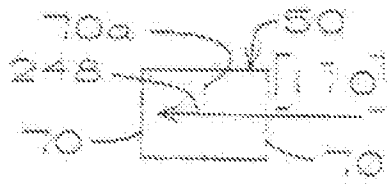


Fig. 12



Fig. 13

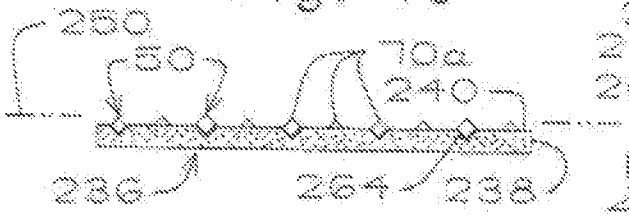


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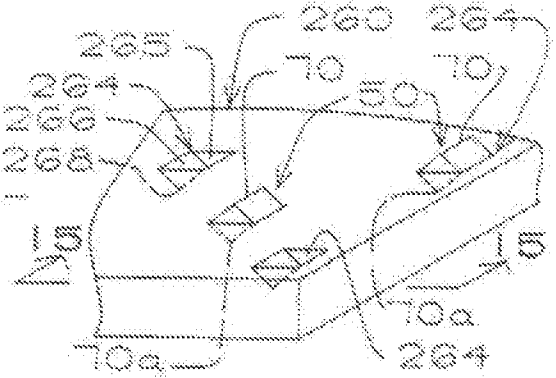


Fig. 14

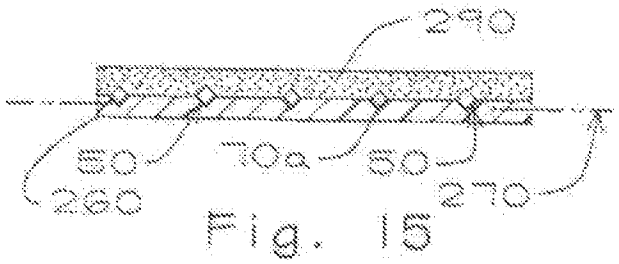


Fig. 15

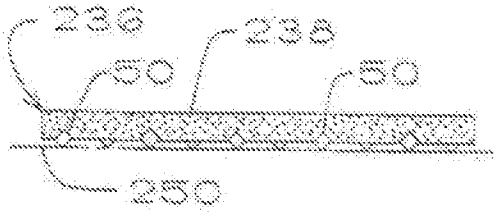


Fig. 16

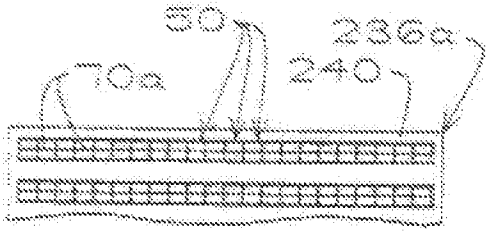


Fig. 17

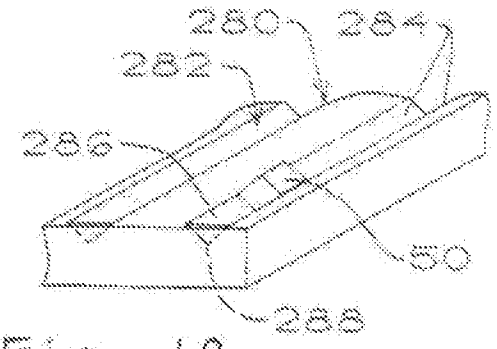


Fig. 18

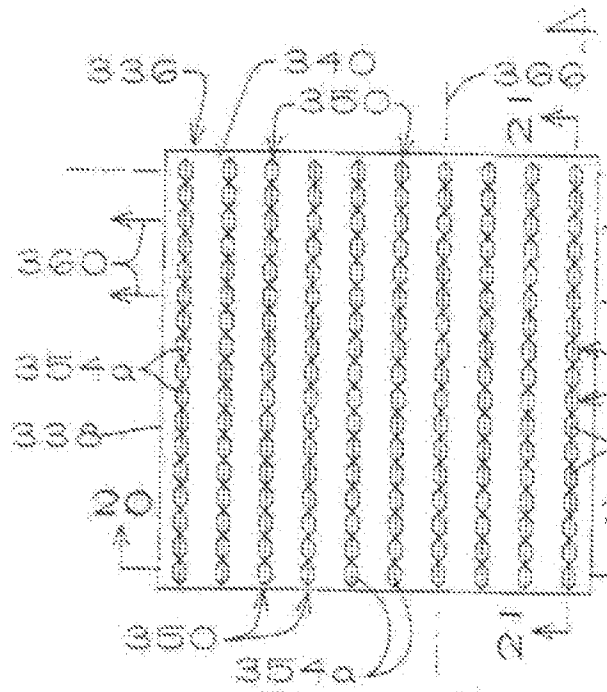


Fig. 19

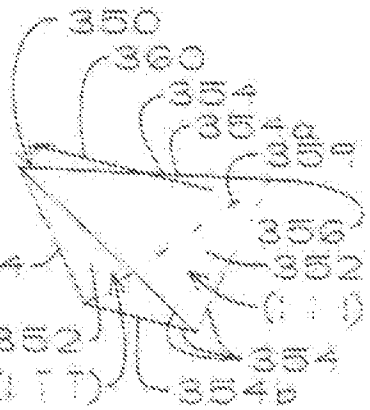


Fig. 22

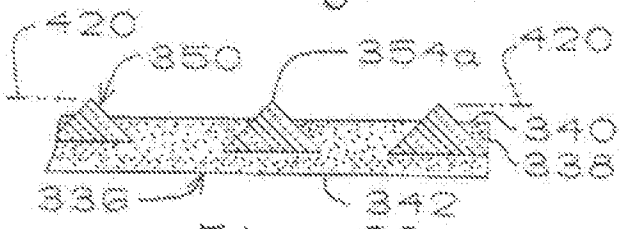


Fig. 20

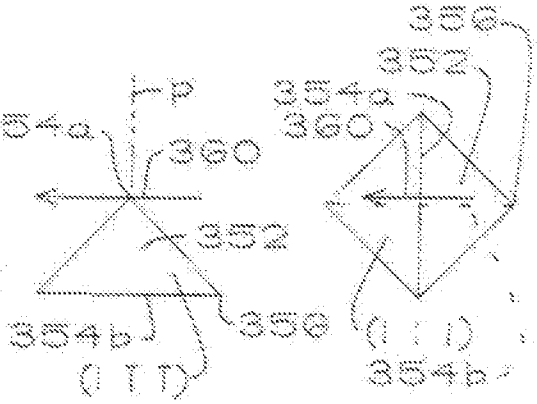


Fig. 23 Fig. 24

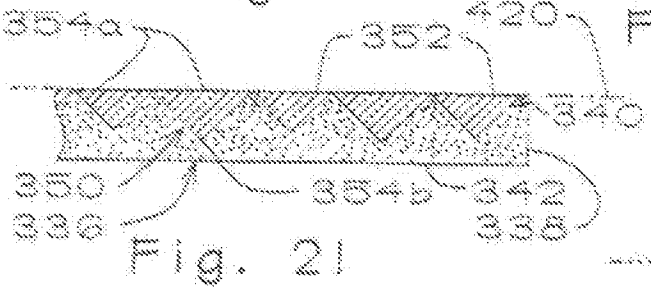


Fig. 21

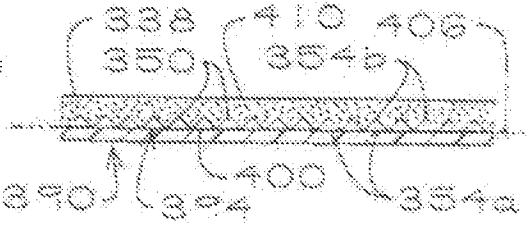


Fig. 26

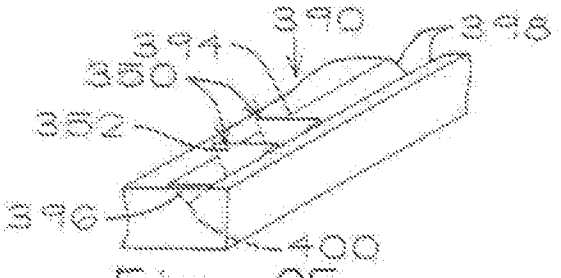


Fig. 25

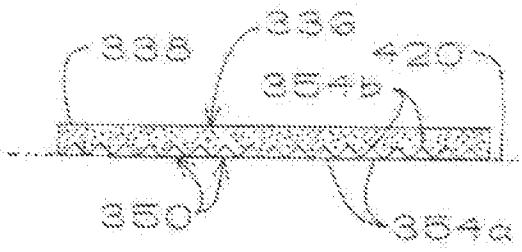


Fig. 27

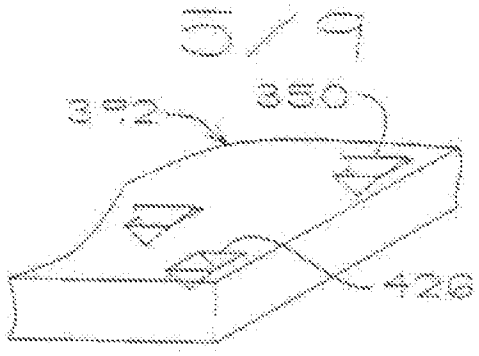


Fig. 28

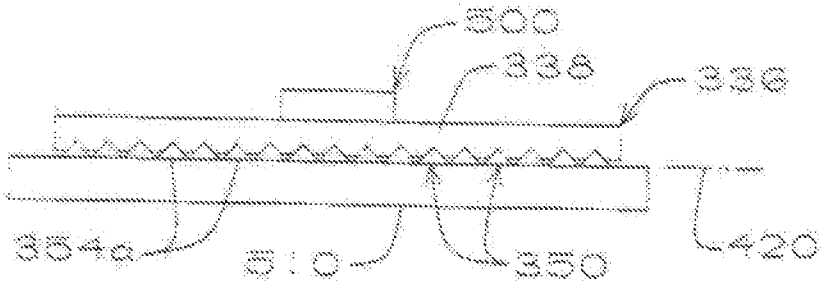


Fig. 29

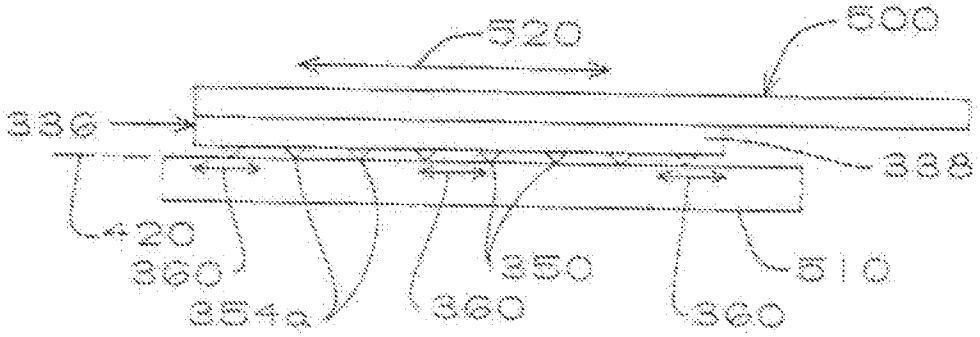


Fig. 30

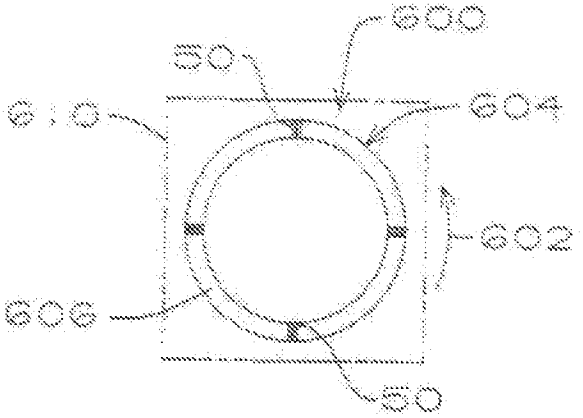


Fig. 31

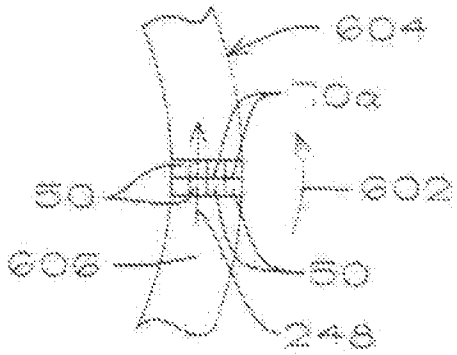


Fig. 32

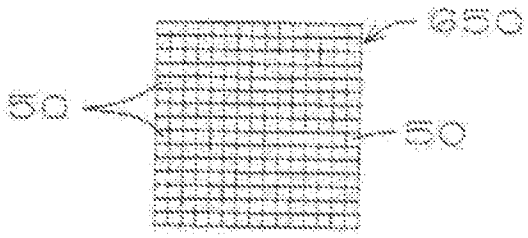


Fig. 33



Fig. 34

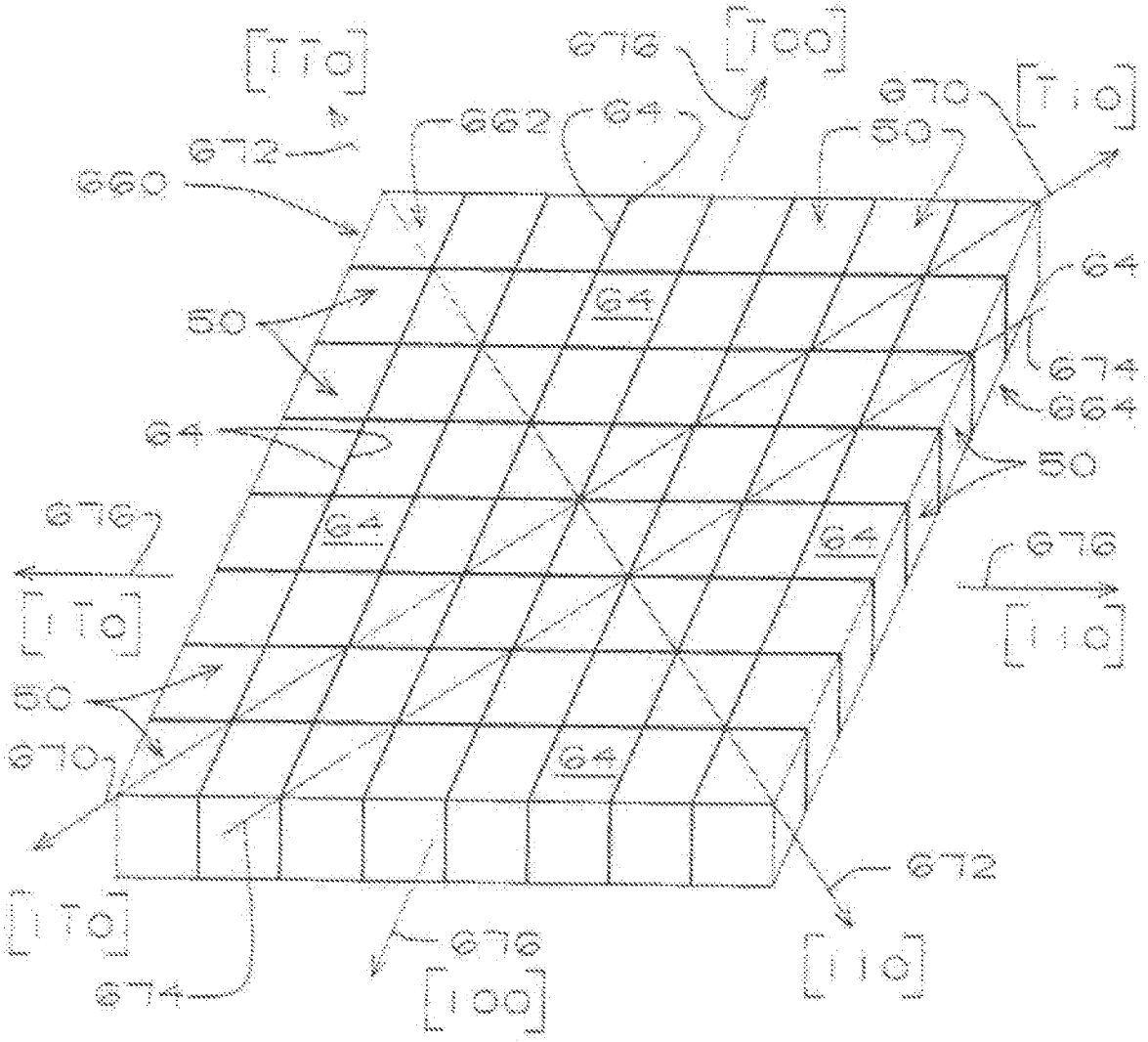


Fig. 35

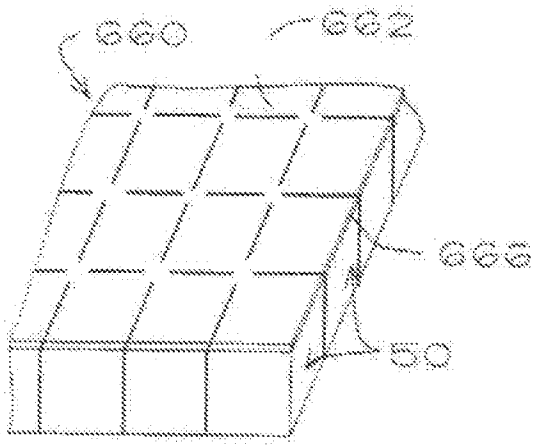


Fig. 36

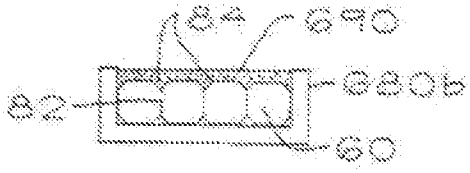


Fig 38a

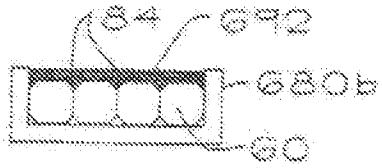


Fig 38b

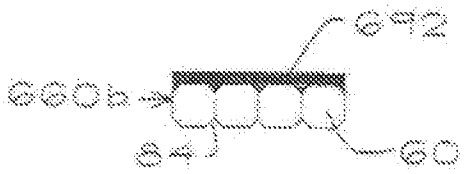


Fig 38c

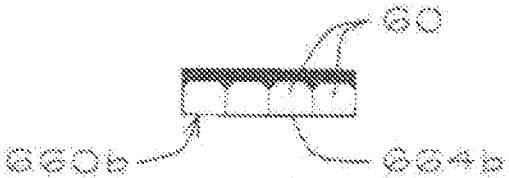


Fig 38d

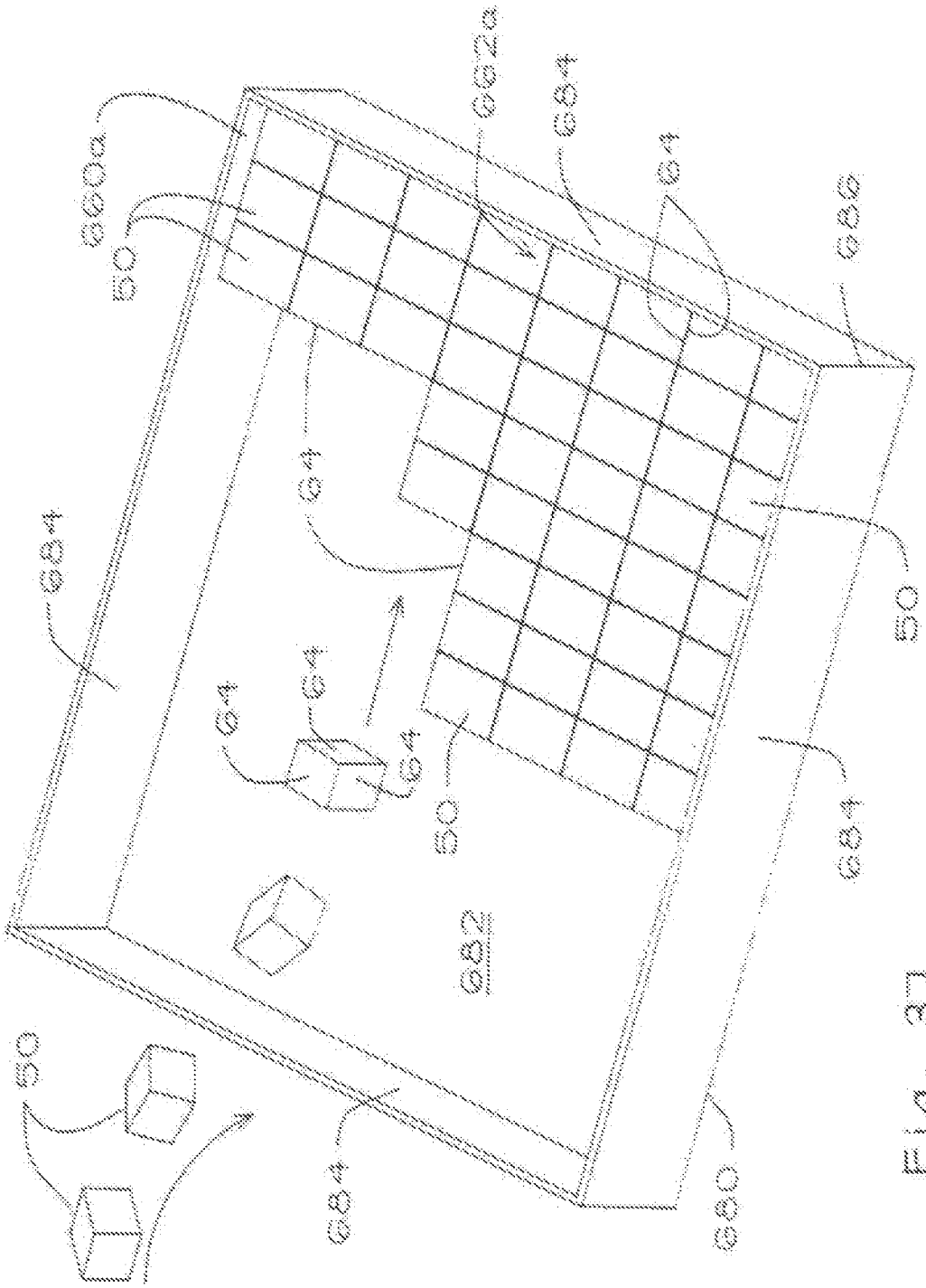


Fig. 8J

9/9

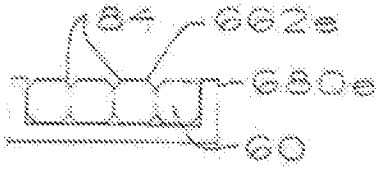


Fig 39a

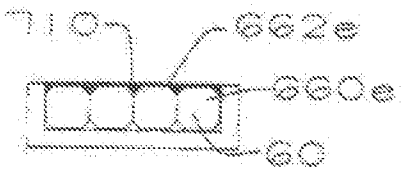


Fig 39b

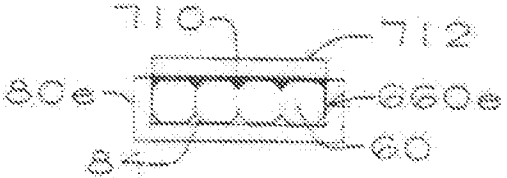


Fig 39c

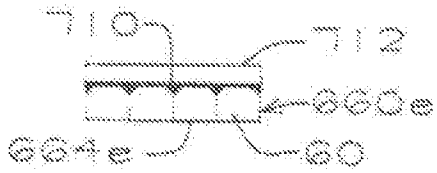


Fig 39d

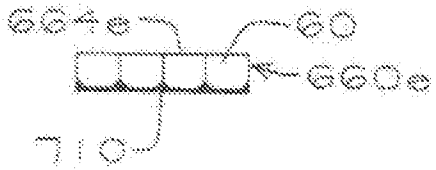


Fig 39e

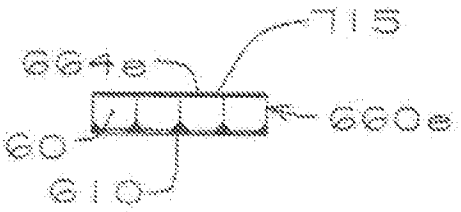


Fig 39f

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US93/10195

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.

* Special categories of cited documents:

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/10185

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

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SUPERHARD CUTTERS AND ASSOCIATED METHODS

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Abstract of WO2006124792

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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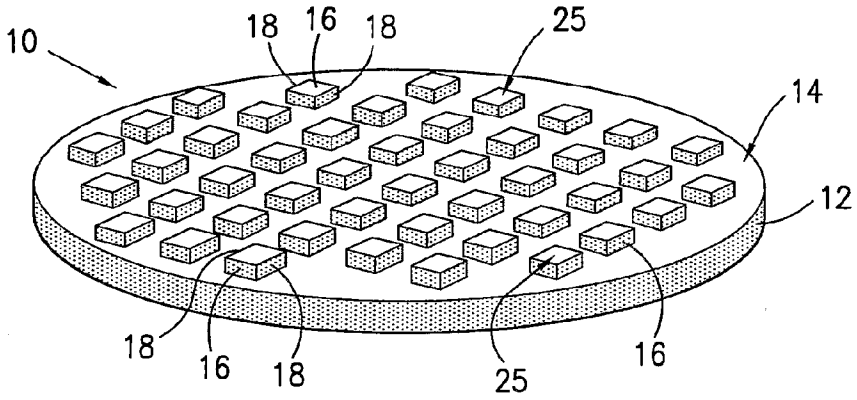
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(57) Abstract: A cutting device (10) comprises a base (12) having a working side (14) that is oriented to face a workpiece (19) from which material is to be removed. A plurality of individual cutting elements (16) are arranged on the working side of 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.

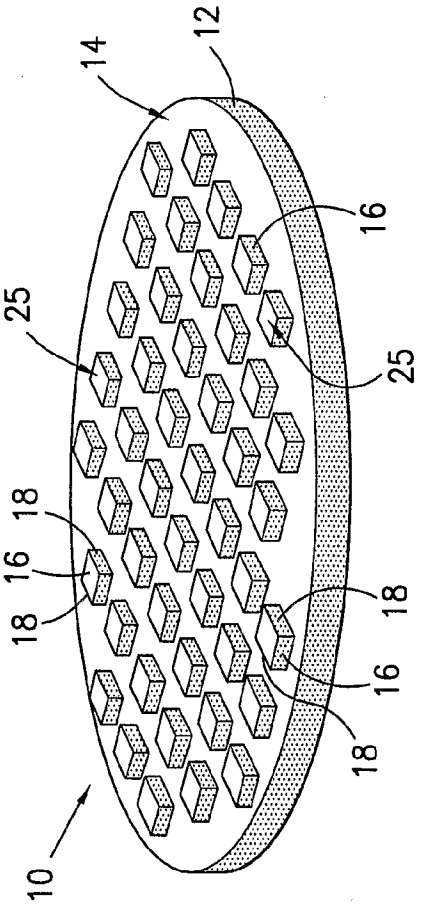


FIG. 1

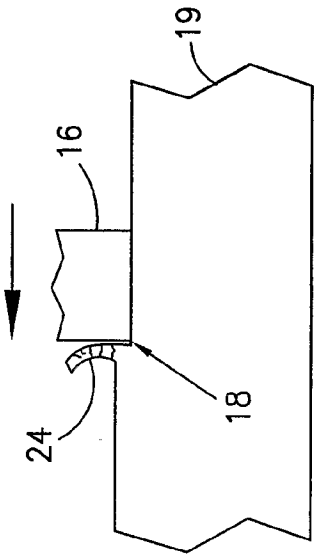


FIG. 3

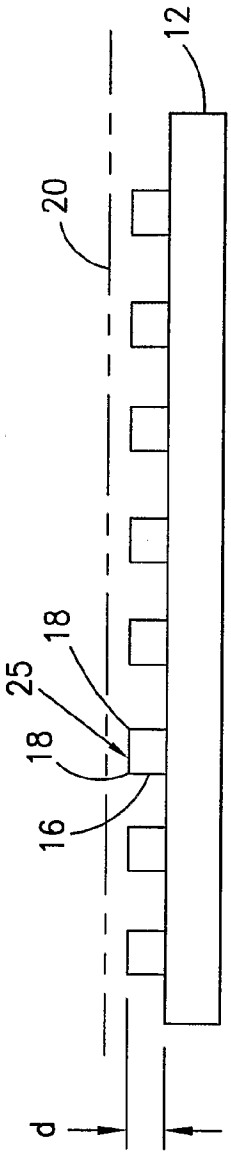


FIG. 2

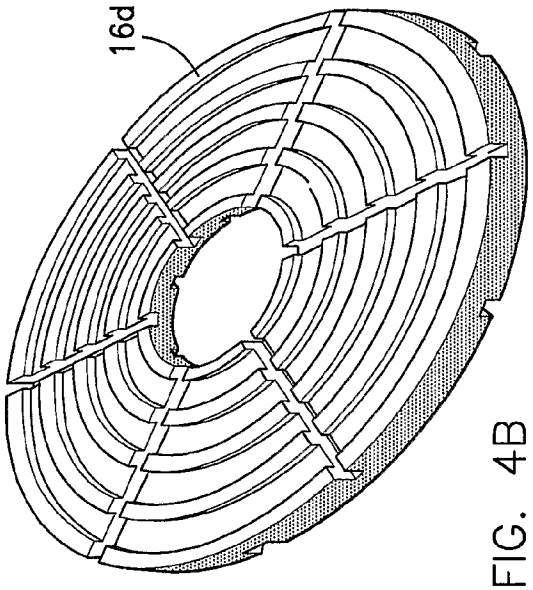


FIG. 4B

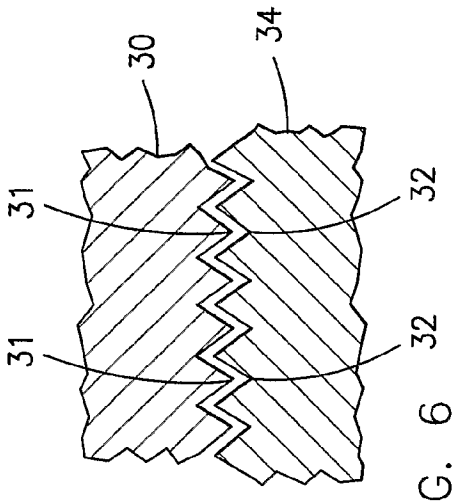


FIG. 6

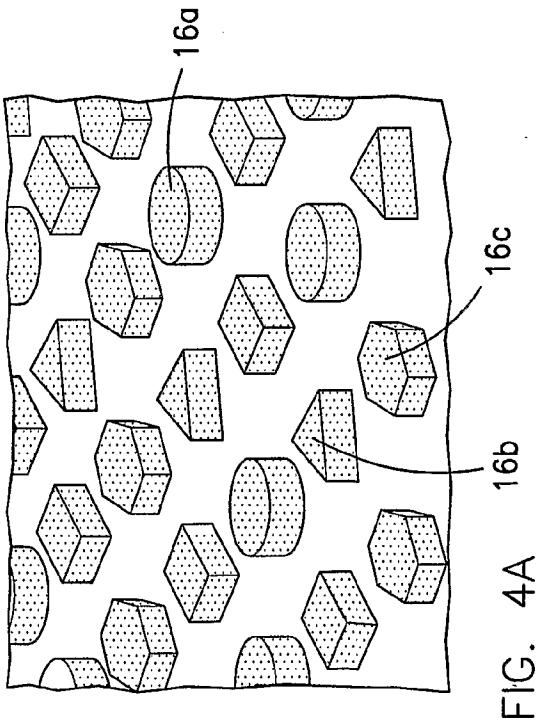


FIG. 4A

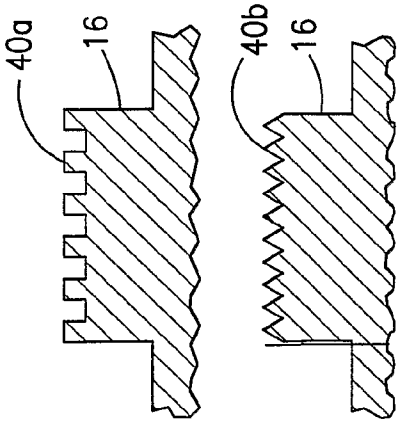


FIG. 5

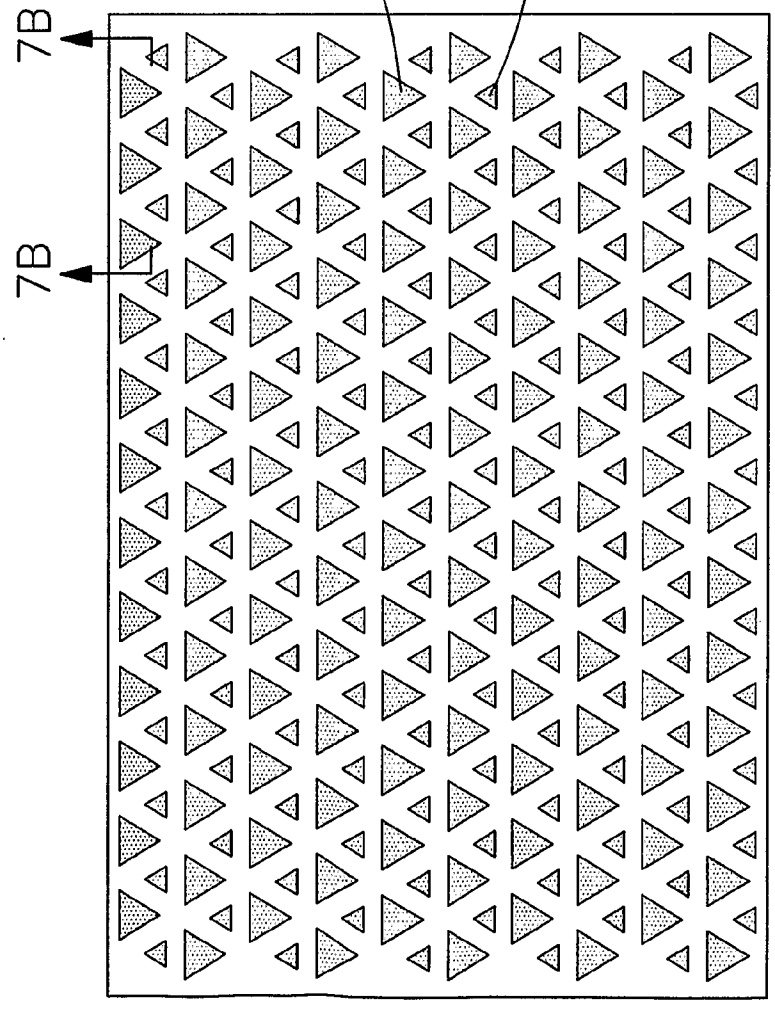


FIG. 7A

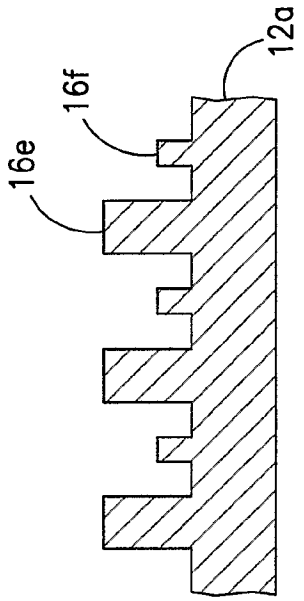


FIG. 7B

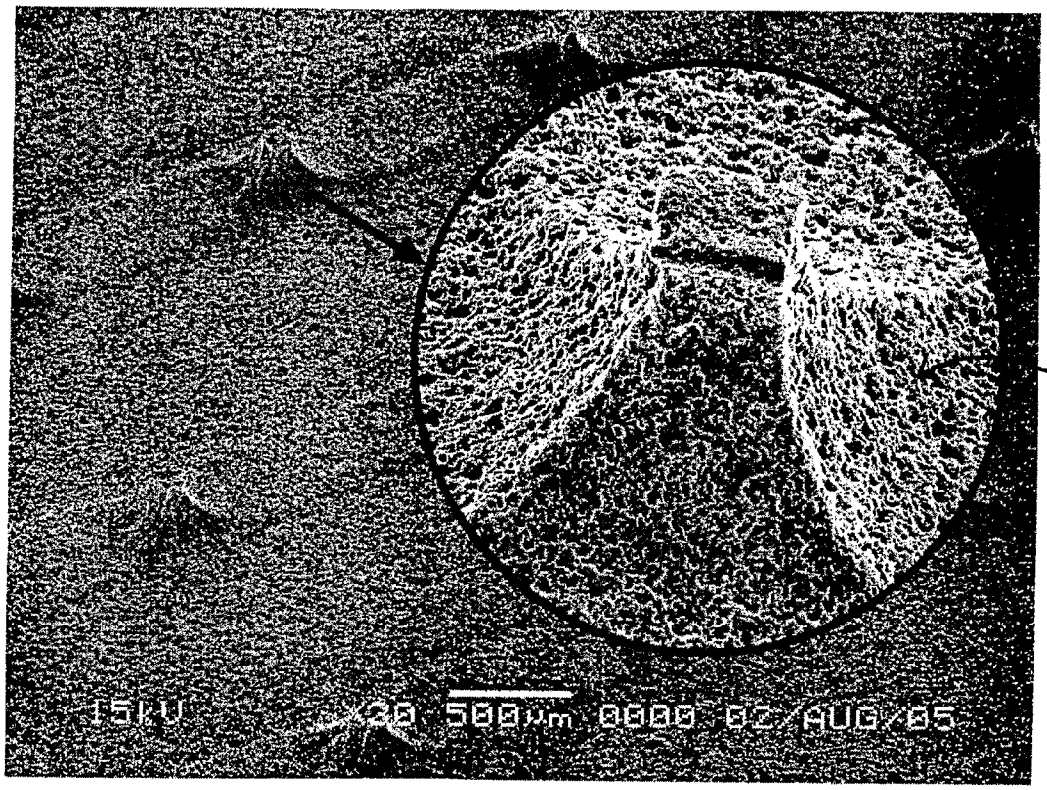


FIG. 8

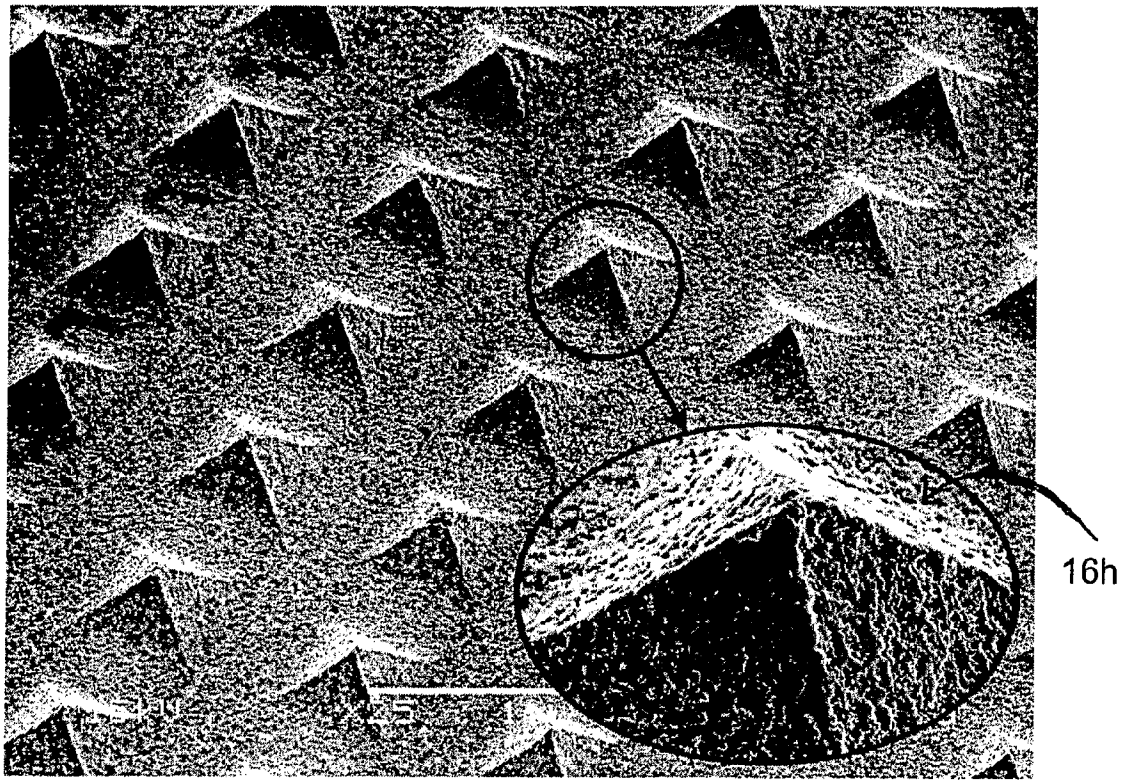


FIG. 9

Espacenet

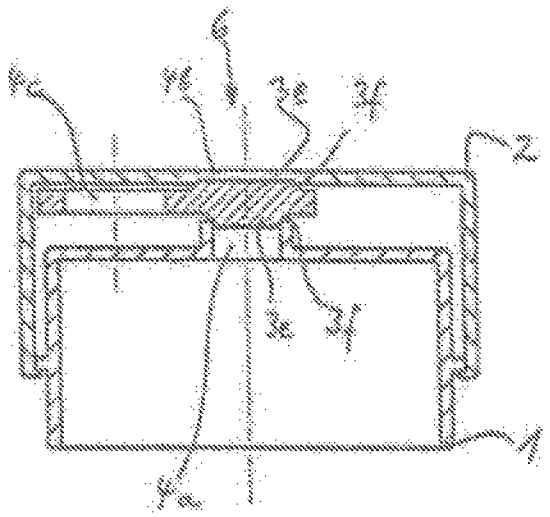
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CLOSURE

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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.



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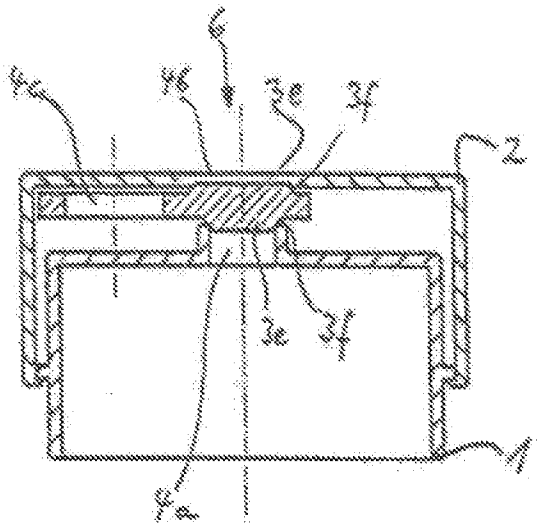
(54) Bezeichnung: VERSCHLUSS

(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.



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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 Obertail 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 vobei der membranartig ausgebildete Grundkörper 1 und die Drehkappe 2 auseinandergebogen, so daß sie durch Vorspannung fest auf das Mittelstück 3 drücken und diesen 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-385 380 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 verschieben, 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 6 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 c 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 Obertails 2 erreicht, die beispielsweise bei einem vorhandenen Spiel, Stößen oder Verbiegungen des Obertails 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 den 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 Rastetellen 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 Anschluß 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 Aufpralleystem 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 Obenseite 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 verspannbar 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 Verspannung 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 verspannbar 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.

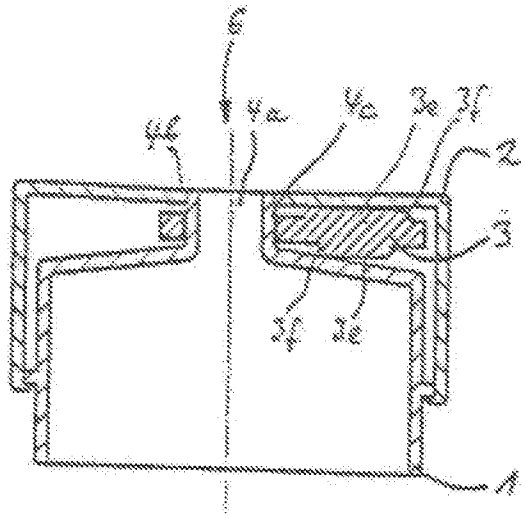


Fig. 1

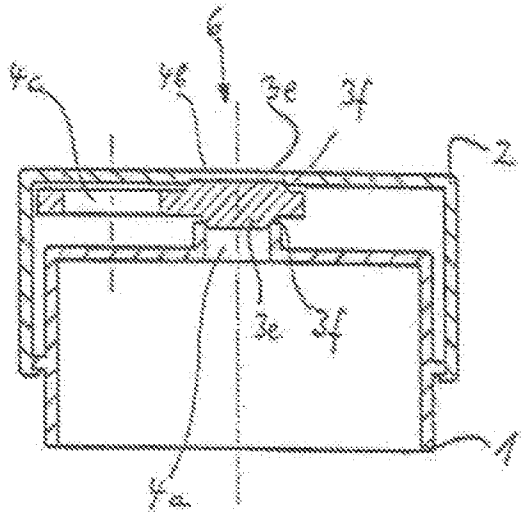


Fig. 2

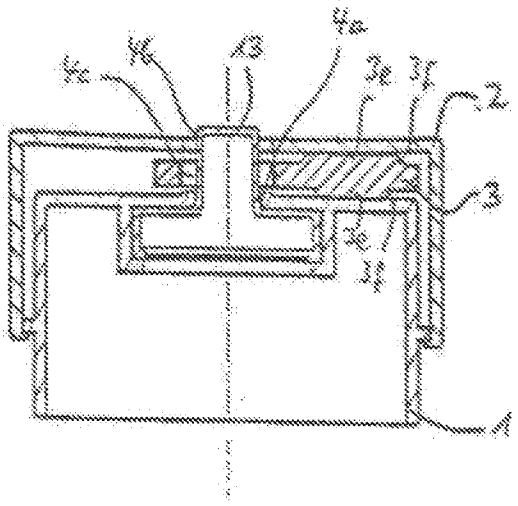


Fig. 3

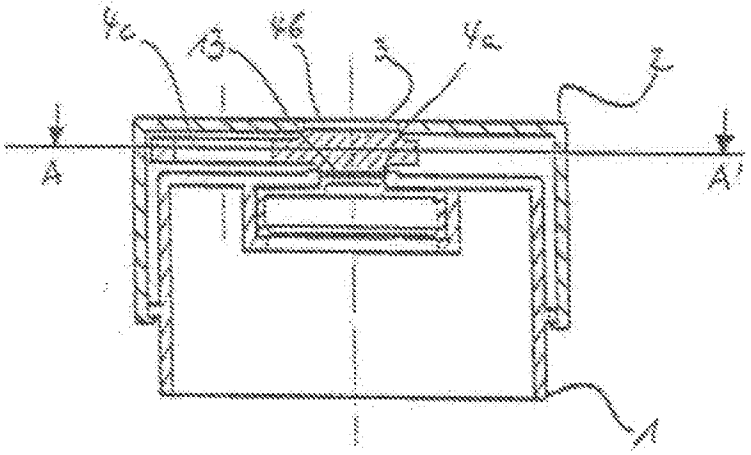


Fig. 4

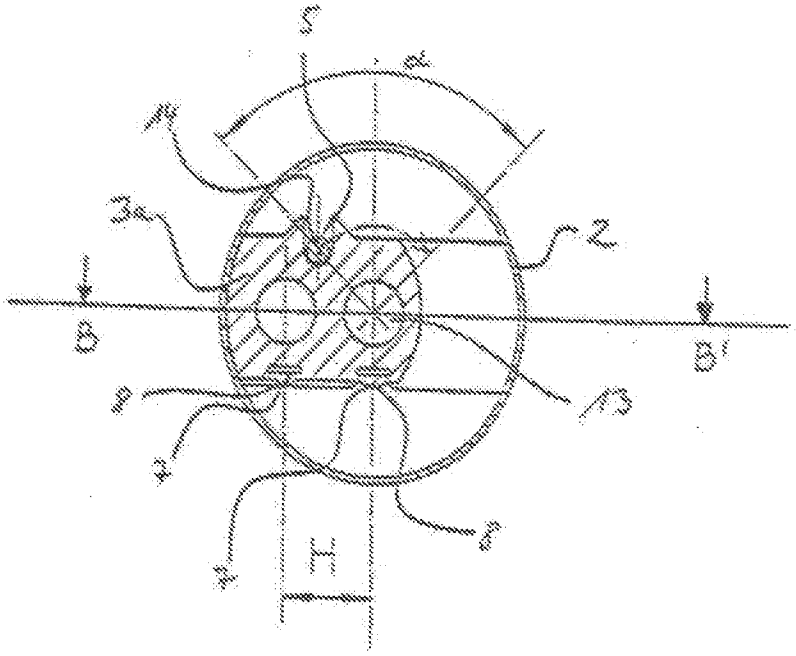


Fig. 5

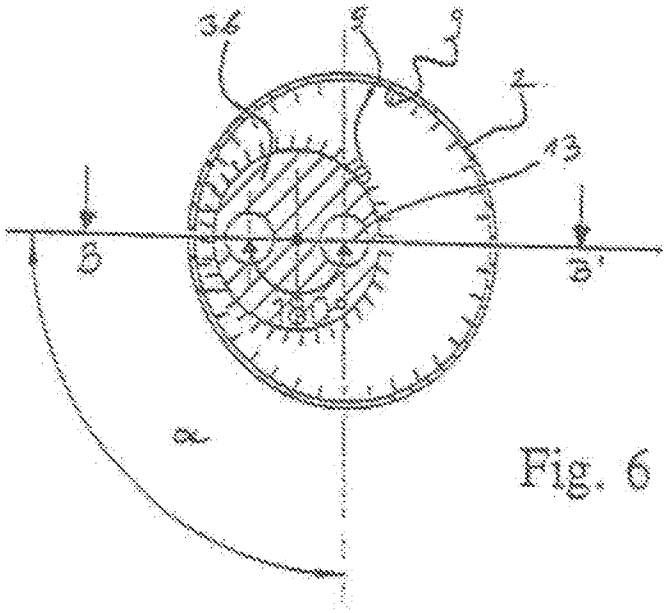


Fig. 6

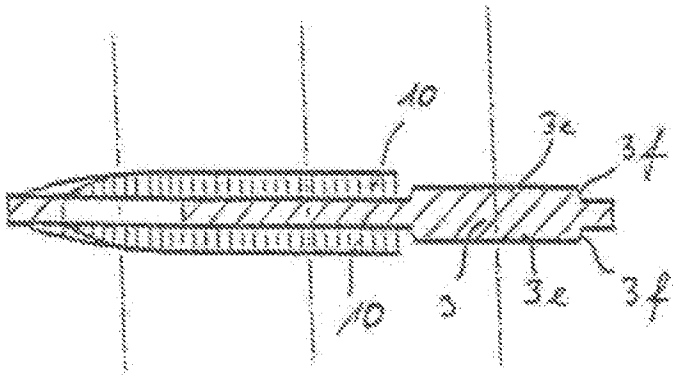


Fig. 7

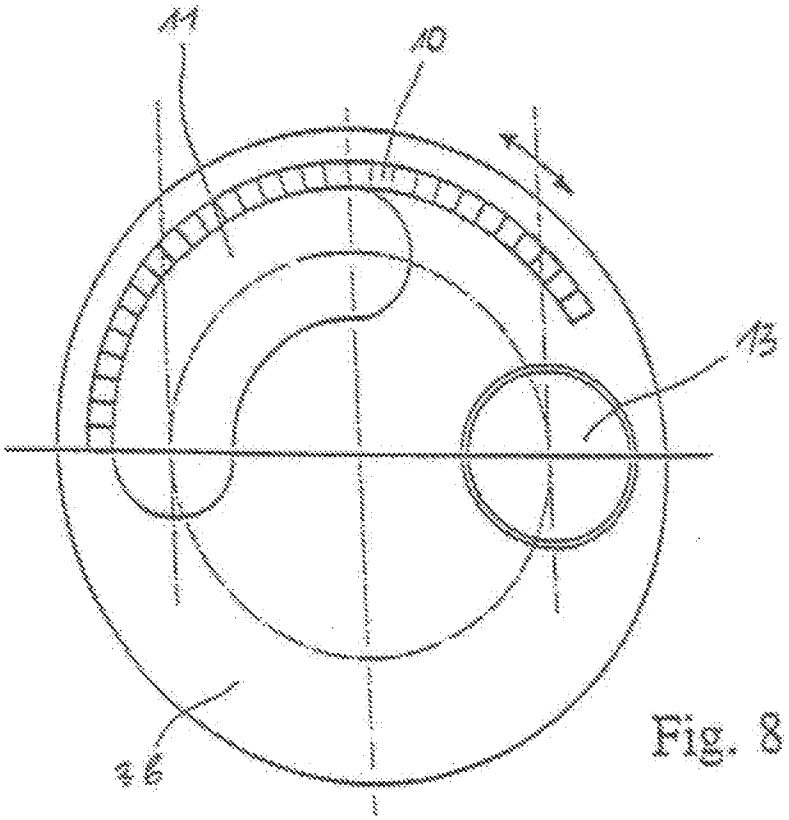


Fig. 8

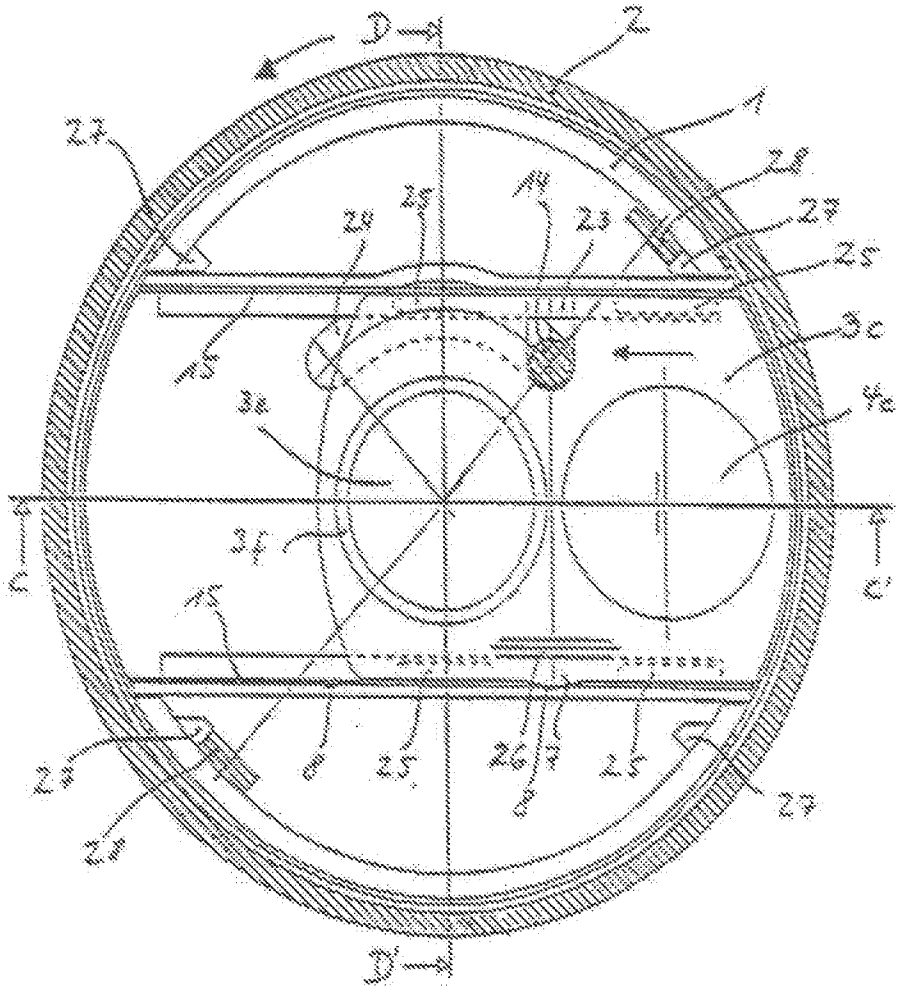


Fig. 9

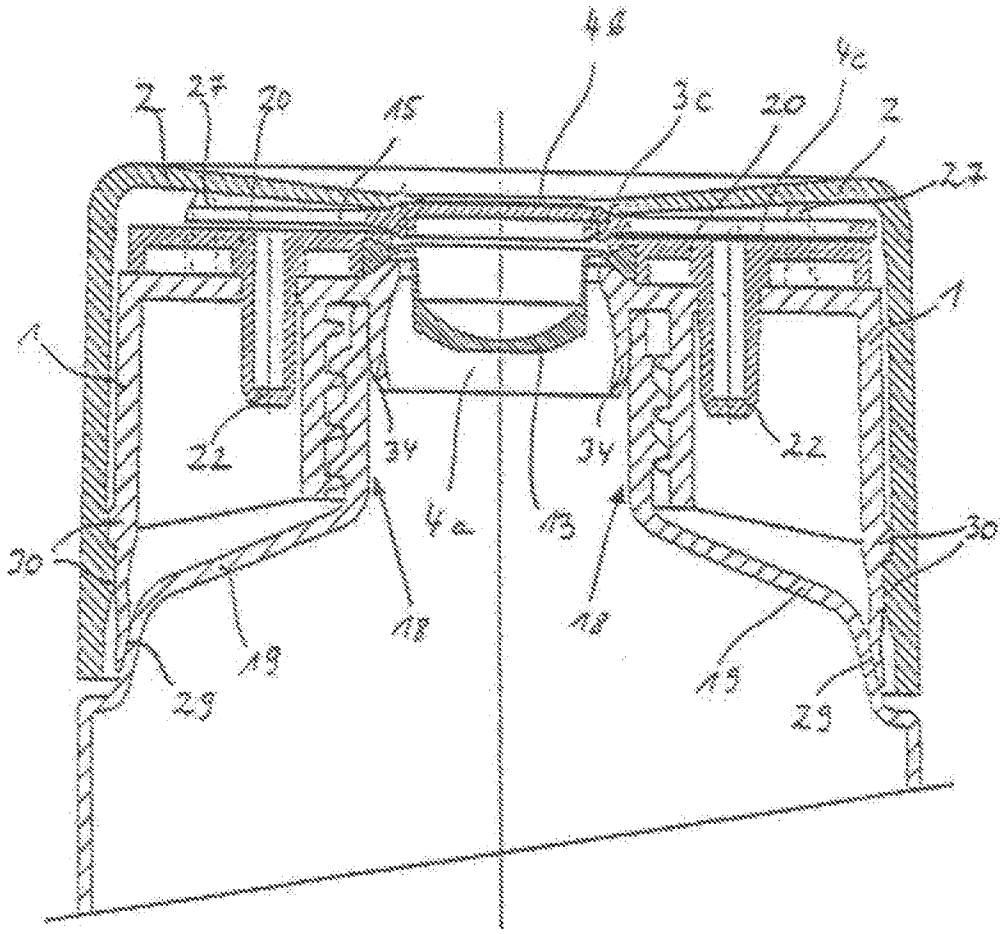


Fig. 10

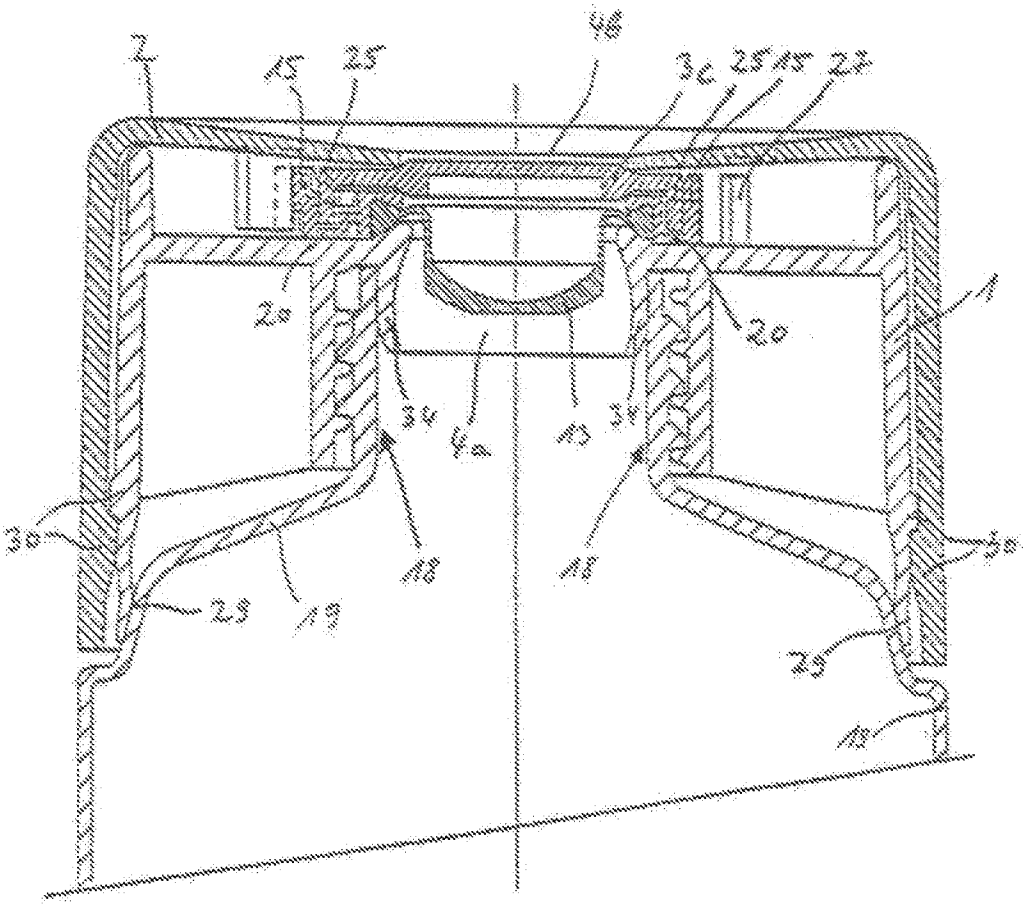


Fig. 11

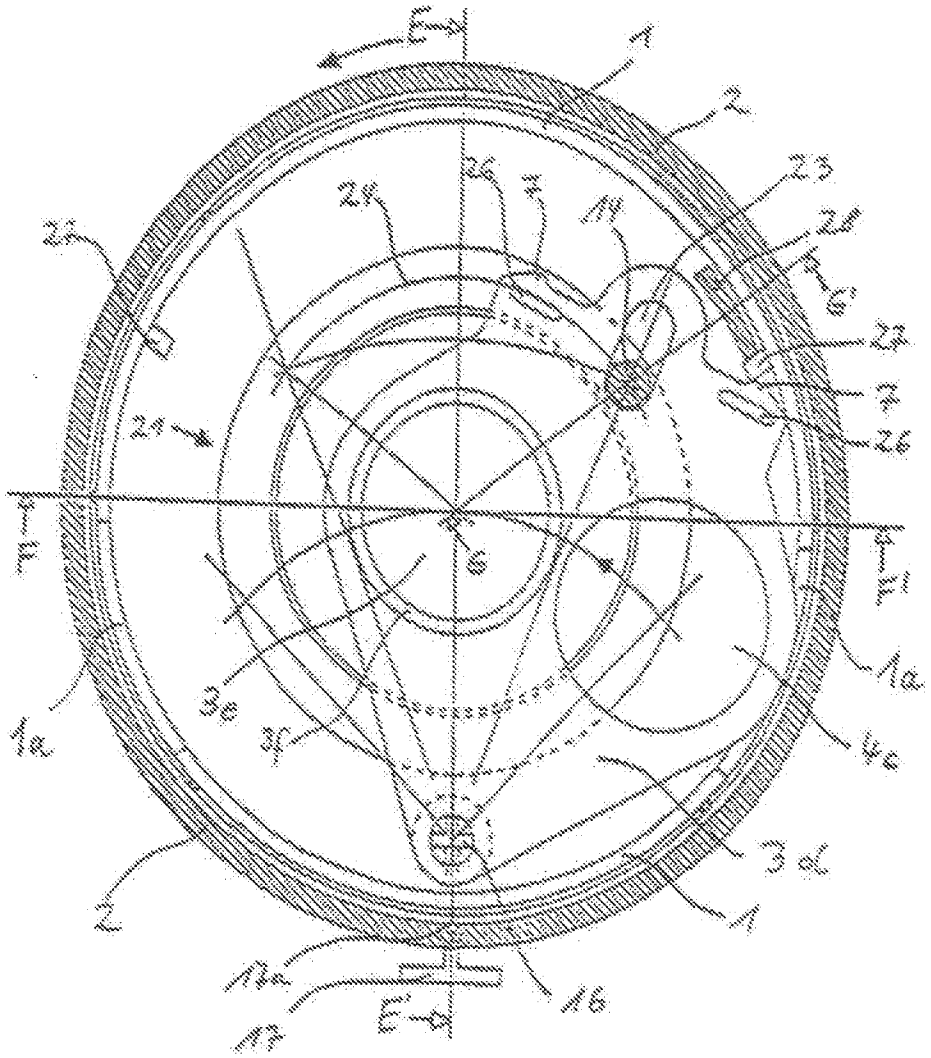


Fig. 12

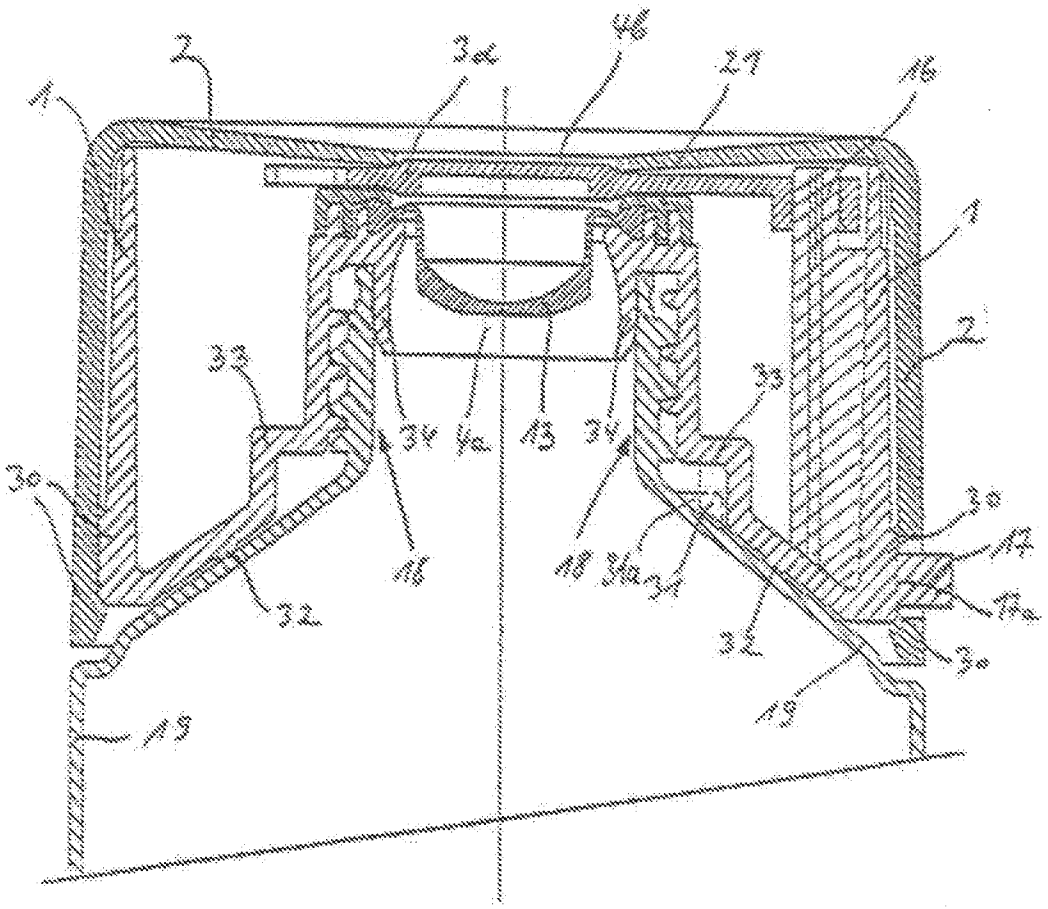


Fig. 13

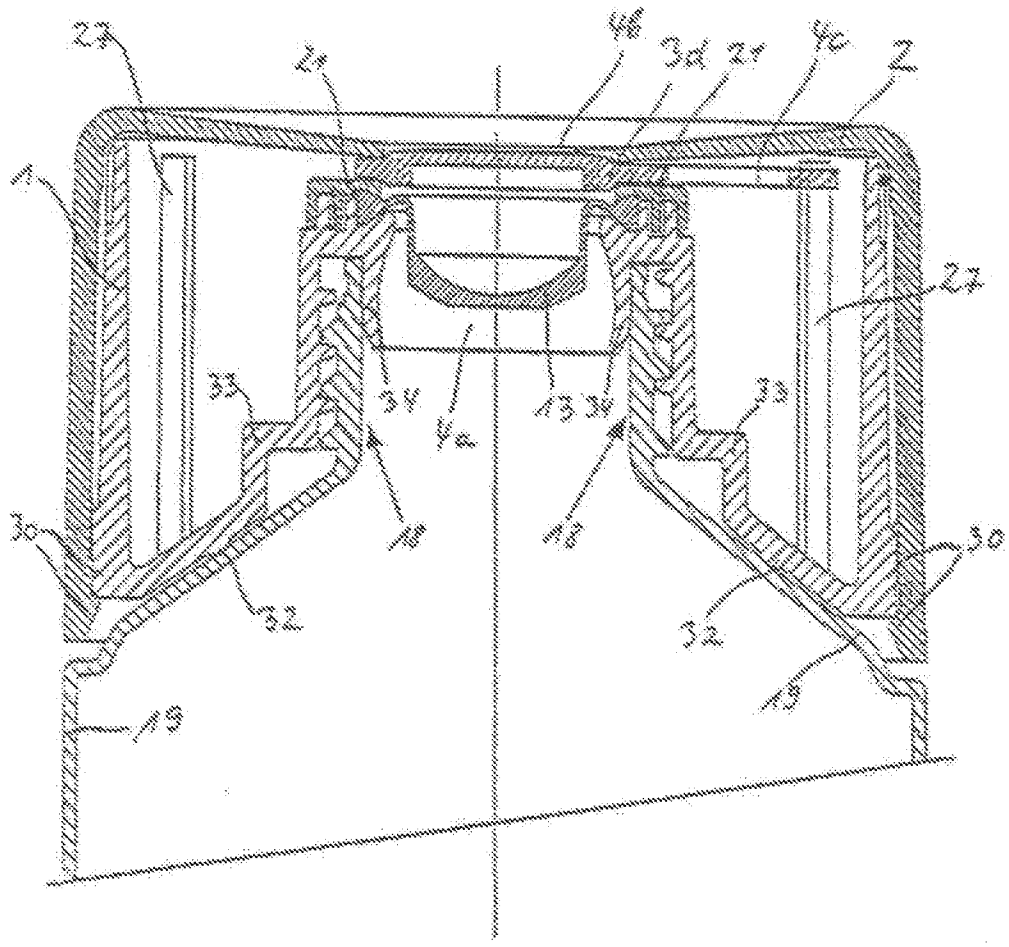


Fig. 14

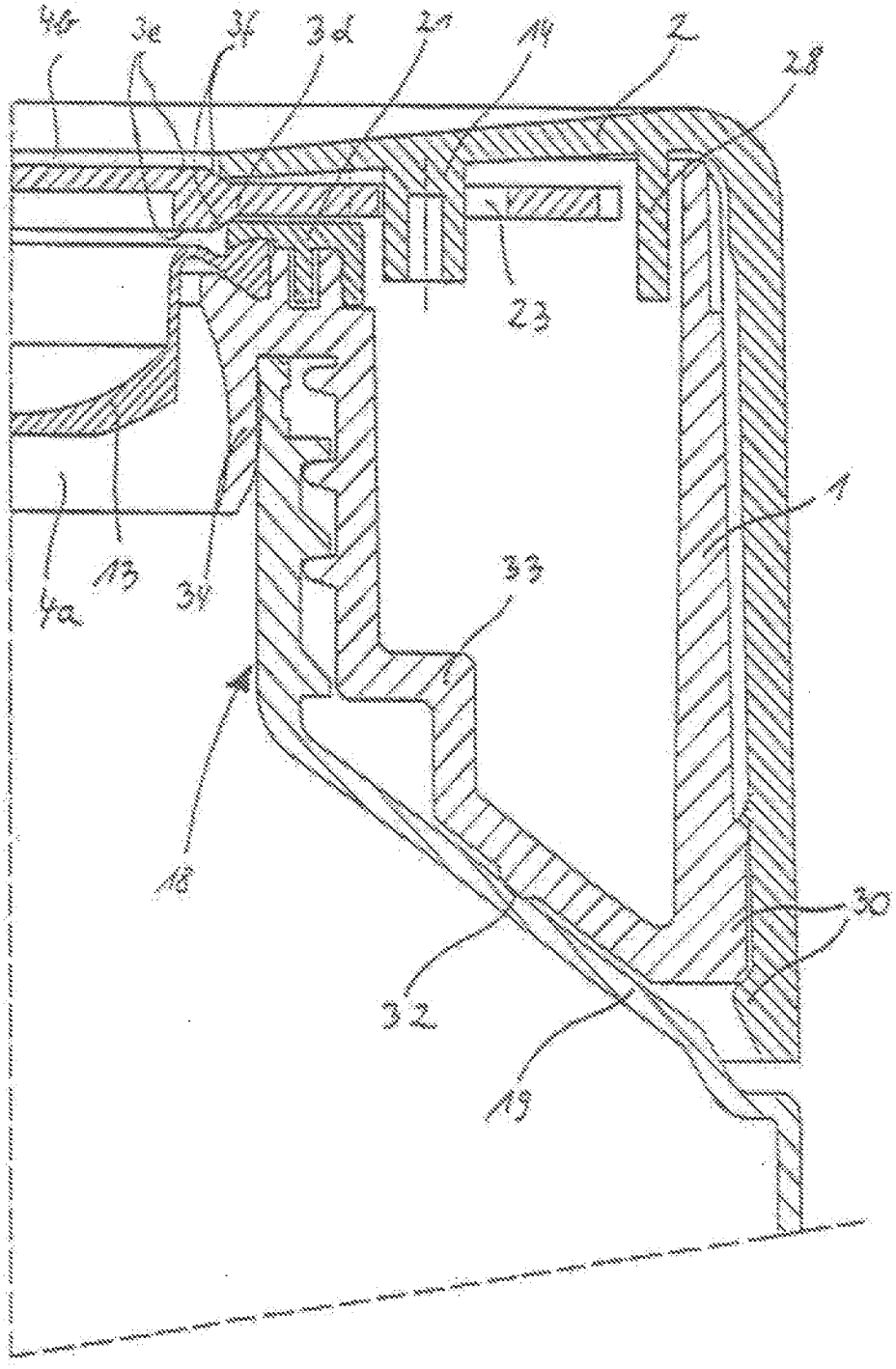


Fig. 15

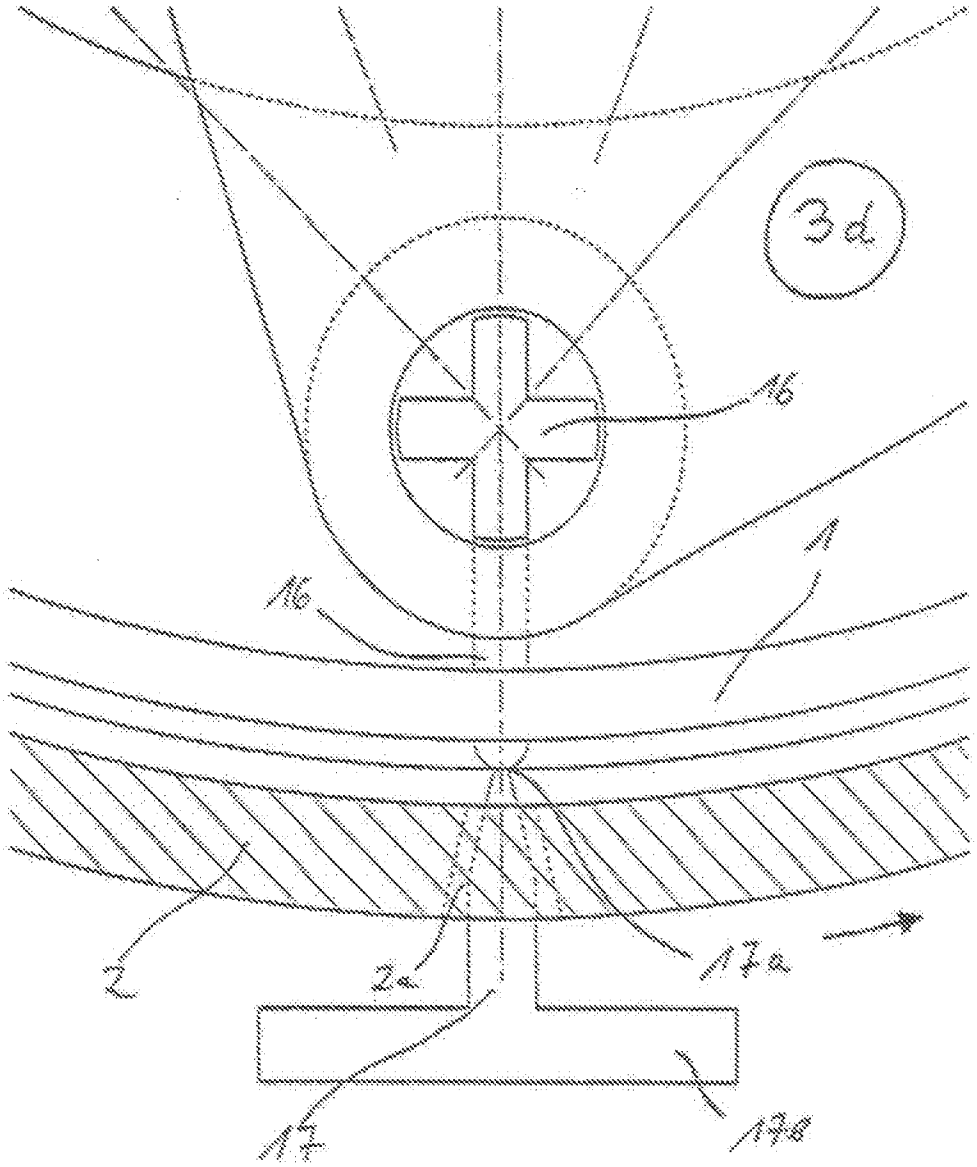


Fig. 16

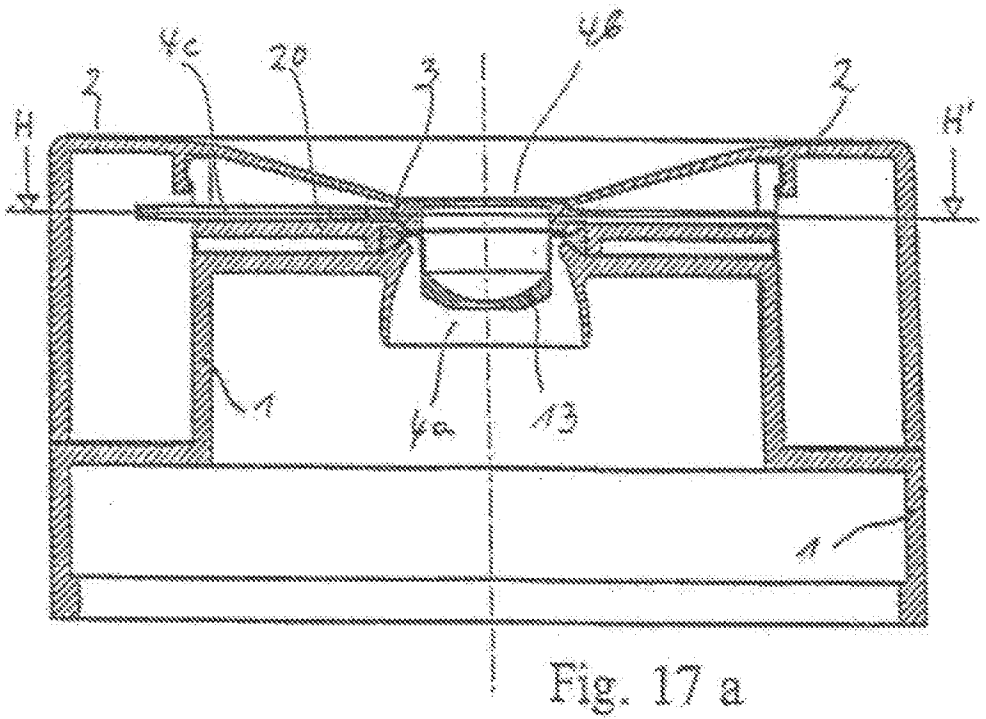


Fig. 17 a

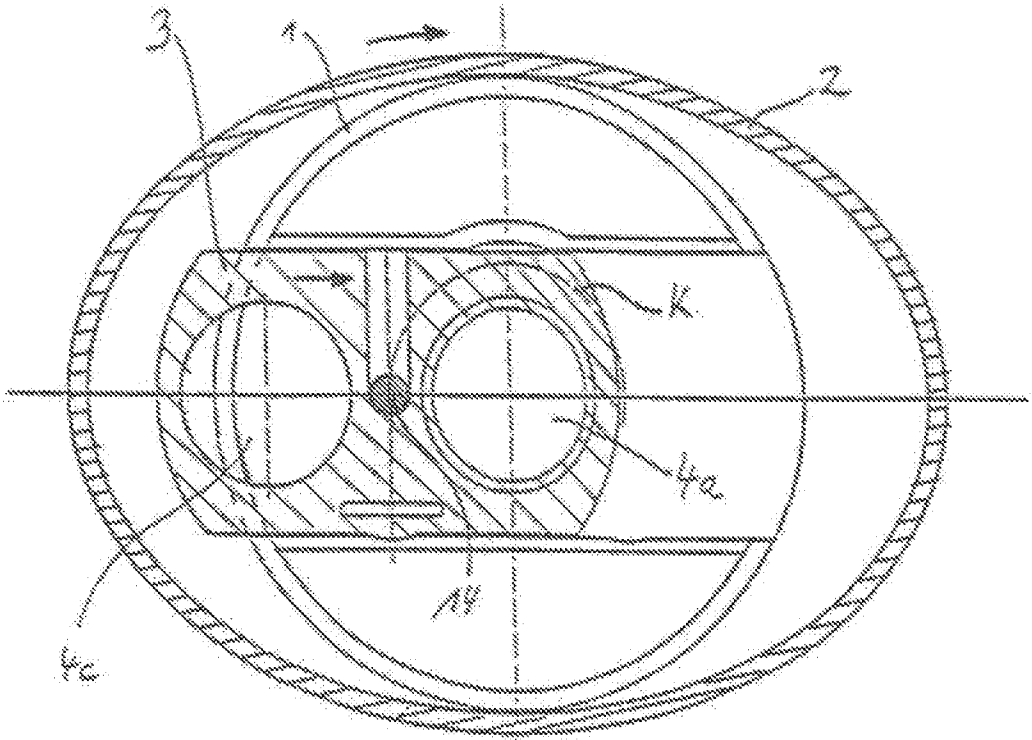


Fig. 17 b

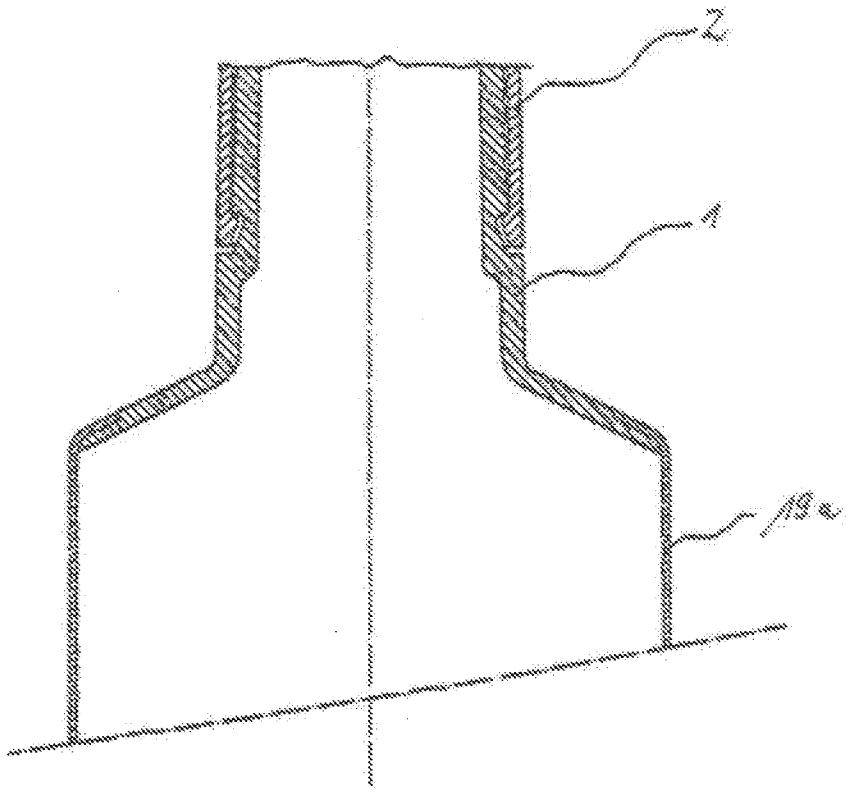


Fig. 18

EX1057, Page 1000

INTERNATIONAL SEARCH REPORT

International 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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[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
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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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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 (HEIDEBAUER) 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 & DISENFABRIK) 28 January 1972 see figure 3	16
A	GB,A,2 088 838 (OROLIK) 16 June 1982	
A	DE,A,16 36 129 (LEITZ) 5 March 1970	

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INTERNATIONAL SEARCH REPORT

information on patent family members

Form ... Application No
PCT/EP 94/01695

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	

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INTERNATIONALER RECHERCHENBERICHT

Intern. Aktenzeichen
PCT/EP 94/01695

A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
IPK 5 B65D47/26 B65D47/24 B65D47/20

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Recherchierte aber nicht zum Mindestprüfstoff gehörende Veröffentlichungen, soweit diese unter die recherchierten Gebiete fallen

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C. ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	US,A,2 082 691 (FARRELLY) 1. Juni 1937	1,2,5-7, 11,13, 14,17
Y	siehe Seite 1, rechte Spalte, Zeile 38 - Seite 3, linke Spalte, Zeile 11; Abbildungen 1-12	9,16
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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EX1057, Page 1004

EINSCHLÄGIG 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 1-15	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 (DROLIK) 16. Juni 1982	
A	DE,A,15 36 129 (LEITZ) 5. März 1970	

EX1057, Page 1005

INTERNATIONALER RECHERCHENBERICHT

Angaben zu Veröffentlichungen, die zu selben Patentfamilie gehören

Interne Aktenzeichen
PCT/EP 94/01695

Im Recherchenbericht angeführtes Patentdokument	Datum der Veröffentlichung	Mitglied(er) der Patentfamilie	Datum der Veröffentlichung
US-A-2082691		KEINE	
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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.

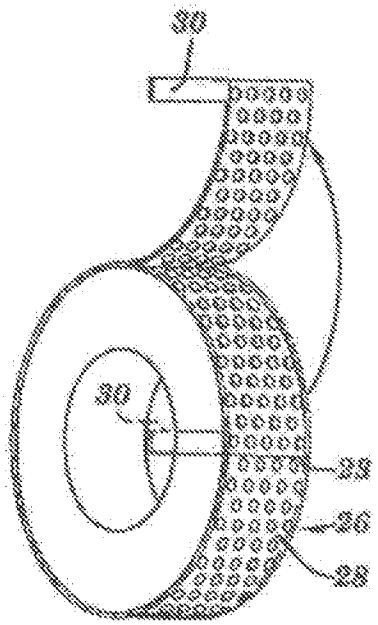
(81) Designated States: AU, BR, CA, CN, JP, KR, MX, RU, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

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 performed 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 g 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 circumferencial 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 multiple 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.

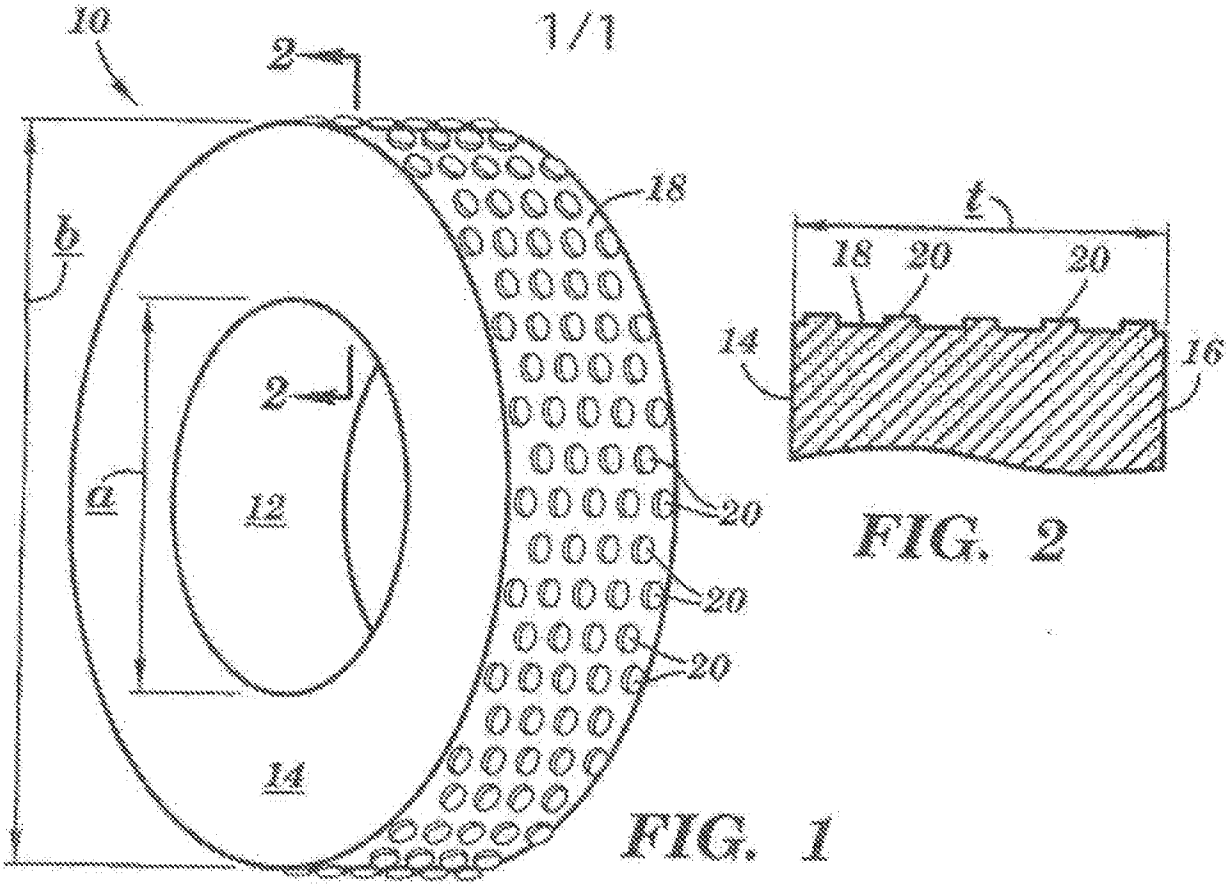


FIG. 2

FIG. 1

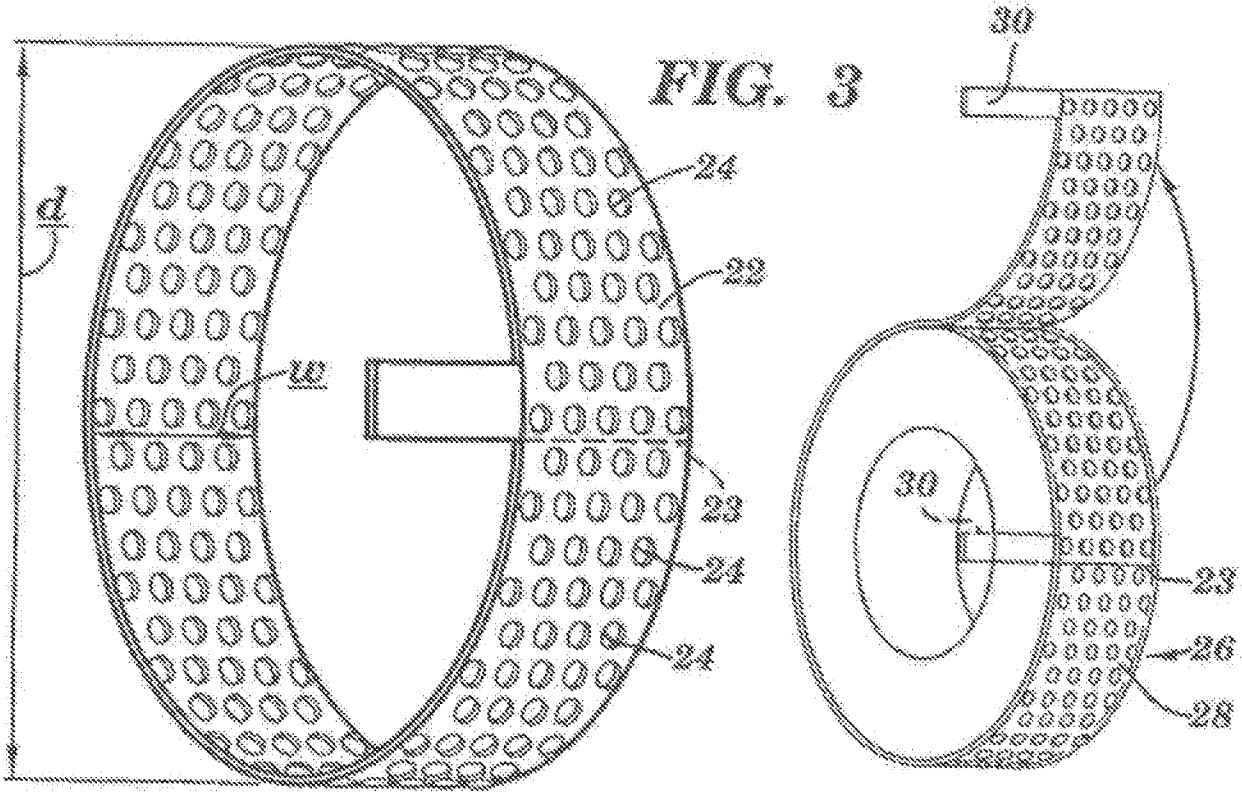


FIG. 3

FIG. 4

INTERNATIONAL SEARCH REPORT

Int. Serial Application No.
PCT/US 97/15724

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24B3/28 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

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	EP 0 010 408 A (ROBERT MICHAEL BARRON) 30 April 1980 see the whole document	6-14
X	EP 0 530 536 A (TYROLIT SCHLEIFMITTELWERKE SWAROVSKI K.G.) 10 March 1993 see the whole document	1

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[X] Further documents are listed in the continuation of box C.

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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
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	Malto Pinol, F

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 97/15724

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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A	EP 0 642 889 A (MINNESOTA MINING AND MANUFACTURING COMPANY) 15 March 1995 see the whole document	1-3
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Information on patent family members

Int. Appl. Application No
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WO2007032946

Publication Title:

METHODS OF BONDING SUPERABRASIVE PARTICLES IN AN ORGANIC MATRIX

Abstract:

Abstract of WO2007032946

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).

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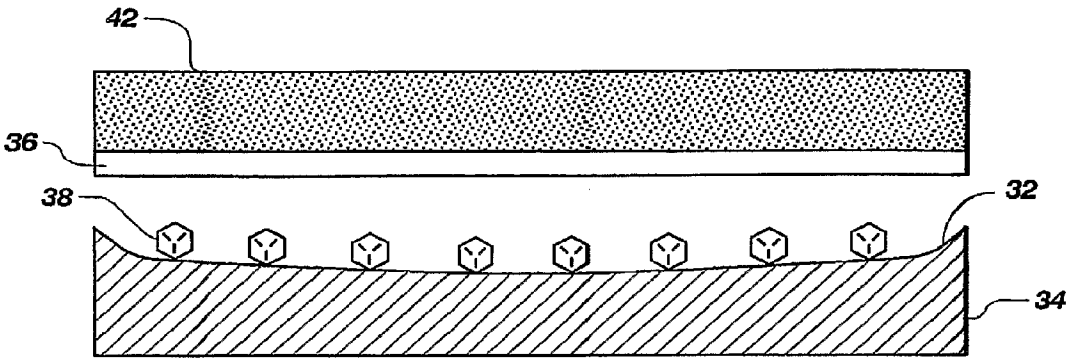
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(54) **Title:** METHODS OF BONDING SUPERABRASIVE PARTICLES IN AN ORGANIC MATRIX



(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).

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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

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

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.

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

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

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.

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

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.

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.

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.

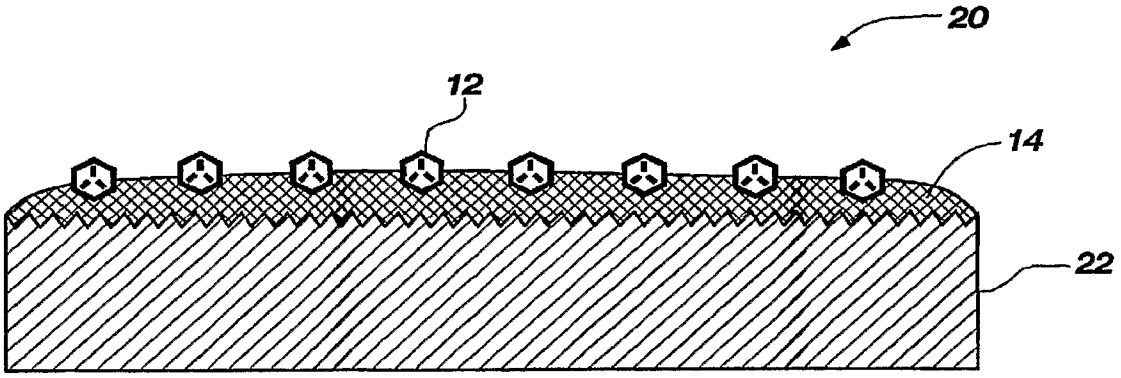


FIG. 1

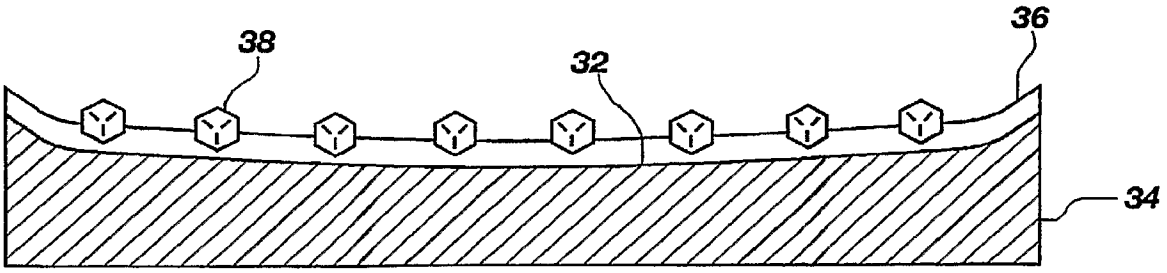


FIG. 2

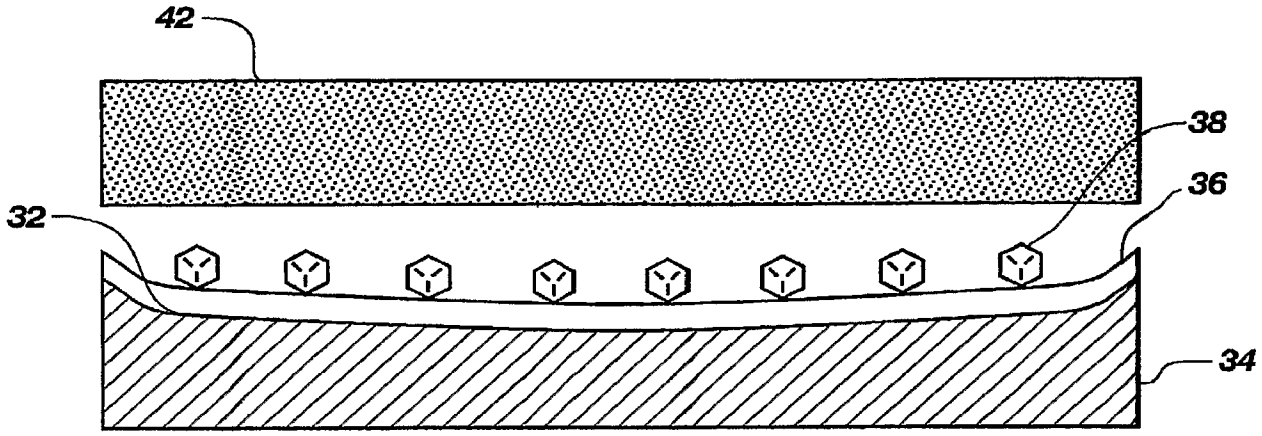


FIG. 3

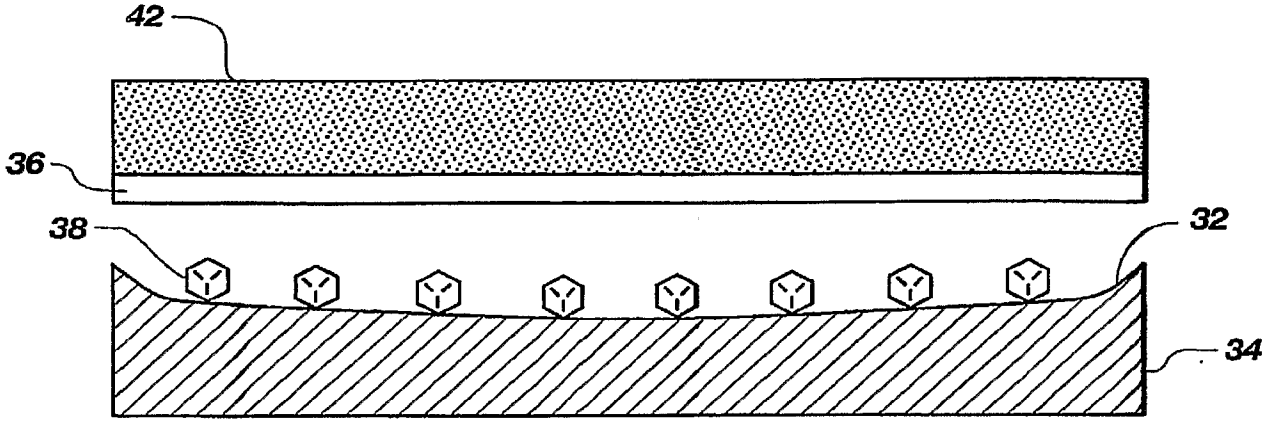


FIG. 4

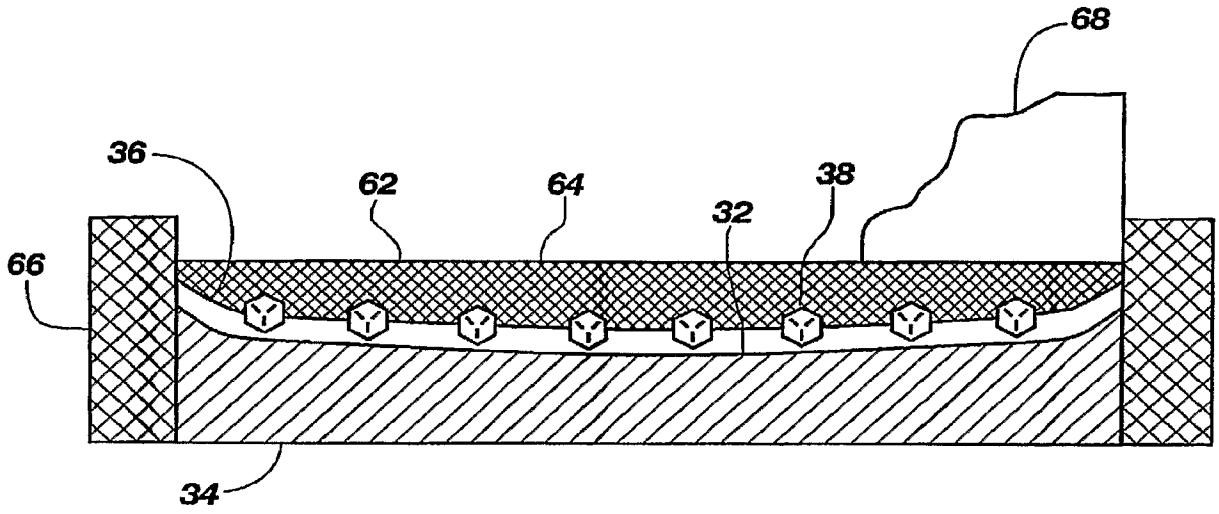


FIG. 5

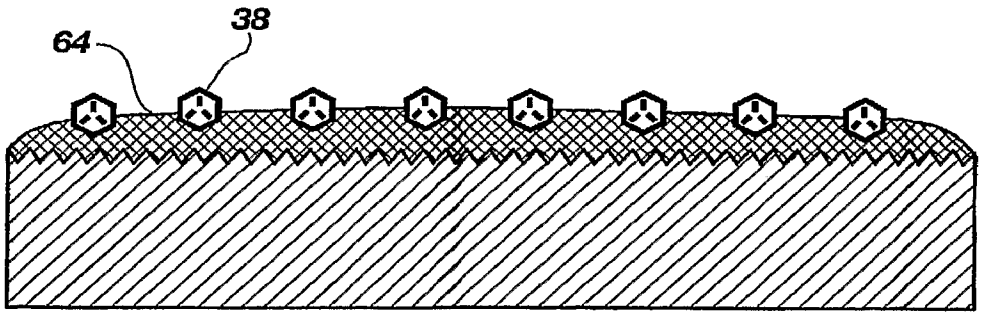


FIG. 6

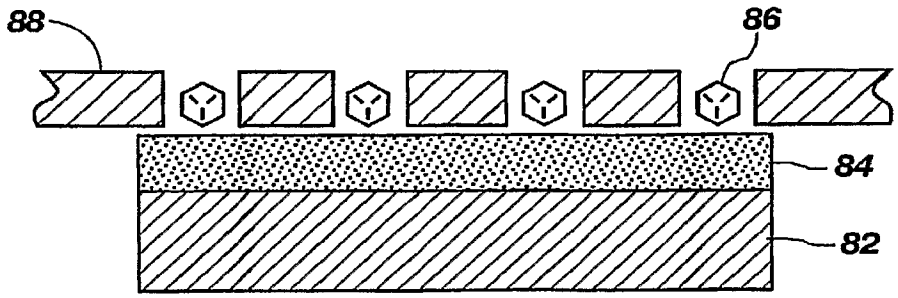


FIG. 7

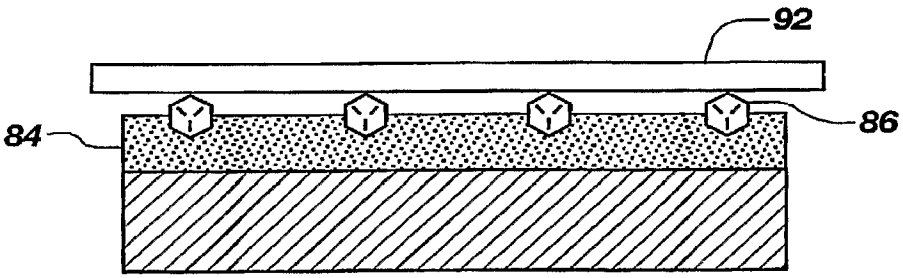


FIG. 8

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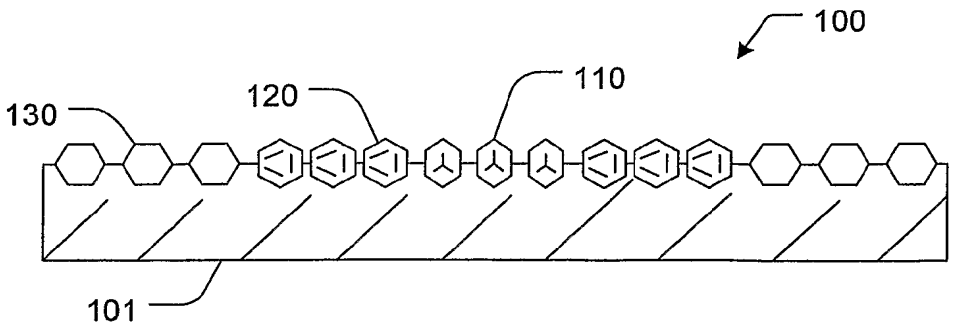
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(54) Title: CMP PADE DRESSER WITH ORIENTED PARTICLES AND ASSOCIATED METHODS



(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.

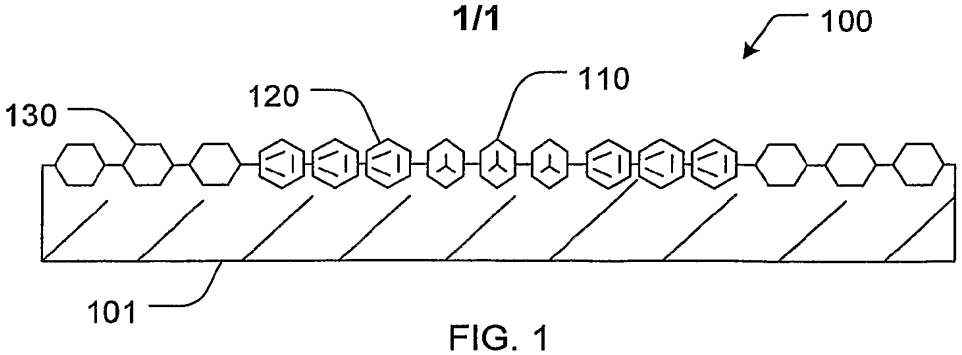


FIG. 1

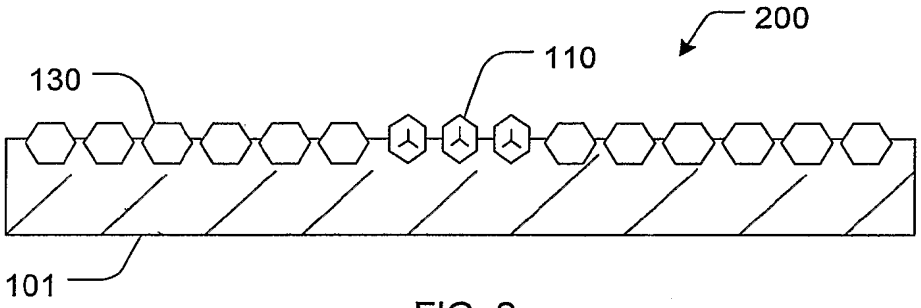


FIG. 2

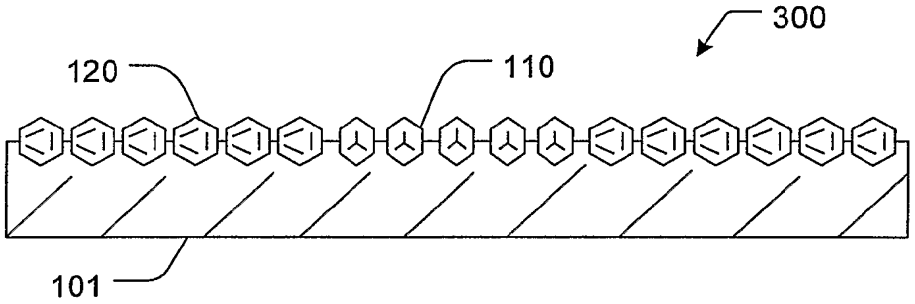


FIG. 3

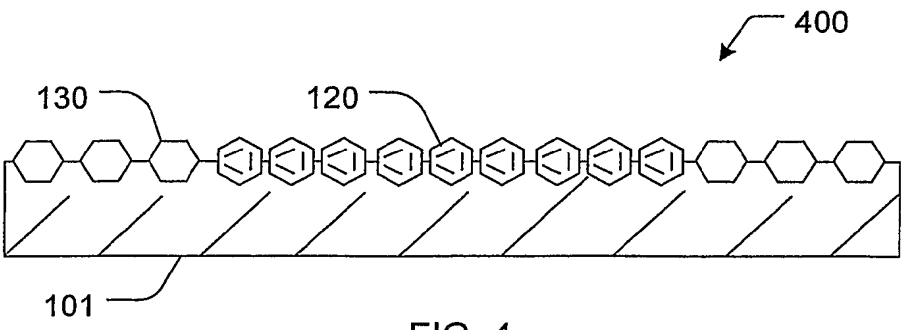


FIG. 4

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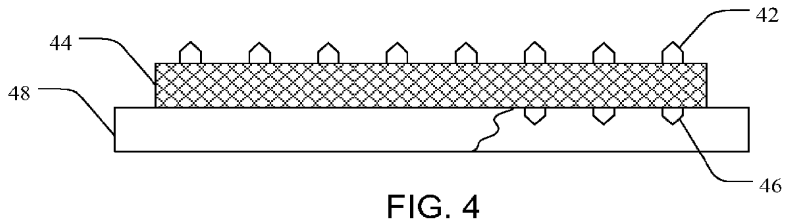


FIG. 4

(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.

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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.

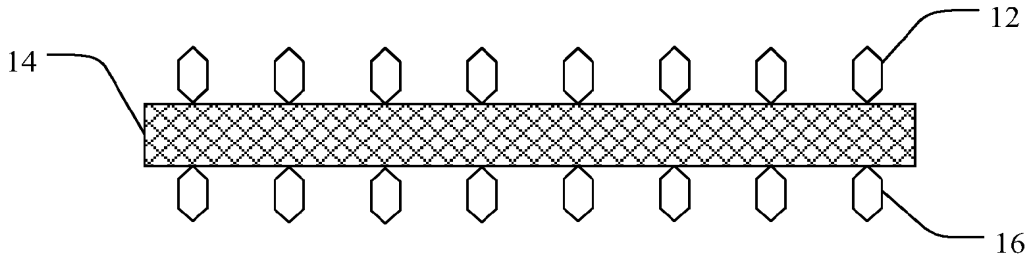


FIG. 1

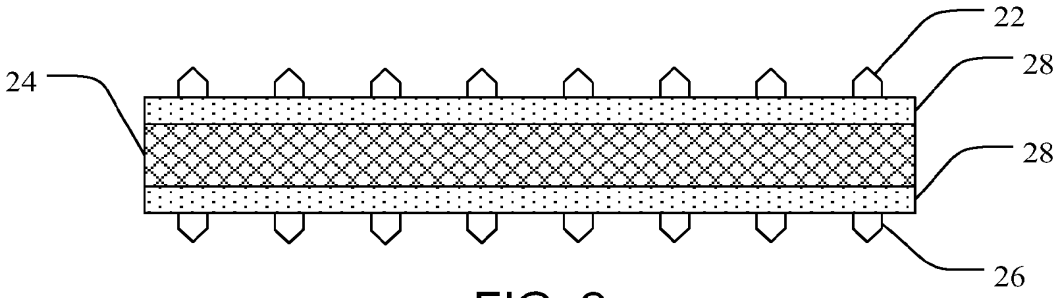


FIG. 2

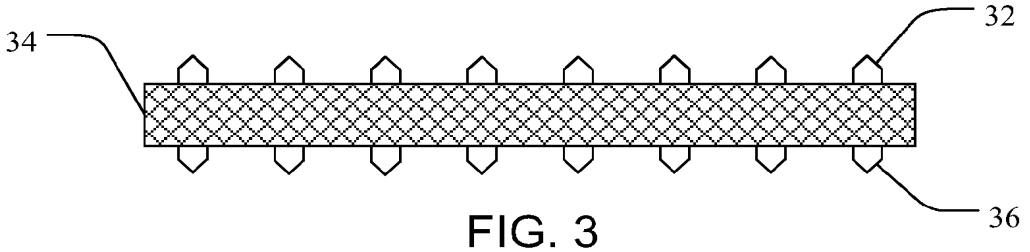


FIG. 3

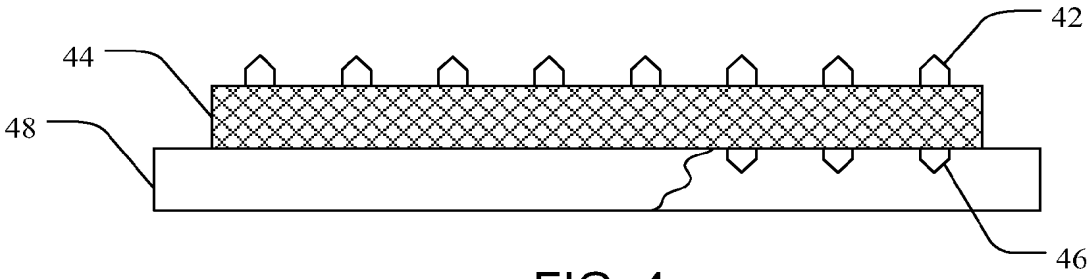


FIG. 4

Electronic Patent Application Fee Transmittal

Application Number:	13797704
Filing Date:	12-Mar-2013
Title of Invention:	COMPOSITE CONDITIONER AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Stephen Neville
Attorney Docket Number:	02074-32836.US

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($)
Miscellaneous:				
Submission- Information Disclosure Stmt	2806	1	90	90
		Total in USD ($)		**90**

Electronic Acknowledgement Receipt

EFS ID:	23694702
Application Number:	13797704
International Application Number:	
Confirmation Number:	1089
Title of Invention:	COMPOSITE CONDITIONER AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Stephen Neville
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-32836.US
Receipt Date:	05-OCT-2015
Filing Date:	12-MAR-2013
Time Stamp:	17:01:52
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
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Information:					
2	Information Disclosure Statement (IDS) Form (SB08)	A.PDF	717185 fdafec0b55b61e72bbd5fc645b6b6fd8cccab34b	no	11
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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
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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3727 EXAMINER: Maurina Rachuba FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/797,704 FILED: 3/12/2013 CONF. NO.: 1089 FOR: COMPOSITE CONDITIONER AND ASSOCIATED METHODS DOCKET NO.: 02074-32836.US	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: October 5, 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. /Stephen Neville/ Stephen Neville

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 $90.00 (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 5th day of October, 2015.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
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Sandy, Utah 84091-1219
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PTO/SB/08A (08-03)
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

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Complete if Known	
Application Number	13/797,704
Filing Date	3/12/2013
First Named Inventor	Chien-Min Sung
Art Unit	3727
Examiner Name	Maurina Rachuba
Attorney Docket Number	02074-32836.US

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
		238,946	03/15/1881	McKitrick	
		296,756	04/15/1884	Kirkpatrick	
		2002/0182401	12/2002	Lawing	
		2004/0048557	03/2004	Nabeya	
		2004/0112359	06/2004	Sung	
		2009/0073774	03/19/2009	Horesh et al.	
		2075354	03/30/1937	Monier	
		3905571	09/16/1975	Lombardo	
		4028576	06/07/1977	Wofsey	
		5492774	02/20/1996	Tateno et al.	
		6616752	09/09/2003	Basura et al.	
		6646725	11/11/2003	Eichinger et al.	
		6935365	08/30/2005	Schuster et al.	
		8622787	01/2014	Sung	
		8974270	03/2015	Sung	
		9138862	09/2015	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]

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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Complete if Known	
Application Number	13/797,704
Filing Date	3/12/2013
First Named Inventor	Chien-Min Sung
Art Unit	3727
Examiner Name	Maurina Rachuba
Attorney Docket Number	02074-32836.US

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 No. 14/223,810; Filing date March 24, 2014; Chien-Min Sung; Office Action dated October 8, 2015.	
		U.S. Application No. 14/120,976; Filing date July 15, 2014; Chien-Min Sung; Office Action dated October 15, 2015.	
		U.S. Application No. 14/506,476; Filing date October 3, 2014; Chien-Min Sung; Office Action dated October 30, 2015.	
		U.S. Application No. 13/846,740; Filing date March 18, 2013; Chien-Min Sung; Office Action dated November 4, 2015.	

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:	24077948
Application Number:	13797704
International Application Number:	
Confirmation Number:	1089
Title of Invention:	COMPOSITE CONDITIONER AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Stephen Neville
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-32836.US
Receipt Date:	13-NOV-2015
Filing Date:	12-MAR-2013
Time Stamp:	14:58:34
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	Transy.PDF	79398 c3e0d7c01b5edafb9a09b4bbb2f76066407c28ca	no	4

Warnings:	
Information:	

2	Information Disclosure Statement (IDS) Form (SB08)	A.PDF	117690 58b9e28d69ec83e049e1335f308c86a7abf40426	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	B.PDF	95371 e9675870cba155e093e8cc92d7e7e412b00a515b	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
			Total Files Size (in bytes):	292459	

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: 3727 EXAMINER: Maurina Rachuba FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/797,704 FILED: 3/12/2013 CONF. NO.: 1089 FOR: COMPOSITE CONDITIONER AND ASSOCIATED METHODS DOCKET NO.: 02074-32836.US	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: November 13, 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. /Stephen Neville/ Stephen Neville

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 13th day of November, 2015.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
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UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/797,704	03/12/2013	Chien-Min Sung	02074-32836.US	1089

20551 7590 12/31/2015

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

EXAMINER
BERONJA, LAUREN M

ART UNIT	PAPER NUMBER
3727	

NOTIFICATION DATE	DELIVERY MODE
12/31/2015	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):

patentdocket@tnw.com
rich@tnw.com
annette.fields@tnw.com

Office Action Summary	Application No. 13/797,704	Applicant(s) SUNG, CHIEN-MIN	
	Examiner LAUREN BERONJA	Art Unit 3727	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 *07/13/2015*.

☐ 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) *1-23 and 28-32* 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) *1-23 and 28-32* 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 *03/12/2013* 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 *attached*.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

1. The present application is being examined under the pre-AIA first to invent provisions.

DETAILED ACTION

Response to Arguments

2. Applicant's arguments with respect to claims 1-23 and 28-32 have been considered but are moot because the arguments do not apply to any of the references being used in the current rejection.

Claim Rejections - 35 USC § 102

3. 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.

4. Claim 1, 2, 6 and 10-12 are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by Kinoshita et al. (US 6,190,240).

5. Regarding claim 1, Kinoshita teaches a composite conditioner comprising: a base plate (3); and a plurality of polishing units (1) secured to the surface of the base plate by an adhesive layer (4), each polishing unit including a plurality of polishing tips (1) secured in a binding layer (2), wherein a height difference between a first highest polishing tip and a second highest polishing tip is **less than** or equal to about 10μm, a height difference between the first highest polishing tip and a tenth highest polishing tip is **less than** or equal to about 20μm, and a height different between the first highest polishing tip and a 100th highest polishing tip is **less than** or equal to about 40μm (all

the polishing tips are around the same height and therefore fall in the range of **less than**), and the first highest polishing tip protrudes from the binding layer to a height of greater than or equal to about 50μm (Col. 3, lines 44-67).

6. Regarding claim 2, Kinoshita teaches the composite conditioner of claim 1, wherein at least 1% of the plurality of polishing tips (1) actively condition a CMP pad during a conditioning process (abstract).

7. Regarding claim 6, Kinoshita teaches the composite conditioner of claim 1, wherein the plurality of polishing tips include diamond (Col. 2, lines 26-36), cubic boron nitride, or a combination thereof (Col, 3, lines 44-67).

8. Regarding claim 10, Kinoshita teaches the composite conditioner of claim 1, wherein each polishing unit further includes a polishing unit substrate () upon which the plurality of polishing tips are secure with the binding layer (2).

9. Regarding claim 11, Kinoshita teaches the composite conditioner of claim 1, wherein the binding layer (2) is selected from the group consisting of a solder layer, a plating layer, a sintering layer, and a resin layer (abstract).

10. Regarding claim 12, Kinoshita teaches the composite conditioner of claim 11, wherein each polishing unit further comprises a metal cover layer (Col. 2, lines 26-36) that covers the binding layer, wherein the metal cover layer includes at least one material selected from the group consisting of Ni, Cr, Pd, Co, Pt, Au, Ti, Cu, W, and alloys thereof (Col. 2, lines 26-36).

Claim Rejections - 35 USC § 103

10. 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.

11. Claims 4, 713, 14, 18, 20, and 28 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita in view of Sung.

12. Regarding claim 4, Kinoshita is silent tin regard to the arrangement of the polishing units on the base plate. Sung, however, teaches the composite conditioner wherein the polishing units are arranged on the base plate in an arrangement selected from the group consisting of a single ring, double rings, multi-rings, radial arrangements, and spiral arrangements (Paragraph 0073). Therefore, it would have been obvious for one having ordinary skill in the art at the time of the invention to have used the teachings of Sung and applied them to the invention of Kinoshita. Kinoshita doesn't teach a specific arrangement for the polishing units and therefore it would be obvious for one to search other conditioning plates in order to come to an arrangement.

13. Regarding claim 7, Kinoshita is silent in regard to the abrasive material on the polishing tips. Sung, however, teaches the plurality of polishing tips including diamond, and the diamond is deposition diamond, polycrystalline diamond, or a combination thereof (Paragraph 0061). Therefore, it would have been obvious to one having

ordinary skill in the art to have used diamond deposited polishing tips in the invention of Kinoshita. Deposition diamond is known, as taught by Sung, to be good for abrading because of its rigidity as well as its thermal conductivity.

14. Regarding claim 13, Kinoshita is silent in regard to the material of the protective layer covering. Sung, however, teaches a metal cover layer (Paragraph 0063) that covers the binding layer and a protective layer including a material selected from the group consisting of Pd, Pt, silicon carbide, aluminum nitride, alumina, zirconia, diamond-like carbon (DLC) (which includes diamond, as diamond is carbon, and is "diamond-like") and combinations thereof (Paragraph 0064). Therefore, it would have been obvious to one having ordinary skill in the art to have learned from Sung that the alloys used would work in the invention of Kinoshita because both are used for the same type of application.

15. Regarding claim 14, Kinoshita is silent in regard to the material of the binding layer. Sung, however, teaches a binding layer that is a solder layer comprising 1 wt% or more of a first material selected from the group consisting of B, P, Ti, or an alloy thereof (Paragraph 0074).). Therefore, it would have been obvious to one having ordinary skill in the art to have learned from Sung that the alloys used would work in the invention of Kinoshita because both are used for the same type of application.

16. Regarding claim 18, Kinoshita is silent in regard to the polishing tip particle size. Sung, however, teaches the composited conditioner wherein the polishing tips have a particle size from about 100 μm to about 500 μm (Paragraph 0068). Therefore, it would have been obvious for one having ordinary skill in the art at the time of the invention to

have searched what a good particle size for a polishing tip is that has a diamond tip and found information taught by Sung to use in Kinoshita.

17. Regarding claim 20, Sung teaches the composite conditioner wherein the polishing tips are arranged in a predetermined pattern on the polishing unit substrate (Paragraph 0078).

18. Regarding claim 28, Sung teaches a process of chemical-mechanical planarization (CMP), including the following steps: polishing a wafer against a rotating polishing pad; and applying the conditioner of claim 1 against the polishing pad to remove debris and condition the pad.

19. Claim 15 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita in view of Romero (US 6,371,842).

20. Regarding claim 15, Kinoshita is silent in regard to the shape of the polishing units. Romero, however, teaches a patterned abrading article wherein the polishing units (21) are disc shaped (Fig. 1). Therefore, it would have been obvious for one having ordinary skill in the art to have used the shape taught by Romero in the invention of Kinoshita because disc abrasive articles are, as taught by Romero, great conditioners. The disc shape is smooth and do not abruptly stop and therefore give the polishing pad a conditioned finish.

21. Claim 17 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita in view of Jeng et al. (US 6,524,523).

22. Regarding claim 19, Kinoshita is silent in regard to the adhesive of the composite conditioner being an organic adhesive. Jeng, however, teaches a polishing pad

conditioner, comprising an organic adhesive that is spread flatly on the base of the dresser. It would have been obvious for one having ordinary skill in the art at the time of the invention to have used the teachings of Jeng in the invention of Kinoshita. Jeng teaches diamond abrasive particles being adhered to the base layer using an organic adhesive because it is a non-toxic adhesive that will not cause any trouble in a work environment.

23. Claims 3, 5, 8, 9, 16, 17, 21-23, and 29-32 rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita.

24. Regarding the range of surface coverage by the units, the number of tips conditioning the pad, the crystal surface coverage, and the thickness of the adhesive, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have made the various components with the claimed size and amount ranges, for the predictable result of forming a conditioning tool, since it has been held that where the general conditions of a claim are disclosed in the prior art, discovering the optimum or workable ranges involves only routine skill in the art. Regarding the diameter and 1C dimension of the workpiece, applicant appears to be claiming dimensions not of currently available workpieces, but of possible future workpieces, see for example pages 20-22 of applicant's specification. As such, it is the examiner's position that one of ordinary skill in the art would have considered it obvious to fashion a conditioning tool that conditions a polishing pad such that it is capable of working not just on present workpieces, but on possible future workpieces of the claimed sizes as well.

Conclusion

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LAUREN BERONJA whose telephone number is (571)270-0167. The examiner can normally be reached on Monday - Friday 7:30am-5pm EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Monica Carter can be reached on 571-272-4475. 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.

/LAUREN BERONJA/
Examiner, Art Unit 3727

/SHELLEY SELF/
Supervisory Patent Examiner, Art Unit 3725

Notice of References Cited	Application/Control No. 13/797,704	Applicant(s)/Patent Under Reexamination SUNG, CHIEN-MIN	
	Examiner LAUREN BERONJA	Art Unit 3727	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	CPC Classification	US Classification
*	A	US-6,190,240 B1	02-2001	Kinoshita; Toshiya	B24B53/017	451/443
*	B	US-2002/0173234 A1	11-2002	Sung, Chien-Min	B24B53/017	451/21
*	C	US-6,371,842 B1	04-2002	Romero; Vincent D.	B24D13/14	451/540
*	D	US-6,524,523 B1	02-2003	Jeng; Sheng-Hun	B22F7/04	419/11
	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	CPC 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/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
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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	13/797,704
Filing Date	3/12/2013
First Named Inventor	Chien-Min Sung
Art Unit	3727
Examiner Name	Maurina Rachuba
Attorney Docket Number	02074-32836.US

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
		0187593	02/20/1877	Brown et al.	
		1854071	04/12/1932	Schacht	
		1988065	01/1935	Wooddell	
		2001/0003884	06/2001	Wei et al.	
		2001/0009844	07/2001	Cho et al.	
		2001/0046835	11/2001	Wielonski et al.	
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		2002/0127962	09/2002	Cho et al.	
		2002/0139680	10/2002	George	
		2002/0164928	11/07/2002	Tolles	
		2002/0173234	11/2002	Sung et al.	
		2002/0182401 A1	12/2002	Lawing	
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		2003/0084894	05/2003	Sung	
		2003/0092357	05/2003	Yoon et al.	
		2003/0114094	06/19/2003	Myoung et al.	
		2003/0207659	11/06/2003	Annen et al.	
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Art Unit	3727
Examiner Name	Maurina Rachuba
Attorney Docket Number	02074-32836.US

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Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13797704	SUNG, CHIEN-MIN
	Examiner	Art Unit
	LAUREN BERONJA	3727

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	12/19/2015								
	1	✓								
	2	✓								
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	26	N								
	27	N								
	28	✓								
	29	✓								
	30	✓								
	31	✓								
	32	✓								

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Attorney Docket Number	02074-32836.US

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NON PATENT LITERATURE DOCUMENTS

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT
(U.S.e as many sheets as necessary)

Sheet		of	

Complete if Known	
Application No. Number	13/797,704
Filing Date	3/12/2013
First Named Inventor	Chien-Min Sung
Art Unit	3727
Examiner Name	Maurina Rachuba
Attorney Docket Number	02074-32836.U.S.

		U.S. Application No. 13/407,634; Filing date 02/28/2012; Chien-Min Sung; Office Action dated 06/13/2014	
		U.S. Application No. 13/407,634; Filing date 02/28/2012; Chien-Min Sung; Office Action dated 10/29/2014	
		U.S. Application No. 13/416,201; Filing date 03/09/2012; Chien-Min Sung; Office Action dated 06/18/2014	
		U.S. Application No. 13/416,201; Filing date 03/09/2012; Chien-Min Sung; Office Action dated 01/22/2015	
		U.S. Application No. 13/479,148; Filing date 05/23/2012; Chien Min-Sung; Notice of Allowance mailed 12/09/2014	
		U.S. Application No. 13/479,148; Filing date 05/23/2012; Chien-Min Sung; Office Action dated 05/15/2014.	
		U.S. Application No. 13/479,148; Filing date 05/23/2012; Chien-Min Sung; Notice of Allowance mailed 01/12/2015	
		U.S. Application No. 13/644,790; Filing date 10/04/2012; Chien-Min Sung; Office Action dated 06/17/2014	
		U.S. Application No. 13/644,790; Filing date 10/04/2012; Chien-Min Sung; Office Action dated 12/24/2014	
		U.S. Application No. 13/794,164; Filing date 03/11/2013; Chien-Min Sung; Office Action dated 07/16/2014	
		U.S. Application No. 13/797,704; Filing date 03/12/2013; Chien-Min Sung; Office Action dated 01/12/2015	
		U.S. Application No. 13/802,112; Filing date 03/13/2013; Chien-Min Sung; Office Action dated 11/06/2014	
		U.S. Application No. No. 13/633,082; Filing date October 1, 2012; Chien-Min Sung; Office Action dated February 26, 2015.	
		U.S. Application No. No. 13/407,634; Filing date February 28, 2012; Chien-Min Sung; Office Action dated March 5, 2015.	
		U.S. Application No. No. 14/248,163; Filing date April 8, 2014; Chien-Min Sung; Office Action dated April 28, 2015.	
		U.S. Application No. No. 13/416,201; Filing date March 9, 2012; Chien-Min Sung; Office Action dated May 15, 2015.	
		U.S. Application No. No. 13/802,112; Filing date March 13, 2013; Chien-Min Sung; Notice of Allowance mailed May 15, 2015.	

ALL REFERENCES CONSIDERED EXCEPT WHERE LINED THROUGH. /L.M.B/

PTO/SB/08B (08-03)
Approved for U.S.e through 07/31/2006. OMB 0651-0031
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Art Unit	3727
Examiner Name	Maurina Rachuba
Attorney Docket Number	02074-32836.U.S.

		U.S. Application No. No. 13/644,790; Filing date October 4, 2012; Chien-Min Sung; Notice of Allowance mailed June 8, 2015.	
		U.S. Application No. 13/113,779; filing date 05/23/2011; Chien-Min Sung; Notice of Allowance mailed July 17, 2015.	
		U.S. Application No. 13/153,176; filing date 06/03/2011; Chien-Min Sung; Office Action dated August 13, 2015.	
		U.S. Application No. 13/633,082; filing date 10/01/2012; Chien-Min Sung; Notice of Allowance mailed August 19, 2015.	
		U.S. Application No. 13/407,634; filing date 02/28/2012; Chien-Min Sung; Notice of Allowance mailed September 3, 2015.	
		YASINAGA et al; Advances in Abrasive Technology, III; Soc. Of Grinding Engineers (SGE) in Japan; 2000. (Abstract Only)	

Examiner Signature	/LAUREN M BERONJA/	Date Considered	12/19/2015

*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 U.S.PTO to process) an Application No.. 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 No. form to the U.S.PTO. 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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First Named Inventor	Chien-Min Sung
Art Unit	3727
Examiner Name	Maurina Rachuba
Attorney Docket Number	02074-32836.US

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]
/L.M.B/		U.S. Application No. 14/223,810; Filing date March 24, 2014; Chien-Min Sung; Office Action dated October 8, 2015.	
/L.M.B/		U.S. Application No. 14/120,976; Filing date July 15, 2014; Chien-Min Sung; Office Action dated October 15, 2015.	
/L.M.B/		U.S. Application No. 14/506,476; Filing date October 3, 2014; Chien-Min Sung; Office Action dated October 30, 2015.	
/L.M.B/		U.S. Application No. 13/846,740; Filing date March 18, 2013; Chien-Min Sung; Office Action dated November 4, 2015.	

Examiner Signature	/LAUREN M BERONJA/	Date Considered	12/19/2015

*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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BIB DATA SHEET

CONFIRMATION NO. 1089

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/797,704	03/12/2013	451	3727	02074-32836.US

APPLICANTS

INVENTORS

Chien-Min Sung, Tansui, TAIWAN;

**** CONTINUING DATA ***************************

This application is a CIP of 12/726,786 03/18/2010 PAT 8622787
which is a CIP of 12/255,823 10/22/2008 PAT 8393934
which is a CIP of 12/168,110 07/05/2008 PAT 8398466
which claims benefit of 60/976,198 09/28/2007
and is a CIP of 11/560,817 11/16/2006 PAT 7762872
which is a CIP of 11/357,713 02/17/2006 ABN
which claims benefit of 60/681,798 05/16/2005
This application 13/797,704 03/12/2013
is a CIP of 12/628,859 12/01/2009 PAT 7901272
which is a CIP of 11/804,221 05/16/2007 PAT 7651386
which is a CIP of 11/223,786 09/09/2005 ABN
This application 13/797,704 03/12/2013
is a CIP of 12/850,747 08/05/2010 PAT 8678878
which claims benefit of 61/246,816 09/29/2009
This application 13/797,704 03/12/2013
is a CIP of 13/034,213 02/24/2011 ABN
which claims benefit of 61/333,162 05/10/2010

**** FOREIGN APPLICATIONS ***************************

TAIWAN 101112625 04/10/2012

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **** ** SMALL ENTITY **
04/12/2013

Foreign Priority claimed ☑ Yes ☐ No 35 USC 119(a-d) conditions met ☑ Yes ☐ No Verified and Acknowledged /Lauren Beronja/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		TAIWAN	9	32	3

ADDRESS

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

TITLE

COMPOSITE CONDITIONER AND ASSOCIATED METHODS

FILING FEE	FEES: Authority has been given in Paper	☐ All Fees ☐ 1.16 Fees (Filing) ☐ 1.17 Fees (Processing Ext. of time)

BIB (Rev. 05/07).

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13797704	SUNG, CHIEN-MIN
	Examiner	Art Unit
	MAURINA RACHUBA	3727

CPC- SEARCHED		
Symbol	Date	Examiner
B24B 37/34, 53/00, 53/017, 53/02	1/7/2015	MTR
update	12/19/2015	LMB

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
SEE eas			

SEARCH NOTES		
Search Notes	Date	Examiner
See EAST, inventor and citation searches	1/7/2015	MTR
update	12/19/2015	LMB

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

/LAUREN BERONJA/ Examiner.Art Unit 3727	/MAURINA RACHUBA/ Primary Examiner.Art Unit 3727

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

ART UNIT: 3727 EXAMINER: Lauren M. Beronja FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/797,704 FILED: 3/12/2013 CONF. NO.: 1089 FOR: COMPOSITE CONDITIONER AND ASSOCIATED METHODS DOCKET NO.: 02074-32836.US	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: **May 2, 2016** 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

RESPONSE UNDER 37 C.F.R. § 1.111

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313

Dear Sir:

In response to the communication mailed on December 31, 2015, please reconsider this application in view of the remarks provided herein. A petition for a 1-month extension of time and associated fees are submitted herewith.

CLAIM LISTING

1. (original) A composite conditioner comprising:

a base plate; and

a plurality of polishing units secured to a surface of the base plate by an adhesive layer, each polishing unit including a plurality of polishing tips secured in a binding layer, wherein a height difference between a first highest polishing tip and a second highest polishing tip is less than or equal to about 10μm, a height difference between the first highest polishing tip and a tenth highest polishing tip is less than or equal to about 20μm, and a height difference between the first highest polishing tip and a 100th highest polishing tip is less than or equal to about 40μm, and the first highest polishing tip protrudes from the binding layer to a height of greater than or equal to about 50μm.

2. (original) The composite conditioner of claim 1, wherein at least 1% of the plurality of polishing tips actively condition a CMP pad during a conditioning process.

3. (original) The composite conditioner of claim 1, wherein less than 40% of the surface of the base plate is covered with polishing units.

4. (original) The composite conditioner of claim 1, wherein the polishing units are arranged on the base plate in an arrangement selected from the group consisting of a single ring, double rings, multi-rings, radial arrangements, and spiral arrangements.

5. (original) The composite conditioner of claim 1, wherein at least one thousand polishing tips of the plurality of polishing tips condition a polishing pad during a conditioning process.

6. (original) The composite conditioner of claim 1, wherein the plurality of polishing tips include diamond, cubic boron nitride, or a combination thereof.

7. (original) The composite conditioner of claim 6, wherein the plurality of polishing tips include diamond, and the diamond is deposition diamond, polycrystalline diamond, or a combination thereof.

8. (original) The composite conditioner of claim 1, wherein the crystal surface coverage of more than 50% of the top 100 height polishing tips are less than 80%.

9. (original) The composite conditioner of claim 8, wherein the crystal surface coverage of more than 50% of the top 100 height polishing tips are less than 50%.

10. (original) The composite conditioner of claim 1, wherein each polishing unit further includes a polishing unit substrate upon which the plurality of polishing tips are secured with the binding layer.

11. (original) The composite conditioner of claim 1, wherein the binding layer is selected from the group consisting of a solder layer, a plating layer, a sintering layer, and a resin layer.

12. (original) The composite conditioner of claim 11, wherein each polishing unit further comprises a metal cover layer that covers the binding layer, wherein the metal cover layer includes at least one material selected from the group consisting of Ni, Cr, Pd, Co, Pt, Au, Ti, Cu, W, and alloys thereof.

13. (original) The composite conditioner of claim 12, wherein each polishing unit further comprises a protective layer covering the metal cover layer, wherein the protective layer includes a material selected from the group consisting of Pd, Pt, silicon carbide, aluminum nitride, alumina, zirconia, diamond-like carbon (DLC), and combinations thereof.

14. (original) The composite conditioner of claim 11, wherein binding layer is a solder layer comprising 1 wt% or more of a first material selected from the group consisting of Cr, B, P, Ti, or

an alloy thereof, or 50 tw% or more of a second material selected from the group consisting of Ni, Cu, or an alloy thereof, or 1 tw% or more of the first material and 50 wt% or more of the second material.

15. (original) The composite conditioner of claim 1, wherein the polishing units are disc-shaped, radial-shaped, or polygon-shaped.

16. (original) The composite conditioner of claim 15, wherein the polishing units are disc-shaped having a diameter of from about 5mm to about 30mm.

17. (original) The composite conditioner of claim 1, wherein the base plate is disc-shaped having a diameter of from about 80mm to about 120mm.

18. (original) The composite conditioner of claim 1, wherein the polishing tips have a particle size of from about 100μm to about 500μm.

19. (original) The composite conditioner of claim 1, wherein the adhesive layer is an organic adhesive.

20. (original) The composite conditioner of claim 1, wherein the polishing tips are arranged in a predetermined pattern on the polishing unit substrate.

21. (original) The composite conditioner of claim 1, wherein the polishing units are spaced no closer than about 0.1mm.

22. (original) The composite conditioner of claim 21, wherein the polishing units are spaced at least 0.5mm apart.

23. (original) The composite conditioner of claim 1, wherein the adhesive layer between the base plate and the polishing units has a thickness of less than or equal to about 0.6 mm.

24. (withdrawn) A method of making a composite conditioner, comprising:

disposing a second mold on a first mold, wherein the second mold includes a plurality of holes;

placing a polishing unit in each of the plurality of holes of the second mold, each polishing unit including a plurality of polishing tips secured in a binding layer;

applying an adhesive layer over the second mold to secure the polishing units; and

removing the first mold and the second mold to form a composite conditioner wherein a height difference between a first highest polishing tip and a second highest polishing tip is less than or equal to about 10μm, a height difference between the first highest polishing tip and a tenth highest polishing tip is less than or equal to about 20μm, and a height difference between the first highest polishing tip and a 100th highest polishing tip is less than or equal to about 40μm and the first highest polishing tip protrudes from the binding layer to a height of greater than or equal to about 50μm.

25. (withdrawn) The method of claim 24, wherein placing the polishing unit in the plurality of holes of the second mold further comprises orienting the polishing units such that the polishing tips face the first mold.

26. (withdrawn) The method of claim 25, wherein the polishing tips contact the first mold such that the polishing unit are leveled across the first mold.

27. (withdrawn) The method of claim 26, wherein the holes of the second mold are arranged around an outer periphery of the second mold.

28. (original) A process of chemical-mechanical planarization (CMP), including the following steps:

polishing a wafer against a rotating polishing pad; and

applying the conditioner of claim 1 against the polishing pad to remove debris and condition the pad.

29. (original) The process of claim 28, wherein the diameter of the wafer is 200mm, 300mm, or 450mm.

30. (original) The process of claim 28, wherein a surface of the wafer has an IC critical dimension of less than or equal to 45nm.

31. (original) The process of claim 30, wherein a surface of the wafer has an IC critical dimension of less than or equal to 28nm.

32. (original) The process of claim 28, wherein the surface of the wafer has an IC critical dimension of less than or equal to 22 nm.

REMARKS

The Applicant expresses appreciation to the Examiner for consideration of the subject patent application. This communication is in response to the Office Action mailed on December 31, 2015. In the Office Action the Examiner rejected claims 1-23 and 28-32 on various statutory grounds, each of which will be addressed in turn below.

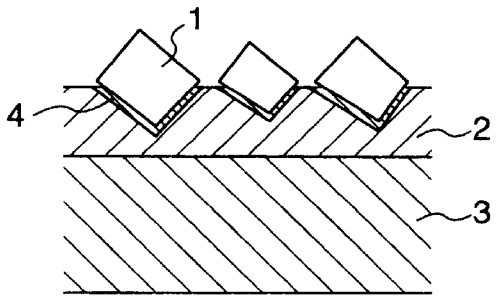
It is noted that any lack of discussion regarding any point, issue, or argument raised by the Examiner should not be seen as being in agreement. The Applicant reserves the right to pursue any such point, issue, or argument at a later time.

Claim Rejections – 35 U.S.C. § 102

In the Office Action the Examiner rejected claims 1, 2, 6, and 10-12 under pre-AIA 102(b) as allegedly anticipated by U.S. Patent 6,190,240 to Kinoshita. The Applicant respectfully disagrees and traverses this rejection.

The Examiner states that "Kinoshita teaches a composite conditioner comprising: a base plate (3); and a plurality of polishing units (1) secured to the surface of the base plate by an adhesive layer (4), each polishing unit including a plurality of polishing tips (1) secured in a binding layer (2)," as represented in FIG. 1 below.

FIG.1



The Examiner's interpretation of FIG. 1 clearly does not anticipate independent claim 1. Specifically, claim 1 recites, in part, "a plurality of polishing units secured to a surface of the base plate by an adhesive layer, each polishing unit including a plurality of tips secured in a binding layer."

The Examiner asserts that feature 1 represents the plurality of polishing units, feature 3 represents the base plate, and feature 4 represents the adhesive layer. Based on this interpretation, the plurality of polishing units 1 are not secured to a surface of the base plate 3 by an adhesive layer 4. Rather, the plurality of polishing units 1 are secured to a surface of the binding layer 2. Thus, for at least this reason, Kinoshita does not anticipate independent claim 1.

Further, it is noted that each of the polishing units includes a plurality of tips secured in a binding layer. Thus, it is unclear how both the polishing unit and the plurality of tips can both be represented by feature 1. If feature 1 is interpreted as the polishing unit, then Kinoshita clearly does not teach that the polishing unit includes a plurality of tips secured in a binding layer. Conversely, if feature 1 is interpreted as the tip, then Kinoshita clearly does not teach that there are a plurality of polishing units.

Therefore, for at least these reasons, Kinoshita clearly does not anticipate independent claim 1, or any of the claims that depend therefrom. Accordingly, the Applicant respectfully requests that the rejection of claims 1, 2, 6, and 10-12 under 35 U.S.C. § 102 be withdrawn.

Claim Rejections - 35 U.S.C. § 103

Before discussing the obviousness rejection herein, it is thought proper to briefly state what is required to sustain such a rejection. The issue under 35 U.S.C. § 103 is whether the USPTO has stated a case of *prima facie* obviousness. The Applicant does not deem it necessary to recite the entire case law standard required in order to establish a *prima facie* case of obviousness. However, the Applicant would like to briefly remind the Examiner that a *prima facie* case of obviousness generally includes establishing 1) that the asserted references as modified or combined teach or suggest each and every element of the claimed invention, 2) that the asserted references as modified or combined provide a sufficient likelihood of successfully making the modification or combination, and 3) a reason for the modification or combination asserted. Under the guidelines in the MPEP, an Examiner must establish that the reference teaches or suggests each and every claim element or explain "why the difference(s) between the prior art and the claimed invention would have been obvious." See MPEP § 2143.03 and MPEP § 2141.III.

Additionally, under *KSR*, and as outlined under the MPEP § 2143, additional rationales include (a) combining prior art elements according to known methods to yield predictable results; (b) simple substitution of one known element for another to obtain predictable results; (c) use of known technique to improve similar devices (methods, or products) in the same way; (d) applying a known technique to a known device (method, or product) ready for improvement to yield predictable results; (e) "obvious to try" - choosing from a finite number of identified, predictable solutions, with a reasonable expectation of success; (f) known work in one field of endeavor may prompt variations of it for use in either the same field or a different one based on design incentives or other market forces if the variations are predictable to one of ordinary skill in the art; and (g) some teaching, suggestion, or motivation in the prior art that would have led one of ordinary skill to modify the prior art reference or to combine prior art reference teachings to arrive at the claimed invention. Additionally, the obviousness inquiry asks "whether the claim inventions are rendered obvious by the teachings of the prior art as a whole." *In re Chevalier*, 500 Fed. Appx. 932, 934 (Fed. Cir. 2013).

Claims 4, 7, 13, 14, 18, 20, and 28

In the Office Action the Examiner rejected claims 4, 7, 13, 14, 18, 20, and 28 under pre-AIA U.S.C. § 103(a) as allegedly unpatentable over Kinoshita in view of U.S. Pub. No. 2002/0173234 to Sung. The Applicant respectfully disagrees and traverses this rejection.

With respect to claims 4, 7, 13, 14, 18, and 20, each of these claims depends from independent claim 1. MPEP 2143.03 clearly states that "If an independent claim is nonobvious under 35 U.S.C. 103, then any claim depending therefrom is nonobvious. *In re Fine,* 837 F.2d 1071, 5 USPQ2d 1596 (Fed. Cir. 1988)." As claim 1 has not been rejected as obvious, it is the Applicant's position that claims 4, 7, 13, 14, 18, and 20 are also not obvious. Accordingly, the Applicant respectfully requests that the rejection of these claims be withdrawn.

With respect to independent claim 28, the Examiner asserts that "Sung teaches a process of chemical-mechanical planarization (CMP), including the following steps: polishing a wafer against a rotating polishing pad; and applying the conditioner of claim 1 against the polishing pad to remove debris and condition the pad." The Applicant respectfully disagrees.

As previously discussed, Kinoshita clearly does not disclose the conditioner of claim 1. Sung likewise does not disclose "a plurality of polishing units secured to a surface of the base plate by an adhesive layer, each polishing unit including a plurality of tips secured in a binding layer." In contrast, Sung discloses "a CMP pad dresser which has a plurality of abrasive particles each coupled to a substrate member." See paragraph [0011], emphasis added. Therefore, each of the plurality of abrasive particles are coupled to the same substrate member. As such, Sung does not disclose a plurality of polishing units each including a plurality of tips secured in a binding layer. Thus, Sung does not teach "applying the conditioner of claim 1 against a polishing pad to remove debris and condition the pad." The Applicant respectfully requests that the Examiner withdraw the rejection of claim 28 under 35 U.S.C. 103.

Claim 15

As discussed above, because independent claim 1, from which claim 15 depends, has not been rejected as obvious, it is the Applicant's position that claim 15 is also not obvious. The Applicant respectfully requests that this rejection be withdrawn.

Claim 17

As discussed above, because independent claim 1, from which claim 17 depends, has not been rejected as obvious, it is the Applicant's position that claim 17 is also not obvious. The Applicant respectfully requests that this rejection be withdrawn.

Claims 3, 5, 8, 9, 16, 17, 21-23, and 29-32

Claims 3, 5, 8, 9, 16, 17, 21-23, and 29-32 have been rejected as obvious under pre-AIA 35 U.S.C. 103(a) as being allegedly unpatentable over Kinoshita. The Applicant respectfully disagrees.

With respect to claims 3, 5, 8, 9, 16, 17, and 21-23, as discussed above, independent claim 1 has not been rejected as obvious. Claims 3, 5, 8, 9, 16, 17, and 21-23 each ultimately depend from independent claim 1. Therefore, because independent claim 1 has not been rejected as

obvious, it is the Applicant's position that claims 3, 5, 8, 9, 16, 17, and 21-23 are also not obvious. The Applicant respectfully requests that these rejections be withdrawn.

With respect to claims 29-32, as discussed above, Kinoshita does not disclose the conditioner of claim 1. Therefore, Kinoshita does not teach "applying the conditioner of claim 1 against a polishing pad to remove debris and condition the pad." The Applicant respectfully requests that these rejections be withdrawn.

CONCLUSION

In view of the foregoing, the Applicant asserts that the pending claims present allowable subject matter and the allowance thereof is respectfully requested. If any impediment remains to examination after consideration of the above-recited remarks, which could be removed during a telephone interview, the Examiner is invited to telephone the undersigned attorney, at (801) 566-6633 so that such issues may be resolved as expeditiously as possible.

The Commissioner is hereby authorized to charge any additional fees associated with this communication or credit any overpayment to Deposit Account No. 20-0100.

DATED this 2nd day of May, 2016.

Respectfully submitted,

THORPE, NORTH & WESTERN, LLP

/David W. Osborne/

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DWO/JB

Electronic Patent Application Fee Transmittal

Application Number:	13797704
Filing Date:	12-Mar-2013
Title of Invention:	COMPOSITE CONDITIONER AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Filer:	David William Osborne/Nicole Solomon
Attorney Docket Number:	02074-32836.US

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($)
Extension - 1 month with $0 paid	2251	1	100	100
Miscellaneous:				
			Total in USD ($)	**100**

Electronic Acknowledgement Receipt

EFS ID:	25663070
Application Number:	13797704
International Application Number:	
Confirmation Number:	1089
Title of Invention:	COMPOSITE CONDITIONER 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:	02074-32836.US
Receipt Date:	02-MAY-2016
Filing Date:	12-MAR-2013
Time Stamp:	20:33:54
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Credit Card
Payment was successfully received in RAM	$100
RAM confirmation Number	21011
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		32836_US_Response.pdf	121563 cdec35d19df788399b47fd5895e894d172ef6dfb	yes	12

Multipart Description/PDF files in .zip description		
Document Description	**Start**	**End**
Amendment/Req. Reconsideration-After Non-Final Reject	1	1
Claims	2	6
Applicant Arguments/Remarks Made in an Amendment	7	12

Warnings:

Information:

2	Fee Worksheet (SB06)	fee-info.pdf	30826 c92234d09583f48184550863 0f174b8ab1238b6f	no	2

Warnings:

Information:

Total Files Size (in bytes):	152389

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/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 13/797,704	Filing Date 03/12/2013	☐ 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 **05/02/2016**

	(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))	* 32	Minus	** 32	= 0	X $40 =	0
Independent (37 CFR 1.16(h))	* 3	Minus	***3	= 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
/CAROLYN COFER/

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.**
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/797,704	03/12/2013	Chien-Min Sung	02074-32836.US	1089

20551 7590 08/26/2016
THORPE NORTH & WESTERN, LLP.
P.O. Box 1219
SANDY, UT 84091-1219

EXAMINER	
BERONJA, LAUREN M	

ART UNIT	PAPER NUMBER
3727	

NOTIFICATION DATE	DELIVERY MODE
08/26/2016	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):

patentdocket@tnw.com
rich@tnw.com
annette.fields@tnw.com

Office Action Summary	Application No. 13/797,704	Applicant(s) SUNG, CHIEN-MIN	
	Examiner LAUREN BERONJA	Art Unit 3727	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 *05/02/2016*.

☐ 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) *1-23 and 28-32* 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) *1-23 and 28-32* 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 _____ 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 _____.

3) ☐ Interview Summary (PTO-413) Paper No(s)/Mail Date. _____ .

4) ☐ Other: _____.

1. The present application is being examined under the pre-AIA first to invent provisions.

DETAILED ACTION

Response to Arguments

2. Applicant's arguments filed 05/02/2016 have been fully considered but they are not persuasive. Regarding claim 1, the Applicant argues that the prior art Kinoshita teaches the polishing units not being secured to a surface of the base plate by an adhesive layer. However, the Applicant has not put this wording into the limitations of claim 1. Claim 1 simply states "a plurality of polishing units secured to a surface of the base plate by an adhesive layer". The applicant does not imply using these words that the polishing units are secured directly to a surface of the base plate and therefore Kinoshita still reads on the limitation. Further, each of the polishing units 1 include multiple polishing tips that do not include a reference number and therefore reference number 1 used by the Examiner was just used in order to direct the Applicant toward the polishing unit and to see the different tips on the polishing unit.

Claim Rejections - 35 USC § 102

3. 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.

4. Claim 1, 2, 6 and 10-12 are rejected under pre-AIA 35 U.S.C. 102(b) as being anticipated by Kinoshita et al. (US 6,190,240).

5. Regarding claim 1, Kinoshita teaches a composite conditioner comprising: a base plate (3); and a plurality of polishing units (1) secured to the surface of the base plate by an adhesive layer (4), each polishing unit including a plurality of polishing tips (1) secured in a binding layer (2), wherein a height difference between a first highest polishing tip and a second highest polishing tip is **less than** or equal to about 10μm, a height difference between the first highest polishing tip and a tenth highest polishing tip is **less than** or equal to about 20μm, and a height different between the first highest polishing tip and a 100th highest polishing tip is **less than** or equal to about 40μm (all the polishing tips are around the same height and therefore fall in the range of **less than**), and the first highest polishing tip protrudes from the binding layer to a height of greater than or equal to about 50μm (Col. 3, lines 44-67).

6. Regarding claim 2, Kinoshita teaches the composite conditioner of claim 1, wherein at least 1% of the plurality of polishing tips (1) actively condition a CMP pad during a conditioning process (abstract).

7. Regarding claim 6, Kinoshita teaches the composite conditioner of claim 1, wherein the plurality of polishing tips include diamond (Col. 2, lines 26-36), cubic boron nitride, or a combination thereof (Col, 3, lines 44-67).

8. Regarding claim 10, Kinoshita teaches the composite conditioner of claim 1, wherein each polishing unit further includes a polishing unit substrate () upon which the plurality of polishing tips are secure with the binding layer (2).

9. Regarding claim 11, Kinoshita teaches the composite conditioner of claim 1, wherein the binding layer (2) is selected from the group consisting of a solder layer, a plating layer, a sintering layer, and a resin layer (abstract).

10. Regarding claim 12, Kinoshita teaches the composite conditioner of claim 11, wherein each polishing unit further comprises a metal cover layer (Col. 2, lines 26-36) that covers the binding layer, wherein the metal cover layer includes at least one material selected from the group consisting of Ni, Cr, Pd, Co, Pt, Au, Ti, Cu, W, and alloys thereof (Col. 2, lines 26-36).

Claim Rejections - 35 USC § 103

10. 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.

11. Claims 4, 7,13, 14, 18, 20, and 28 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita in view of Sung.

12. Regarding claim 4, Kinoshita is silent tin regard to the arrangement of the polishing units on the base plate. Sung, however, teaches the composite conditioner wherein the polishing units are arranged on the base plate in an arrangement selected from the group consisting of a single ring, double rings, multi-rings, radial arrangements, and spiral arrangements (Paragraph 0073). Therefore, it would have been obvious for

one having ordinary skill in the art at the time of the invention to have used the teachings of Sung and applied them to the invention of Kinoshita. Kinoshita doesn't teach a specific arrangement for the polishing units and therefore it would be obvious for one to search other conditioning plates in order to come to an arrangement.

13. Regarding claim 7, Kinoshita is silent in regard to the abrasive material on the polishing tips. Sung, however, teaches the plurality of polishing tips including diamond, and the diamond is deposition diamond, polycrystalline diamond, or a combination thereof (Paragraph 0061). Therefore, it would have been obvious to one having ordinary skill in the art to have used diamond deposited polishing tips in the invention of Kinoshita. Deposition diamond is known, as taught by Sung, to be good for abrading because of its rigidity as well as its thermal conductivity.

14. Regarding claim 13, Kinoshita is silent in regard to the material of the protective layer covering. Sung, however, teaches a metal cover layer (Paragraph 0063) that covers the binding layer and a protective layer including a material selected from the group consisting of Pd, Pt, silicon carbide, aluminum nitride, alumina, zirconia, diamond-like carbon (DLC) (which includes diamond, as diamond is carbon, and is "diamond-like") and combinations thereof (Paragraph 0064). Therefore, it would have been obvious to one having ordinary skill in the art to have learned from Sung that the alloys used would work in the invention of Kinoshita because both are used for the same type of application.

15. Regarding claim 14, Kinoshita is silent in regard to the material of the binding layer. Sung, however, teaches a binding layer that is a solder layer comprising 1 wt% or

more of a first material selected from the group consisting of B, P, Ti, or an alloy thereof (Paragraph 0074).). Therefore, it would have been obvious to one having ordinary skill in the art to have learned from Sung that the alloys used would work in the invention of Kinoshita because both are used for the same type of application.

16. Regarding claim 18, Kinoshita is silent in regard to the polishing tip particle size. Sung, however, teaches the composited conditioner wherein the polishing tips have a particle size from about 100 μm to about 500 μm (Paragraph 0068). Therefore, it would have been obvious for one having ordinary skill in the art at the time of the invention to have searched what a good particle size for a polishing tip is that has a diamond tip and found information taught by Sung to use in Kinoshita.

17. Regarding claim 20, Sung teaches the composite conditioner wherein the polishing tips are arranged in a predetermined pattern on the polishing unit substrate (Paragraph 0078).

18. Regarding claim 28, Sung teaches a process of chemical-mechanical planarization (CMP), including the following steps: polishing a wafer against a rotating polishing pad; and applying the conditioner of claim 1 against the polishing pad to remove debris and condition the pad.

19. Claim 15 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita in view of Romero (US 6,371,842).

20. Regarding claim 15, Kinoshita is silent in regard to the shape of the polishing units. Romero, however, teaches a patterned abrading article wherein the polishing units (21) are disc shaped (Fig. 1). Therefore, it would have been obvious for one

having ordinary skill in the art to have used the shape taught by Romero in the invention of Kinoshita because disc abrasive articles are, as taught by Romero, great conditioners. The disc shape is smooth and do not abruptly stop and therefore give the polishing pad a conditioned finish.

21. Claim 17 is rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita in view of Jeng et al. (US 6,524,523).

22. Regarding claim 19, Kinoshita is silent in regard to the adhesive of the composite conditioner being an organic adhesive. Jeng, however, teaches a polishing pad conditioner, comprising an organic adhesive that is spread flatly on the base of the dresser. It would have been obvious for one having ordinary skill in the art at the time of the invention to have used the teachings of Jeng in the invention of Kinoshita. Jeng teaches diamond abrasive particles being adhered to the base layer using an organic adhesive because it is a non-toxic adhesive that will not cause any trouble in a work environment.

23. Claims 3, 5, 8, 9, 16, 17, 21-23, and 29-32 rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Kinoshita.

24. Regarding the range of surface coverage by the units, the number of tips conditioning the pad, the crystal surface coverage, and the thickness of the adhesive, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have made the various components with the claimed size and amount ranges, for the predictable result of forming a conditioning tool, since it has been held that where the general conditions of a claim are disclosed in the prior art, discovering

the optimum or workable ranges involves only routine skill in the art. Regarding the diameter and 1C dimension of the workpiece, applicant appears to be claiming dimensions not of currently available workpieces, but of possible future workpieces, see for example pages 20-22 of applicant's specification. As such, it is the examiner's position that one of ordinary skill in the art would have considered it obvious to fashion a conditioning tool that conditions a polishing pad such that it is capable of working not just on present workpieces, but on possible future workpieces of the claimed sizes as well.

Conclusion

25. THIS ACTION IS MADE FINAL. Applicant is reminded of the extension of time policy as set forth in 37 CFR 1.136(a).

A shortened statutory period for reply to this final action is set to expire THREE MONTHS from the mailing date of this action. In the event a first reply is filed within TWO MONTHS of the mailing date of this final action and the advisory action is not mailed until after the end of the THREE-MONTH shortened statutory period, then the shortened statutory period will expire on the date the advisory action is mailed, and any extension fee pursuant to 37 CFR 1.136(a) will be calculated from the mailing date of the advisory action. In no event, however, will the statutory period for reply expire later than SIX MONTHS from the mailing date of this final action.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to LAUREN BERONJA whose telephone number is

(571)270-0167. The examiner can normally be reached on Monday - Friday 7:30am-5pm EST.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Monica Carter can be reached on 571-272-4475. 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.

/LAUREN BERONJA/
Examiner, Art Unit 3727

/MONICA CARTER/
Supervisory Patent Examiner, Art Unit 3727

Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13797704	SUNG, CHIEN-MIN
	Examiner	Art Unit
	MAURINA RACHUBA	3727

CPC- SEARCHED		
Symbol	Date	Examiner
B24B 37/34, 53/00, 53/017, 53/02	1/7/2015	MTR
update	12/19/2015	LMB

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
SEE eas			

SEARCH NOTES		
Search Notes	Date	Examiner
See EAST, inventor and citation searches	1/7/2015	MTR
update	12/19/2015	LMB
update	8/19/2016	LMB

INTERFERENCE SEARCH			
US Class/ CPC Symbol	US Subclass / CPC Group	Date	Examiner

/LAUREN BERONJA/ Examiner.Art Unit 3727	/MAURINA RACHUBA/ Primary Examiner.Art Unit 3727

EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	32	("5197249" "6190240" "6213856" "6371842" "20020173234" "20060079160" "7201645" "20070155298" "7658666" "20120301146" "8398466" "20140099868").pn.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/07 14:00
S2	15	(US-20140099868-$ or US-20070155298-$ or US-20060079160-$ or US-20020173234-$).did. or (US-8398466-$ or US-7658666-$ or US-7201645-$ or US-6371842-$ or US-6213856-$ or US-6190240-$ or US-5197249-$).did. or (US-20070155298-$ or US-20020173234-$ or US-20060079160-$ or US-5197249-$).did.	US-PGPUB; USPAT; DERWENT	OR	ON	2015/12/19 13:29
S3	7	S2 and (ring or (double adj rings) or radial or spiral)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:31
S4	4	S2 and (radial or polygon)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:36
S5	2	S2 and (organic with adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:52
S6	1	(composite near2 conditioner)and (organic with adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:53
S7	1	(composite near2 conditioner) and (organic with adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:53

S8	111	(composite near2 condition$3) and (organic with adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:53
S9	3	(composite near2 condition$3) with (organic with adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:53
S10	15	(composite near3 condition$3) with (organic with adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:53
S11	16	(composite near3 condition$3) with ((natural or organic) with adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:55
S12	7	S2 and adhesive	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:56
S13	7124	(organic adj adhesive)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:58
S14	40	S13 and conditioner	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:58
S15	32	S13 and (polishing adj pad)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	ON	2015/12/19 13:58
S16	46	("4992082" | "5384986" | "5454752" | "5486131" | "5522965" | "5707409" | "5785585" | "5916010" | "5921856").PN. OR ("6190240").URPN.	US-PGPUB; USPAT; USOCR	OR	ON	2016/08/05 14:52

8/ 22/ 2016 10:48:11 AM
C:\ Users\ lberonja2\ Documents\ EAST\ Workspaces\ 13797704.wsp

Index of Claims	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13797704	SUNG, CHIEN-MIN
	Examiner	Art Unit
	LAUREN BERONJA	3727

✓	Rejected	-	Cancelled	N	Non-Elected	A	Appeal
=	Allowed	÷	Restricted	I	Interference	O	Objected

☐ Claims renumbered in the same order as presented by applicant ☐ CPA ☐ T.D. ☐ R.1.47

CLAIM		DATE								
Final	Original	12/19/2015	08/05/2016							
	1	✓	✓							
	2	✓	✓							
	3	✓	✓							
	4	✓	✓							
	5	✓	✓							
	6	✓	✓							
	7	✓	✓							
	8	✓	✓							
	9	✓	✓							
	10	✓	✓							
	11	✓	✓							
	12	✓	✓							
	13	✓	✓							
	14	✓	✓							
	15	✓	✓							
	16	✓	✓							
	17	✓	✓							
	18	✓	✓							
	19	✓	✓							
	20	✓	✓							
	21	✓	✓							
	22	✓	✓							
	23	✓	N							
	24	N	N							
	25	N	N							
	26	N	N							
	27	N	N							
	28	✓	✓							
	29	✓	✓							
	30	✓	✓							
	31	✓	✓							
	32	✓	✓							

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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/797,704	03/12/2013	Chien-Min Sung	02074-32836.US	1089

20551 7590 03/10/2017

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SANDY, UT 84091-1219

EXAMINER
BERONJA, LAUREN M

ART UNIT	PAPER NUMBER
3727	

NOTIFICATION DATE	DELIVERY MODE
03/10/2017	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):

patentdocket@tnw.com
rich@tnw.com
annette.fields@tnw.com

Notice of Abandonment	Application No.	Applicant(s)
	13/797,704	SUNG, CHIEN-MIN
	Examiner	Art Unit
	LAUREN BERONJA	3727

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

This application is abandoned in view of:

1. ☒ Applicant's failure to timely file a proper reply to the Office letter mailed on *26 August 2016*.
   (a) ☐ A reply was received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply (including a total extension of time of _____ month(s)) which expired on _____.
   (b) ☐ A proposed reply was received on _____, but it does not constitute a proper reply under 37 CFR 1.113 to the final rejection.
   (A proper reply under 37 CFR 1.113 to a final rejection consists only of: (1) a timely filed amendment which places the application in condition for allowance; (2) a timely filed Notice of Appeal (with appeal fee); or (3) if this is utility or plant application, a timely filed Request for Continued Examination (RCE) in compliance with 37 CFR 1.114. Note that RCEs are not permitted in design applications.)
   (c) ☐ A reply was received on _____ but it does not constitute a proper reply, or a bona fide attempt at a proper reply, to the non-final rejection. See 37 CFR 1.85(a) and 1.111. (See explanation in box 7 below).
   (d) ☒ No reply has been received.

2. ☐ Applicant's failure to timely pay the required issue fee and publication fee, if applicable, within the statutory period of three months from the mailing date of the Notice of Allowance (PTOL-85).
   (a) ☐ The issue fee and publication fee, if applicable, was received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the statutory period for payment of the issue fee (and publication fee) set in the Notice of Allowance (PTOL-85).
   (b) ☐ The submitted fee of $_____ is insufficient. A balance of $_____ is due.
   The issue fee required by 37 CFR 1.18 is $_____. The publication fee, if required by 37 CFR 1.18(d), is $_____.
   (c) ☐ The issue fee and publication fee, if applicable, has not been received.

3. ☐ Applicant's failure to timely file corrected drawings as required by, and within the three-month period set in, the Notice of Allowability (PTO-37).
   (a) ☐ Proposed corrected drawings were received on _____ (with a Certificate of Mailing or Transmission dated _____), which is after the expiration of the period for reply.
   (b) ☐ No corrected drawings have been received.

4. ☐ The letter of express abandonment which is signed by the attorney or agent of record or other party authorized under 37 CFR 1.33(b). See 37 CFR 1.138(b).

5. ☐ The letter of express abandonment which is signed by an attorney or agent (acting in a representative capacity under 37 CFR 1.34) upon the filing of a continuing application.

6. ☐ The decision by the Board of Patent Appeals and Interference rendered on _____ and because the period for seeking court review of the decision has expired and there are no allowed claims.

7. ☒ The reason(s) below:

Attorney David Osborne confirmed that there will be no response filed regarding the Final Rejection.

/LAUREN BERONJA/ Examiner, Art Unit 3727	/Larry E Waggle, Jr/ Primary Examiner, Art Unit 3775

Petitions to revive under 37 CFR 1.137, or requests to withdraw the holding of abandonment under 37 CFR 1.181, should be promptly filed to minimize any negative effects on patent term.