CMP PAD DRESSERS WITH HYBRIDIZED ABRASIVE SURFACE AND RELATED METHODS

PRIORITY CLAIM:

This application is a continuation in part of copending U.S. Patent Application Serial No. 12/255,823, filed on October 22, 2008, which is a continuation in part of U.S. Patent Application Serial No. 12/168,110, filed on July 5, 2008, which claims the benefit of U.S. Provisional Patent Application Serial No. 60/976,198, filed September 28, 2007. U.S. Patent Application Serial No. 12/168,110 is also a continuation-in-part of copending U.S. Patent Application Serial No. 11/560,817, filed November 16, 2006. All of the above applications are hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to CMP pad conditioners used to remove material from (e.g., smooth, polish, dress, etc.) CMP pads. Accordingly, the present invention involves the fields of chemistry, physics, and materials science.

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 invention provides CMP pad dressers and methods for dressing or conditioning CMP pads. In one aspect, for example, a method for conditioning a CMP pad can include cutting the CMP pad with superabrasive cutting elements and controlling a degree of contact between the CMP pad and the cutting elements using control elements. In this case, the degree of contact is established through placement of the control elements relative to the cutting elements.

The degree of contact can be controlled using a variety of placements of the control elements relative to the cutting elements. In one aspect, for example, controlling the degree of contact includes alternating regions of cutting elements with regions of control elements. In another aspect, the degree of contact can be controlled by locating the regions of control elements at a distance from the regions of cutting elements to establish the degree of contact in relation to material characteristics of the CMP pad. This can be accomplished in an alternating pattern or a non-alternating pattern. In yet another aspect, controlling the degree of contact includes locating the regions of control elements at a distance from the regions of cutting elements to affect a degree of compression of the CMP pad along a leading edge of the regions of cutting elements.

In another aspect of the present invention, a CMP pad dresser is provided. Such a dresser can include an organic matrix and a plurality of cutting elements partially embedded

directly in the organic matrix, where the cutting elements are arranged into a plurality of distinct cutting element regions. The dresser can also include a plurality of control elements partially embedded directly in the organic matrix, where the control elements are arranged into a plurality of distinct control element regions. Furthermore, the cutting element regions and the control element regions are positioned in an alternating pattern, and the control element regions are spaced relative to the cutting element regions to control a degree of contact between the cutting elements and a CMP pad. In some aspects, the organic matrix is coupled to a CMP pad dresser support substrate.

In one aspect, each of the plurality of cutting elements and each of the plurality of control elements includes a CMP pad contact region, and wherein the contact regions are leveled relative to one another such that no contact region protrudes above another contact region by more than about 30 microns.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, top plan view of an exemplary pad conditioner in accordance with an embodiment of the invention;

FIG. 2A is an enlarged, perspective schematic view of an exemplary abrasive segment that can be used in the pad conditioner of FIG. 1;

FIG. 2B is an enlarged, perspective schematic view of an exemplary abrasive segment that can be used in the pad conditioner of FIG. 1;

FIG. 2C is an enlarged, perspective schematic view of an exemplary abrasive segment that can be used in the pad conditioner of FIG. 1;

FIG. 3A is a side, schematic view of an abrasive segment having a cutting face shown removing material from a section of a CMP pad;

FIG. 3B is a side, schematic view of an abrasive segment having a differently configured cutting face shown removing material from a section of a CMP pad;

FIG. 3C is a side, schematic view of an abrasive segment having a differently configured cutting face shown removing material from a section of a CMP pad; and

FIG. 4 is a schematic, side view of a portion of a CMP pad dresser having a series of abrasive segments arranged at varying elevations relative to one another.

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. For example, an abrasive layer is illustrated in some of the figures as including a plurality of abrasive particles: however, many of the specific embodiments disclosed herein do not necessarily include abrasive particles. Therefore, it will be appreciated that departure can and likely will be made from the specific dimensions and aspects shown in the figures in order to produce the pad conditioners 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 should be noted that, as used in this specification and any appended or following claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "an abrasive segment" can include one or more of such segments.

Definitions

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

All mesh sizes that may be referred to herein are U.S. mesh sizes 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 terms "pad conditioner" and "pad 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, a pad conditioner "substrate" or "support substrate" refers to a portion of a pad conditioner that supports an organic matrix, and to which abrasive materials, segment

blanks that carry abrasive materials, cutting elements, control elements, etc. may be affixed. Substrates useful in the present invention may be of a variety of shapes, thicknesses, or materials that are capable of supporting an organic matrix in a manner that is sufficient to provide a pad conditioner useful for its intended purpose. Substrates may be of a solid material, a powdered material that becomes solid when processed, or a flexible material. Examples of typical substrate materials include without limitation, metals, metal alloys, ceramics, relatively hard polymers or other organic materials, glasses, and mixtures or combinations thereof.

As used herein, "segment blank" refers to a structure similar in many respects to the pad conditioner substrates defined above. Segment blanks are utilized in the present invention to carry abrasive layers: attachment of the abrasive layers to the pad conditioner substrates is typically achieved by way of attaching the segment blanks to the pad conditioner substrates. It is important to note that a variety of techniques of attaching the segment blanks to the substrates, and a variety of techniques of attaching the abrasive layers to the segment blanks, are discussed herein. It is to be understood that all of these various attachment mechanisms can be used interchangeably herein: that is, if a method of attaching a segment blank to a substrate is discussed herein, the method of attachment discussed can also be used to attach an abrasive layer to a segment blank. For any particular CMP pad dresser being discussed, however, it is understood that attachment methods of the abrasive layers to the segment blanks can differ from, or can be the same as, the method used to attach the segment blanks to the pad conditioner substrate.

As used herein, “geometric configuration” refers to a shape that is capable of being described in readily understood and recognized mathematical terms. Examples of shapes

qualifying as "geometric configurations" include, without limitation, cubic shapes, polyhedral (including regular polyhedral) shapes, triangular shapes (including equilateral triangles, isosceles triangles and three-dimensional triangular shapes), pyramidal shapes, spheres, rectangles, "pie" shapes, wedge shapes, octagonal shapes, circles, etc.

As used herein, "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, "abrasive profile" is to be understood to refer to a shape, configuration, or a space defined by abrasive materials that can be used to remove material from or reorganize material on a CMP pad. Examples of abrasive profiles include, without limitation, rectangular shapes, tapering rectangular shapes, truncated wedge shapes, wedge shapes, a "saw tooth" profile and the like. In some embodiments, the abrasive profile exhibited by abrasive segments of the present invention will be apparent when viewed through a plane in which the CMP pad will be oriented during removal of material from the CMP pad.

As used herein, an "abrading surface or point" may be used to refer to a surface, edge, face, point or peak of an abrasive segment or cutting element that contacts and removes material from a CMP pad. Generally speaking, the abrading surface or point is the portion of the abrasive segment that first contacts the CMP pad as the abrasive segment or cutting element and the CMP pad are brought into contact with one another.

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

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

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

As used herein, an "abrasive layer" describes a variety of structures capable of removing (e.g., cutting, polishing, scraping) material from a CMP pad. An abrasive layer can include a mass having several cutting points, ridges or mesas formed thereon or therein. It is notable that such cutting points, ridges or mesas may be from a multiplicity of protrusions or asperities included in the mass. Furthermore, an abrasive layer can include a plurality of individual abrasive particles that may have only one cutting point, ridge or mesa formed thereon or therein. An abrasive layer can also include composite masses, such as PCD pieces, segment or blanks, either individually comprising the abrasive layer or collectively comprising the abrasive layer.

As used herein, "metallic" includes 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, "material characteristic" refers to the physical and/or chemical properties of a CMP pad. These can include properties such as molecular makeup, compressibility, softness, pore density, and the like.

As used herein, "cutting element" refers to an element of a CMP pad dresser that is intended to cut, abrade, remover, or otherwise reorganize the material of a CMP pad for the purpose of conditioning or dressing. Cutting elements can function using a point, edge, face, or any other region of the cutting element that is capable of conditioning or dressing the CMP pad. Cutting elements should be considered to include individual cutters such as diamond particles, as well as segment blanks that contain multiple cutters provided the context allows.

As used herein, "control element" refers to an element of a CMP pad dresser that is intended to control the degree of contact between the CMP pad dresser and a CMP pad, or portions of the dresser, such as cutting elements and the CMP pad. Thus, in some aspects

control elements compress the CMP pad to a degree that alters the contact between the cutting elements and the CMP pad. It should be noted that control elements can be made of abrasive materials, and as such can function to dress or condition the CMP pad during compression. However, in such cases, the CMP pad is primarily conditioned by the cutting elements. As such, the use of the term "abrasive" herein should also include control elements when appropriate.

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. As an arbitrary example, when two or more objects are referred to as being spaced a "substantially" constant distance from one another, it is understood that the two or more objects are spaced a completely unchanging distance from one another, or so nearly an unchanging distance from one another that a typical person would be unable to appreciate the difference. The exact allowable degree of deviation from absolute completeness may in some cases depend upon 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. As an arbitrary example, a cavity that is "substantially free of" foreign matter would either completely lack any foreign matter, or so nearly completely lack foreign matter that the effect would be the same as if it completely lacked foreign matter. In other words, a cavity that is "substantially free of" foreign matter may still actually contain minute portions of foreign matter so long as there is no measurable effect upon the cavity as a

result thereof.

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 generally provides pad conditioners and associated methods that can be utilized in conditioning (e.g., smoothing, polishing, dressing) or otherwise affecting a CMP pad to remove material from the CMP pad in order to provide a finished, smooth and/or flat surface to the pad. Pad conditioners of the present invention can be advantageously utilized, for example, in dressing CMP pads that are used in polishing, finishing or otherwise affecting silicon wafers.

It has now been discovered that CMP pad dressing can be improved by alternating cutting and furrowing in the same dressing operation. This can be accomplished by utilizing a CMP pad dresser having a dressing surface containing blade abrasive segments and particle abrasive segments arranged in an alternating fashion. Thus as the CMP pad dresser moves relative to the CMP pad, the surface of the CMP pad is alternately cut with the blade abrasive segments and furrowed with the particle abrasive segments.

It has also been discovered that CMP pad dressing can be improved by utilizing different CMP pad dresser elements in an alternating fashion to control the degree of contact between the CMP pad and portions of the CMP pad dresser that are cutting the pad. By positioning control elements relative to cutting elements, the degree of contact between the CMP pad and the cutting elements can be controlled, thus increasing the efficiency and/or quality of the dressing action. In a circular tool such as a CMP pad dresser, an alternating arrangement of regions of cutting elements and regions of control elements can be used.

For example, by alternating regions of cutting elements each having a sharp abrading surface and regions of control elements each having a blocky or dull abrading surface, compression of the CMP pad by the sharper cutting elements can be minimized. As an

explanatory example, a CMP pad dresser having cutting elements spaced far apart requires more downward compression into the pad to facilitate cutting as compared to a CMP pad dresser having cutting elements closer together, due in part to the upwelling of CMP pad material between the cutting elements. A CMP pad dresser having cutting elements positioned more closely together facilitates the cutting of the pad with less compression, thus reducing damage to the pad from overcutting.

By alternating regions of control elements in between regions of cutting elements, the compression of the CMP pad during dressing can be controlled. Positioning the control elements further away from the cutting elements causes the degree of contact and thus the compression of the pad by the cutting elements to be increased. This increase in compression can result in a more aggressive dressing by the cutting elements. Positioning the control elements closer to the cutting elements reduces the upwelling of the pad material between the cutting elements, thus decreasing the degree of contact and the compression of the pad. Such a configuration can be particularly effective when using CMP pads made from the soft materials required for many current delicate polishing procedures. Such soft materials can be more effectively dressed using lower dresser compression due to the material characteristics of the CMP pad, which can experience high degrees of deformation when pressure from a dresser is applied.

Additionally, the control elements can be spaced from the cutting elements at a distance that allows the CMP pad to be cut as it is being expanded from a compressed state. More specifically, as the CMP pad is relaxing from the compressed state caused by the control elements a slope is formed in the pad. The abrading surfaces of the cutting elements can engage the pad along this slope and thus cut the pad with less compression. This can

minimize the extent of penetration of the bodies of the cutting elements into the pad, thus minimizing drag and reducing tearing the CMP pad material.

While these techniques can be used to dress a variety of CMP pad materials, they can be particularly beneficial for dressing pads made of soft CMP pad materials. A variety of soft materials are contemplated. In one aspect, for example, the soft material can be about as soft as a conventional polyurethane pad. In another aspect, the soft material can be softer than a conventional polyurethane pad. In yet another aspect, the soft material can be at least about 10% softer than a conventional polyurethane pad. In a further aspect, the soft material can be at least about 25% softer than a conventional polyurethane pad. In yet a further aspect, the soft material can be at least about 50% softer than a conventional polyurethane pad.

As is shown in FIG. 1, a CMP pad conditioner 10 is provided. In one aspect, the pad conditioner can include a plurality of distinct cutting element regions 12 and a plurality of distinct control element regions 14 positioned in an alternating arrangement on a support substrate 16. In one specific aspect, the cutting element regions can be cutting elements disposed directly in an organic matrix on the pad conditioner substrate and the control element region can be blocky control elements disposed directly in the same organic matrix. The control element regions are thus positioned and spaced relative to the cutting element regions to control the degree of contact between the sharp cutting elements and the CMP pad. In another aspect, the pad conditioner can include a plurality of blade abrasive segments and a plurality of particle abrasive segments positioned in an alternating arrangement on a pad conditioner substrate.

Numerous alternating arrangements are contemplated, including, without limitation, the radial arrangement shown in FIG. 1. It is noted that blade abrasive segments, particle

abrasive segments, cutting elements, and control elements can be referred to herein collectively as the "abrasive elements" or "abrasive segments" for the sake of simplicity. Similarly, the term "abrasive layer" may be used to refer collectively to any abrasive material, segment, or element for simplicity sake.

The CMP pad conditioner can also include multiple annular rings of abrasive segments, cutting elements, and/or control elements, as opposed to the single annular ring shown in FIG. 1. Furthermore, it should be noted that regions or segments would also include arrangements where grouped multiples of one or more regions or segments were included in the pattern. For example, in one aspect the pattern of abrasive elements can include two or more blade abrasive segments alternating between each pair of particle abrasive segments. In another aspect the pattern of abrasive elements can include three or more blade abrasive segments alternating between each pair of particle abrasive segments. Additionally, in some aspects, multiple particle abrasive segments can be grouped and alternated in between blade abrasive segments or segment groups.

Various configurations of cutting elements and control elements are contemplated. As such, any configuration of elements whereby control elements function to control the degree of contact and thus the compression of the cutting elements during conditioning of a CMP pad should be considered to be within the present scope. For example, in one aspect, the cutting elements can be blade elements and the control elements can be particle elements having a dull edge or face oriented toward the pad. In this case, the placement of the dull control elements relative to the blade elements can control the compression and thus the cutting of the pad by the blade elements. In another aspect, the cutting elements can be blade elements having a sharp cutting edge oriented toward the pad and the control elements can be blade elements

having a dull edge as compared to the blade cutting elements. Thus the duller blade elements compress the CMP pad and control the degree of contact between the sharper blade elements and the CMP pad. In yet another aspect, the cutting elements can be particle elements having a sharp point or edge oriented toward the pad and the control elements can be particle elements having a dull edge or point oriented toward the pad.

A variety of materials are contemplated for use as control and cutting elements. 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 cutting elements and control elements include diamond materials. Such diamond materials can include natural or synthetic diamond, single crystal, polycrystalline, and the like. In another aspect, the cutting elements and control elements include cubic boron nitride materials.

The pad conditioner substrate 16 can vary according to the applications for which the pad conditioner is designed, but in one aspect includes a face on which the organic matrix can be affixed to allow the pad conditioner to be used to grind, plane, cut or otherwise remove material from a CMP pad (not shown). The abrasive elements or segments can be permanently fixed to the pad conditioner 16 in an orientation that enables removal of material from the CMP pad as the pad conditioner and the pad are moved relative to one another. For example, as has been described and as shown in FIG. 1, the regions 12 and 14 are arranged radially along an edge of a substantially circular pad conditioner substrate. Such an arrangement has been found well suited to remove material from a CMP pad (while "dressing" the pad) by rotating the pad conditioner substrate relative to the pad.

The present invention provides a number of advantages over conventional devices. For embodiments using abrasive segments, one such advantage lies in the ability to customize methods of attachment of the abrasive layer to the segment blank independently of methods of attachment of the segment blank or blanks to the pad conditioner substrate. For example, as various attachment methods may involve very high temperatures and/or pressures, very demanding environmental conditions, or simply are very labor intensive when attempted with pad conditioners of large or complex surface areas, performing the attachment method on distinct, easily handled segment blanks can improve costs, efficiencies and integrities of the attachment process. Also, leveling of the components of the abrasive layer on each segment blank can be performed more easily when done in discrete, relatively small lots. The resulting plurality of abrasive segments can likewise be more easily positioned, leveled, spaced, oriented, etc., across the face of the pad conditioner substrate after the abrasive layer is individually attached to each of the abrasive segments.

In addition, by obtaining a plurality of abrasive segments, each with an abrasive layer already attached thereto, an abrasive pattern across the face of the pad conditioner substrate can be designed to optimize various conditioning procedures. For example, the spacing between adjacent abrasive segments can be carefully selected to aid in, or better control, the flow of various fluids (e.g., slurry) around and through the abrasive segments to increase the efficacy and efficiency of the material removing process. Also, as shown in FIG. 1, segment blanks having differing abrasive profiles (e.g., different sizes, shapes, abrasive aggressiveness, etc.) can be used on a single substrate, to enable customization of an abrading profile of the pad conditioner as a whole. The same principles apply to CMP pad dressers having cutting elements and control elements embedded in an organic matrix.

Numerous configurations of abrasive segments are contemplated, depending on the nature of the CMP pad and the desired dressing characteristics. In one aspect, as exemplified in FIG. 2A, each particle abrasive segment 14 can include a segment blank 18 and an abrasive layer 20 attached to the segment blank. The abrasive layer 20 can include a superhard abrasive material: in the exemplary embodiment of FIG. 2A, the superhard abrasive material includes a plurality of superabrasive particles 22.

In another aspect, as exemplified in FIG. 2B, a blade abrasive segment 12 can include a segment blank 24 and an abrasive layer 26 attached to the segment blank as an elongate cutting blade. It should be noted that these blades can also be used as cutting elements or control elements that are disposed directly into the organic matrix. These blades can include a significantly longer length than a width, similar to blade of a conventional knife. In this aspect of the invention, the blade can be used to cut, scrape, carve, or control a relatively wide swath of area of the CMP pad. The abrasive layer 26 of the blade abrasive element includes a continuous cutting edge 28. In another aspect, as exemplified in FIG. 2C, a blade abrasive element 12 can include a segment blank 30 and an abrasive layer 32 attached to the segment blank as an elongate cutting blade. Additionally, in some aspect the abrasive layer can be disposed directly in the organic matrix. In contrast to the aspect shown in FIG. 2B, the abrasive layer 32 of the blade abrasive element includes a series of cutting teeth 34 formed in the abrasive layer. Further details regarding the construction and use of abrasive segments and/or blades can be found in U.S. Provisional Patent Application Serial No. 60/987,687, filed November 13, 2007, which is hereby incorporated herein by reference.

The cutting action of the blade elements is now shown to be advantageous to the dressing of a CMP pad. As is shown in FIGs. 3A-3C, for example, an embodiment is shown

which aids in addressing issues relating to plastic deformation of a CMP pad (shown by example and in sectioned view at 42). As has been described, this embodiment reduces the downward force required between the pad conditioner and the CMP pad. As a result, the CMP pad is left with a conditioned surface that is much more smooth and level than that obtained using conventional methods.

The conditioner shown in FIGs. 3A-3C can include abrasive layer 44 (only a section of which is shown). The abrasive layer can include a cutting face 46 angled at 90 degrees or less relative to a finished surface to be applied to the CMP pad (e.g., relative to movement of the cutting face away from the finished surface – sometimes referred to as a positive cutting angle). The face 46 of the abrasive layer 44 can be oriented such that relative movement of the pad conditioner (in the direction indicated at 48 in FIG. 3A) and the CMP pad 42 results in clean removal of material from the CMP pad with the cutting face to thereby condition the CMP pad.

By angling the cutting face 46 at 90 degrees or less, relative to a finished surface to be applied to the pad 42, the dressing process can cleanly shave a layer of pad material from the pad. The resultant surface applied to the pad can be safely used in the CMP process without damaging expensive silicon wafers. The present pad conditioners can be used to shave even a very shallow, thin layer of material from the pad and leave behind a clean, smooth and even finished surface on the pad. This technique can be used to remove thin layers of glaze that can be formed on the surface of the CMP pad.

The cutting face 46 is shown in FIGs. 3A and 3B oriented at an angle $\square_1$ of about 90 degrees relative to the finished surface to be applied to the CMP pad. Cutting face 50 of FIG. 3C is oriented at angle $\square_2$ that is less than 90 degrees relative to the finished surface to be

applied to the CMP pad, on the order of about 60 degrees. The cutting faces can be oriented at a variety of angles, and in one embodiment vary from about 45 degrees to about 90 degrees relative to the finished surface of the CMP pad. It has been found that reducing the angle creates an even sharper cutting interface between the cutting element and the pad.

Those embodiments illustrated in the figures that include angled cutting faces each include a cutting face that is formed having the corresponding angle. In some embodiments, however, it is to be understood that a relatively normal (e.g., 90 degree) cutting face can be utilized, except that the abrasive segment on which the cutting face is formed can be "tilted" when attached to the substrate. In other words, the cutting face is not angled relative to the abrasive segment, rather angling of the abrasive segment results in angling of the cutting face. In this manner, an angled cutting face is provided without requiring that the referenced angle be formed on (or in) the abrasive segment.

Additional and varying abrasive segments, cutting elements, and control elements for use in the present invention are also contemplated. For example, use is contemplated of the various cutting elements/abrasive segments detailed in U.S. Patent Application No. 11/357,713, filed February 17, 2006, which is hereby incorporated herein by reference. In addition, formation of the abrasive layer on the segment blanks can be accomplished by way of a variety of techniques, including but not limited to vapor deposition techniques similar to those outlined in U.S. Patent Application Serial No. 11/512,755, filed August 29, 2006, which is hereby incorporated herein by reference. In addition, the abrasive segments can be formed utilizing ceramic components (as either or both the segment blank and/or the abrasive layer); electroplating techniques, etc.

In the embodiment illustrated in FIG. 4, a series of abrasive layers 54, 54' and 54" is provided, each of which includes a cutting tip oriented at a different elevation. In this aspect of the invention, the leading abrasive segment or cutting element (of which abrasive layer 54 forms a part) is generally at a relatively higher elevation than are trailing abrasive layers 54' and 54", as the trailing layers would not otherwise contact pad material remaining after the leading blade has passed. The abrasive segments having abrasive layers 54, 54' and 54" can be formed in a variety of manners and in a variety of shapes, sizes and configurations, as detailed, for example, in U.S. Provisional Patent Application Serial 60/988,643, filed November 16, 2007, which is hereby incorporated herein by reference in its entirety. This embodiment can utilize intentionally cascaded cutting elements to achieve a desired abrading affect.

Numerous materials and methods of manufacturing are contemplated for constructing the CMP pad conditioners of the present invention. It should be noted that the materials and techniques disclosed herein are exemplary, and additional materials and techniques can be utilized without departing from the present scope.

The various segment blanks shown and discussed herein can be formed from a variety of materials, including, without limitation, metallic materials such as aluminum, copper, steel, metal alloys, etc., ceramic materials, glasses, polymers, composite materials, etc. Generally speaking, virtually any material to which an abrasive segment can be attached thereto will suffice.

In some embodiments, the material of the segment blank can be chosen to provide superior results during the process of attaching the abrasive layer thereto. The abrasive layer can be attached to the segment blank in a variety of manners, including epoxy bonding methods (e.g., organic bonding methods), metal brazing, sintering, electrodeposition, etc. The

material of the segment blank can thus be chosen based upon the attachment process anticipated. For example, a segment blank formed partially or fully from nickel, or stainless steel, can be utilized in some processes involving brazing and/or sintering. Also, ceramic or metallic materials might be utilized in organic attachment methods.

Various embodiments of the invention employ various methods of attachment of the abrasive layer to the segment blank, or the cutting and control elements to the support substrate. In one aspect, an organic material layer or matrix can be deposited on the segment blank or support substrate, and one or more abrasive particles, chips, segments, elements, etc., can be fixed thereto by way of the organic material layer or matrix. Examples of suitable organic matrix materials include, without limitation, amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof.

So-called "reverse casting" methods can be used to accurately and controllably orient and attach the abrasive materials or elements onto a segment blank (and to orient and attach the segment blanks or the cutting elements and control elements to the pad conditioner support substrate). Such methods can include initially securing a superabrasive material, e.g., a plurality of superabrasive particles, to a substrate using a "mask" material. The portions of the particles protruding from the mask material can then be attached to a substrate, such as a segment blank, using the methods discussed herein, after which (or during which), the masking material can be removed.

Suitable reverse casting methods can be found in various patents and patent applications to the present inventor, including U.S. Patent Application Serial No. 60/992,966, filed December 6, 2007; U.S. Patent Application Serial No. 11/804,221, filed May 16, 2007; and U.S. Patent Application Serial No. 11/805,549,filed May 22, 2007, each of which is hereby incorporated herein by reference. These techniques can also be used when attaching the abrasive segments or cutting and control elements of the present invention to pad conditioner support substrate in addition to attaching the abrasive layers of the present invention to the segment blanks. Such techniques allow very precise control of lateral placement of the abrasive segments or abrasive layers, as well as very precise control of relative elevation of the abrasive segments or abrasive layers.

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

In one aspect of the present invention, the organic material 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 can be essentially irreversible, if desired.

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

Numerous additives may be included in the organic material to facilitate its use. For example, additional crosslinking agents and fillers may be used to improve the cured characteristics of the organic material layer. Additionally, solvents may be utilized to alter the characteristics of the organic material in the uncured state. Also, a reinforcing material may be disposed within at least a portion of the solidified organic material layer. Such reinforcing material may function to increase the strength of the organic material layer, and thus further

improve the retention of the individual abrasive segments. In one aspect, the reinforcing material may include ceramics, metals, or combinations thereof. Examples of ceramics include alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof.

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

Specific non-limiting examples of silanes suitable for use in the present invention include: 3- glycidoxypropyltrimethoxy silane (available from Dow Corning as Z-6040); γ-methacryloxy propyltrimethoxy silane (available from Union Carbide Chemicals Company as A-174); β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, γ- aminopropyltriethoxy silane, N-(β-aminoethyl)-γ-aminopropylmethyldimethoxy silane (available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.).

Specific non-limiting examples of titanate coupling agents include:

isopropyltriisostearoyl titanate, di(cumylphenylate)oxyacetate titanate, 4-aminobenzenesulfonyldodecylbenzenesulfonyl titanate, tetraoctylbis (ditridecylphosphite) titanate, isopropyltri(N-ethylamino-ethylamino) titanate (available from Kenrich Petrochemicals. Inc.), neoalkyoxy titanates such as LICA-01, LICA-09, LICA-28, LICA-44 and LICA-97 (also available from Kenrich), and the like.

Specific non-limiting examples of aluminum coupling agents include acetoalkoxy aluminum diisopropylate (available from Ajinomoto K.K.), and the like.

Specific non-limiting examples of zirconate coupling agents include: neoalkoxy zirconates, LZ-01, LZ-09, LZ- 12, LZ-38, LZ-44, LZ-97 (all available from Kenrich Petrochemicals, Inc.), and the like. Other known organometallic coupling agents, e.g., thiolate based compounds, can be used in the present invention and are considered within the scope of the present invention.

Metal brazing can also be utilized to attach the abrasive layer to a segment blank. Metal brazing techniques are known in the art. For example, in fabricating a diamond particle abrasive segment, the process can include mixing diamond particles (e.g., 40/50 U.S. mesh grit) with a suitable metal support matrix (bond) powder (e.g., cobalt powder of 1.5 micrometer in size). The mixture is then compressed in a mold to form a desired shape. This "green" form of the tool can then be consolidated by sintering at a temperature between 700-1200 degrees C to form a single body with a plurality of abrasive particles disposed therein. Finally, the consolidated body can be attached (e.g., by brazing) to a segment blank. Many other exemplary uses of this technology are known to those having ordinary skill in the art.

It should also be noted that various sintering methods can also be utilized to attach the

abrasive layer to the segment blank. Suitable sintering methods will be easily appreciated by one of ordinary skill in the art having possession of this disclosure.

The abrasive layer can also be attached to a segment blank by way of known electroplating and/or electrodeposition processes. As an example of a suitable method for positioning and retaining abrasive materials prior to and during the electrodeposition process, a mold can be used that includes an insulating material that can effectively prevent the accumulation of electrodeposited material on the molding surface. Abrasive particles can be held on the molding surface of the mold during electrodeposition. As such, the accumulation of electrodeposited material can be prevented from occurring on the particle tips and the working surface of the pad conditioner substrate. Such techniques are described in U.S. Patent Application Serial No. 11/292,938, filed December 2, 2005, which is hereby incorporated herein by reference.

One or more apertures can extend through the insulating material to allow for circulation of an electrolytic fluid from an area outside the mold through the mold and to the surface of the pad conditioner substrate in order to facilitate electrodeposition. Such circulation can be advantageous as it is generally necessary to keep a sufficient concentration of ions in an electrolytic fluid at the location of electrodeposition. Other well known techniques can also be utilized, it being understood that the above-provided example is only one of many suitable techniques.

The segment blank can similarly be attached to the pad conditioner substrate in a variety of manners. Depending upon the material from which the segment blank is formed, various manners of fixing the segment blank to the pad conditioner substrate may be utilizing.

Suitable attachment methods include, without limitation, organic binding, brazing, welding, etc.

The geometric configuration of a given abrasive segment can vary. For example, in one aspect the abrasive segment can include a generally rectangular or trapezoidal segment blank with a layer of abrasive material attached to an upper portion thereof. The size of the segment blank can vary. In one aspect of the invention, segment blank size can be adjusted to achieve uniform distribution of diamond particles and/or cutting blades about an annular ring array. In the case of particle abrasive segments, each segment can contain a plurality of diamond particles with pitch set from 3X to 10X of the diamond size. Smaller segments can be better distributed to share the loading during dressings.

The modular nature of the present systems allows a great deal of flexibility in attaching the abrasive layer to the segment blanks. As the segment blanks can be prepared separately from the pad conditioner substrate, a variety of manufacturing advantages can be realized when applying the abrasive layer to the segment blank, without regard to the size, shape, mass, material, etc., of the pad conditioner substrate to which the segment blanks will eventually be attached.

In one aspect, the abrasive segments arranged about the face of the conditioner substrate can each be substantially the same in size, shape, abrasive composition, height relative to one another, etc. In other embodiments, the size, shape, abrasive composition, height relative to one another, etc., can be purposefully varied, to achieve optimal design flexibility for any particular application. Also, each of the afore-mentioned qualities can be varied from one segment to another: e.g., alternating segments can include PCD abrasive pieces, chips or slats, with adjacent segments including abrasive particles.

The retention of abrasive segments or elements on the pad conditioner substrate can be improved by arranging the abrasive segments or elements such that mechanical stress impinging on any individual abrasive segment or element is minimized. By reducing the stress impinging thereon, abrasive materials can be more readily retained in place on the substrate, particularly for delicate tasks. Minimizing of stress variations between segments or elements can be accomplished by spacing the segments or elements evenly (or consistently) from one another, leveling to a uniform height (relative to the face of the pad conditioner substrate) an uppermost portion of each segment or element, radially aligning the segments or elements about the face of the pad conditioner substrate, etc. Various other height and spacing techniques can be utilized to obtain a desired affect.

In one embodiment of the invention, the spacing of the abrasive segments can be adjusted to alter the contact pressure of the contact portion (e.g., the portion of the segment that engages and removes material from the CMP pad) of each segment. In general, the farther the segments are spaced from one another, the higher the contact pressure between the segment and the CMP pad. Thus, a higher density of abrasive segments across the face of the pad conditioner substrate can, in some cases, provide a more desirable abrasive interface between the pad conditioner substrate and the CMP pad. In other applications, a lower density of abrasive segments may be beneficial. In either case, the present invention provides a great deal of design flexibility to obtain the optimal abrading profile.

By forming the abrasive segments in individual units having defined geometric shapes, arrangement of the abrasive segments in a very precise manner becomes much easier. As the defined geometric shapes can be replicated fairly precisely from one abrasive segment to another, the positioning of, and accordingly, the stress impinged upon, each abrasive segment

can be accomplished fairly consistently across the face of the pad conditioner substrate in question. With prior art abrasive grits, for example, the overall shape and size of each a plurality of grits might change considerably from one grit to another, making precise placement of the grits difficult to accomplish. This problem is adequately addressed by the advantageous features of the present invention.

It has been found that diamond pad conditioners used commercially normally contain about ten thousand diamond particles. Due to the distortion of the substrate, particularly when the disk is manufactured by a high temperature process (e.g. by brazing), and also the distribution of particle sizes and diamond orientations, the cutting tips are located at different heights. When they are pressed against a polishing pad, only about 1% of the protruded diamond can be in engagement with a pad. This can increase the stress on the diamond cutting most deeply into the pad, and the diamond may break and cause catastrophic scratching of the expensive wafers.

By utilizing the reverse casting methods as described above, the height difference of between particles can be greatly reduced. In one aspect of the invention, abrasive segments or elements are set on a flat metal (e.g. stainless steel) mold with designed spacing in a retainer ring. Epoxy with hardener fully mixed can be poured into the retainer ring to fill up and cover all segments. After curing (with or without heating), the retainer ring and the mold can be removed. The abrasive segments or elements are thereby firmly embedded in the epoxy matrix. Due to the leveling of the abrasives by the flat mold, the tip height variations of the tallest abrasives are minimized.

EXAMPLES

The following examples present various methods for making the pad conditioners of the present invention. Such examples are illustrative only, and no limitation on the present invention is to be thereby realized.

Example 1:

A pad conditioner is formed by arranging diamond particles (e.g. 50/60 mesh) on a stainless steel flat mold (also, a slightly convex or contoured mold can be utilized) having a layer of adhesive (e.g. acrylic). A hard rubber material is used to press individual diamond particles into the adhesive while tips of the particle are leveled by the flat mold. A mixture of epoxy and hardener is then poured onto the particles protruding outside the adhesive (a containment ring oriented outside the mold can retain the epoxy). After curing, the mold is then removed and the adhesive is peeled away. The resulting dresser contains diamond particles protruding outside a solidified epoxy substrate. The back of the epoxy can be machined and the disk adhered to a stainless steel (e.g. 316) plate with fastening holes for mounting on a CMP machine.

Example 2:

A pad conditioner is formed by radially arranging serrated PCD blades. As in the previous example, the teeth of the PCD blade are leveled with a mold that can be positioned either on the bottom or on the top of the pad conditioner. Epoxy is then cast as in the previous example. In the situation where the mold is on the top, the blades are pressed slightly into the slot of a substrate and the slot is sealed by epoxy or silicone.

Example 3:

A composite design combining the embodiments of Example 1 and Example 2 discussed above. This design leverages the many cutting tips of Example 1 with the cutting efficiency of Example 2. In this Example 3, smaller organic abrasive segments were formed by using a fiber reinforced polymer that is generally harder than epoxy. The organic segments are then radially arranged about a pad conditioner substrate with the blades of Example 2 interspersed therebetween. The cutting tips of the blades are leveled so as to be about 20 microns higher than were the tips of the organic abrasive segments. In this manner, the penetration depth of blade cutting teeth is controlled, while the organic cutting teeth play a secondary role in dressing the pad with the effect of removing glaze and also grooving the pad.

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. A method for conditioning a CMP pad, comprising:

cutting the CMP pad with superabrasive cutting elements; and

controlling a degree of contact between the CMP pad and the cutting elements using control elements, wherein the degree of contact is established through placement of the control elements relative to the cutting elements.

2. The method of claim 1, wherein controlling the degree of contact includes alternating regions of cutting elements with regions of control elements.

3. The method of claim 2, wherein controlling the degree of contact includes locating the regions of control elements at a distance from the regions of cutting elements to establish the degree of contact in relation to material characteristics of the CMP pad.

4. The method of claim 2, wherein controlling the degree of contact includes locating the regions of control elements at a distance from the regions of cutting elements to affect a degree of compression of the CMP pad along a leading edge of the regions of cutting elements.

5. A CMP pad dresser, comprising:

an organic matrix;

a plurality of cutting elements partially embedded directly in the organic matrix, the cutting elements being arranged into a plurality of distinct cutting element regions;

a plurality of control elements partially embedded directly in the organic matrix, the control elements being arranged into a plurality of distinct control element regions; and

wherein the cutting element regions and the control element regions are positioned in an alternating pattern, and wherein the control element regions are spaced relative to the cutting element regions to control a degree of contact between the cutting elements and a CMP pad.

6. The CMP pad dresser of claim 5, wherein the organic matrix is coupled to a CMP pad dresser support substrate.

7. The CMP pad dresser of claim 5, wherein the cutting elements include a member selected from the group consisting of particle elements, blade elements, and combinations thereof.

8. The CMP pad dresser of claim 7, wherein at least a portion of the blade elements have a serrated cutting edge.

9. The CMP pad dresser of claim 7, wherein at least a portion of the blade elements have a flat cutting edge.

10. The CMP pad dresser of claim 7, wherein the control elements include a member selected from the group consisting of particle elements, blade elements, and combinations thereof.

11. The CMP pad dresser of claim 5, wherein each of the plurality of cutting elements and each of the plurality of control elements includes a CMP pad contact region, and wherein the contact regions are leveled relative to one another such that no contact region protrudes above another contact region by more than about 30 microns.

12. The CMP pad dresser of claim 5, wherein the control elements are made of a member selected from the group consisting of single crystal diamond, polycrystalline diamond, and combinations thereof.

13. The CMP pad dresser of claim 5, wherein the cutting elements are made of a member selected from the group consisting of single crystal diamond, polycrystalline diamond, and combinations thereof.

14. The CMP pad dresser of claim 5, wherein the alternating pattern includes single blade elements alternating between regions of particle elements.

15. The CMP pad dresser of claim 5, wherein the alternating pattern includes groups of two or more blade elements alternating between regions of particle elements.

16. The CMP pad dresser of claim 5, wherein the organic matrix includes 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 combinations thereof.

17. The CMP pad dresser of claim 16, wherein the organic matrix is an epoxy resin.

18. The CMP pad dresser of claim 16, wherein the organic matrix is a polyimide resin.

19. The CMP pad dresser of claim 16, wherein the organic matrix is a polyurethane resin.

ABSTRACT OF THE DISCLOSURE

The present invention provides CMP pad dressers and methods for dressing or conditioning CMP pads. In one aspect, a method for conditioning a CMP pad can include cutting the CMP pad with superabrasive cutting elements and controlling a degree of contact between the CMP pad and the cutting elements using control elements. The degree of contact is established through placement of the control elements relative to the cutting elements.

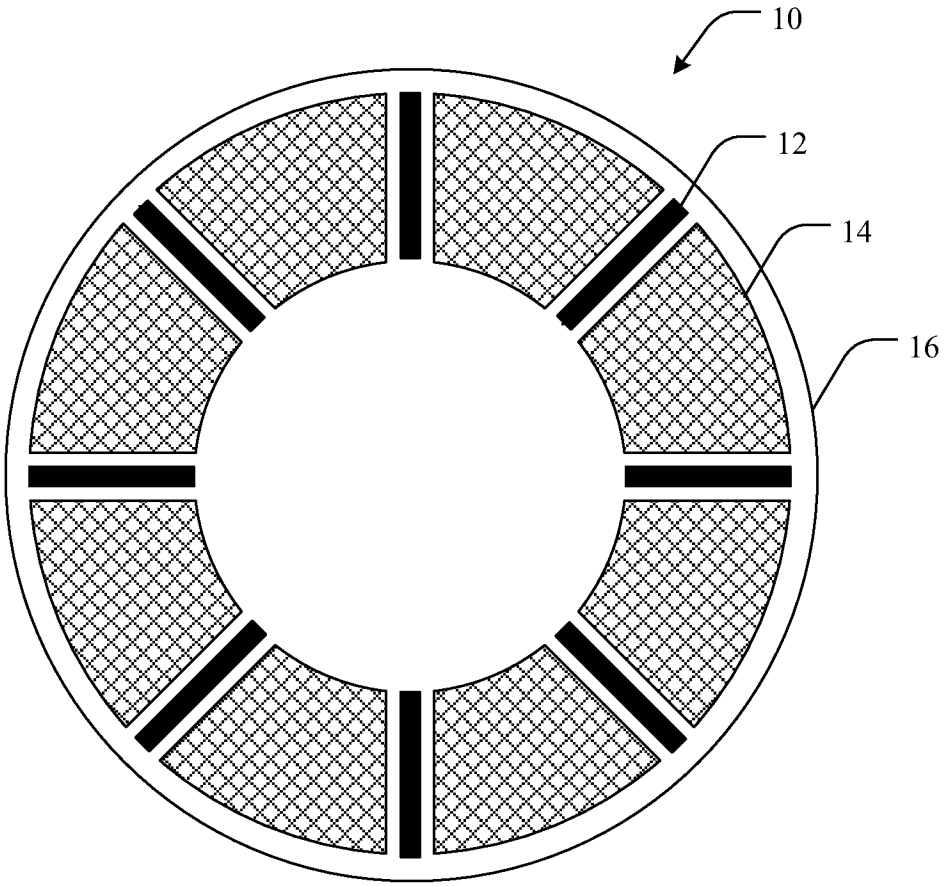


FIG. 1

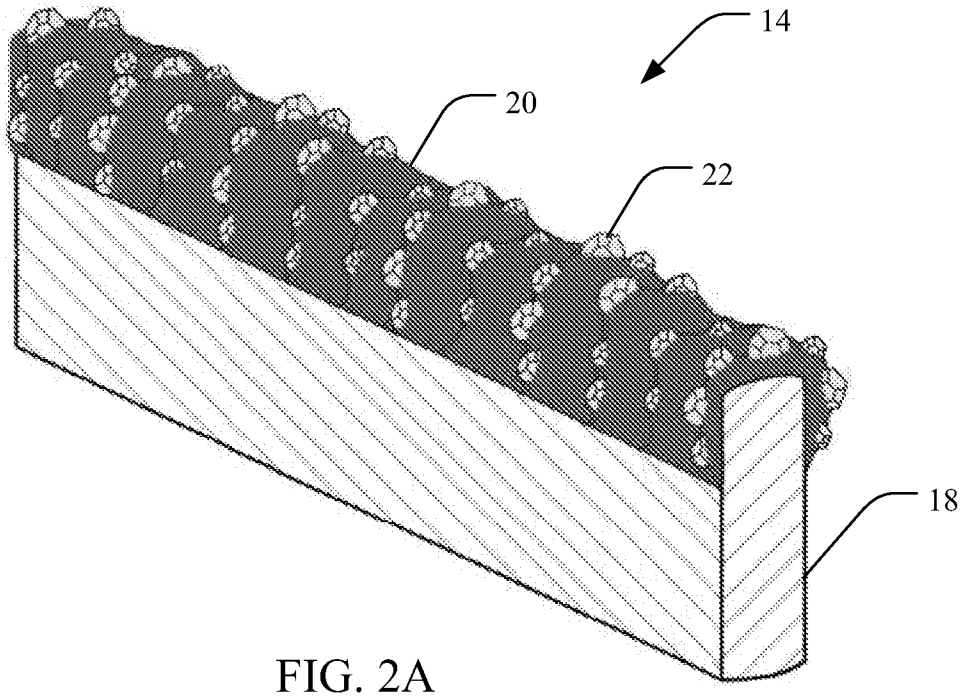


FIG. 2A

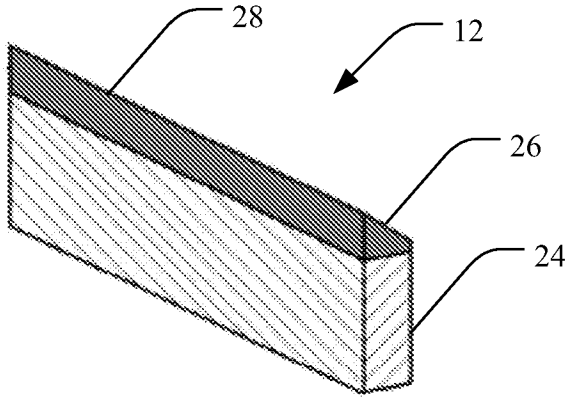


FIG. 2B

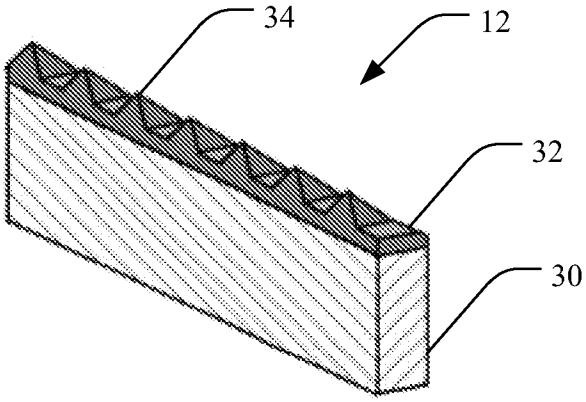


FIG. 2C

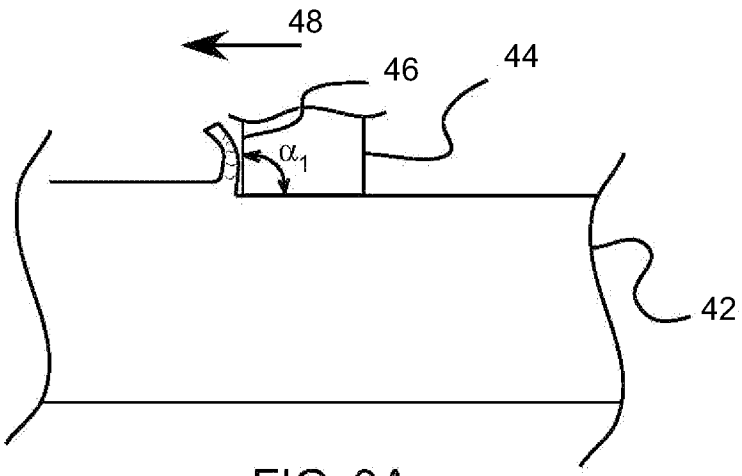


FIG. 3A

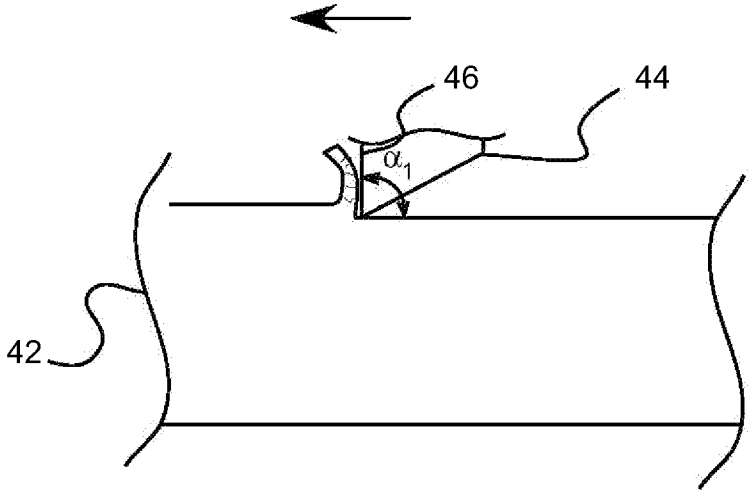


FIG. 3B

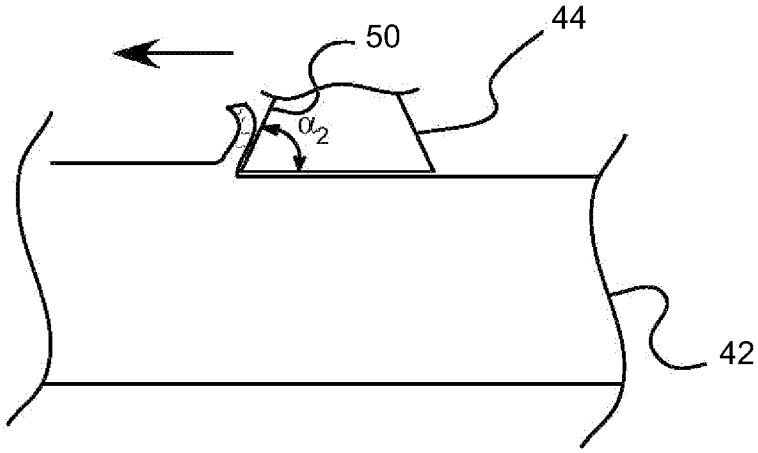


FIG. 3C

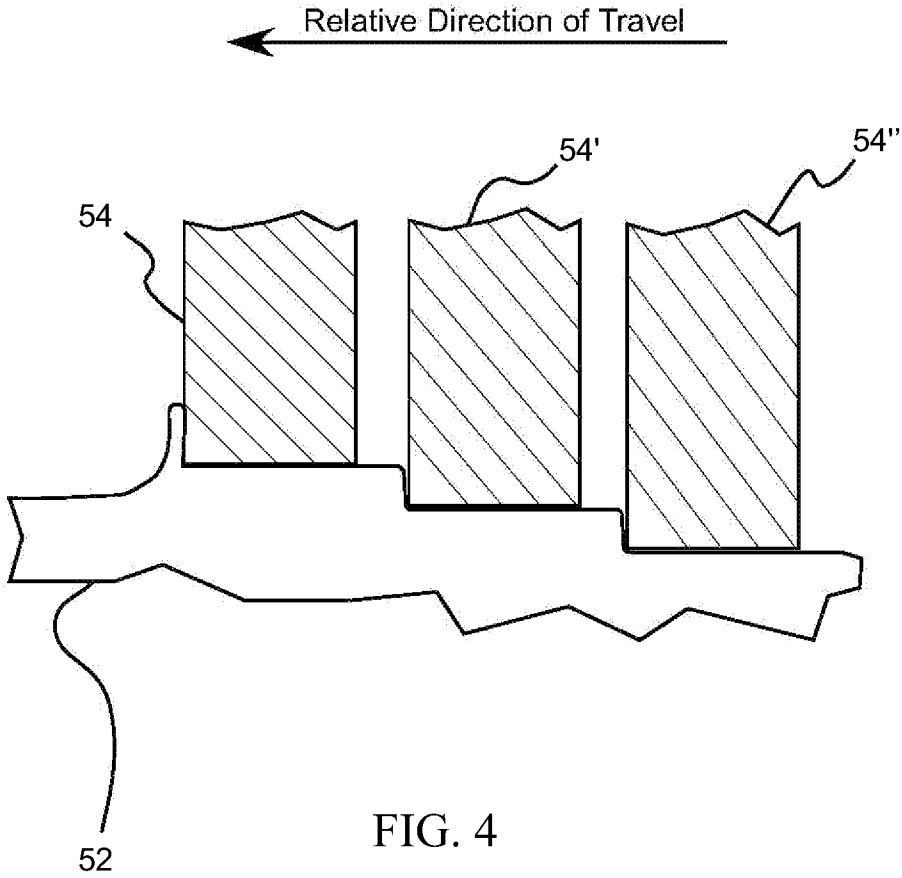


FIG. 4

Electronic Acknowledgement Receipt

EFS ID:	7238428
Application Number:	12726786
International Application Number:	
Confirmation Number:	1959
Title of Invention:	CMP Pad Dresser with Hybridized Abrasive Surface and Related 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:	00802-32779.NP.CIP2
Receipt Date:	18-MAR-2010
Filing Date:	
Time Stamp:	15:44:58
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		32779NPCIP2app.pdf	156410 2ab1c34f7d7fb8d01d143b8ce0da8f3e328f2384	yes	37

	Multipart Description/PDF files in .zip description		
	Document Description	**Start**	**End**
	Specification	1	32
	Claims	33	36
	Abstract	37	37

Warnings:					
Information:					
2	Drawings-only black and white line drawings	32779NPCIP2drawings.pdf	276199 872d7b76f96b2c302dbdce982493d900b9f42abf	no	4
Warnings:					
Information:					
		Total Files Size (in bytes):	432609		

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.

SCORE Placeholder Sheet for IFW Content

Application Number: 12726786 Document Date: 3/18/2010

The presence of this form in the IFW record indicates that the following document type was received in electronic format on the date identified above. This content is stored in the SCORE database.

- Drawings – Other than Black and White Line Drawings

Since this was an electronic submission, there is no physical artifact folder, no artifact folder is recorded in PALM, and no paper documents or physical media exist. The TIFF images in the IFW record were created from the original documents that are stored in SCORE.

To access the documents in the SCORE database, refer to instructions developed by SIRA.

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- Examiners may access SCORE content via the eDAN interface.
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Form Revision Date: February 8, 2006

PTO/SB/06 (12-04)

Date: **03/18/2010**

Approved for use through 7/31/2006. 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: **12/726,786**

APPLICATION AS FILED – PART I

FOR	(Column 1) NUMBER FILED	(Column 2) NUMBER EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY FEE ($)	OR	LARGE ENTITY RATE ($)	LARGE ENTITY FEE ($)
BASIC FEE (37 CFR 1.16(a), (b), or (c))	N/A	N/A	N/A			N/A	**330**
SEARCH FEE (37 CFR 1.16(k), (i), or (m))	N/A	N/A	N/A			N/A	**540**
EXAMINATION FEE (37 CFR 1.16(o), (p), or (q))	N/A	N/A	N/A			N/A	**220**
TOTAL CLAIMS (37 CFR 1.16(i))	**19**	**0**	X$ 26		OR	2X$52	**0**
INDEPENDENT CLAIMS (37 CFR 1.16(h))	**2** minus 3 =	**0**	X$110			1X$220	**0**
APPLICATION SIZE FEE (37 CFR 1.16(s))	If the specification and drawings exceed 100 sheets of paper, the application size fee due is $260 ($130 for small entity) for each additional 50 sheets or fraction thereof. See 35 U.S.C. 41(a)(1)(G) and 37 CFR						
MULTIPLE DEPENDENT CLAIM PRESENT (37 CFR 1.16(j))			195			390	
* If the difference in column 1 is less than zero, enter "0" in column 2.			TOTAL			TOTAL	**1090**

APPLICATION AS AMENDED – PART II

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
AMENDMENT A	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T FEE	

		(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA	SMALL ENTITY RATE ($)	SMALL ENTITY ADDITIONAL FEE ($)	OR	OTHER THAN SMALL ENTITY RATE ($)	OTHER THAN SMALL ENTITY ADDITIONAL FEE ($)
AMENDMENT B	Total (37 CFR 1.16(i))	*	Minus	**	=	x =		OR	x =	
	Independent (37 CFR 1.16(h))	*	Minus	***	=	x =		OR	x =	
	Application Size Fee (37 CFR 1.16(s))									
	FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM (37 CFR 1.16(j))					N/A		OR	N/A	
						TOTAL ADD'T FEE		OR	TOTAL ADD'T 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.

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

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

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/726,786	03/18/2010		00802-32779.NP.CIP2

CONFIRMATION NO. 1959

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

FORMALITIES LETTER

OC000000041005474

Date Mailed: 04/12/2010

NOTICE TO FILE MISSING PARTS OF NONPROVISIONAL APPLICATION

FILED UNDER 37 CFR 1.53(b)

Filing Date Granted

Items Required To Avoid Abandonment:

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

- The statutory basic filing fee is missing.
  *Applicant must submit $**330** to complete the basic filing fee for a non-small entity. If appropriate, applicant may make a written assertion of entitlement to small entity status and pay the small entity filing fee (37 CFR 1.27).*
- The oath or declaration is missing.
  A properly signed oath or declaration in compliance with 37 CFR 1.63, identifying the application by the above Application Number and Filing Date, is required.
  Note: If a petition under 37 CFR 1.47 is being filed, an oath or declaration in compliance with 37 CFR 1.63 signed by all available joint inventors, or if no inventor is available by a party with sufficient proprietary interest, is required.

The applicant needs to satisfy supplemental fees problems indicated below.

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

- To avoid abandonment, a surcharge (for late submission of filing fee, search fee, examination fee or oath or declaration) as set forth in 37 CFR 1.16(f) of $**130** for a non-small entity, must be submitted with the missing items identified in this notice.

SUMMARY OF FEES DUE:

Total additional fee(s) required for this application is $**1220** for a non-small entity
- $**330** Statutory basic filing fee.
- $**130** Surcharge.
- The application search fee has not been paid. Applicant must submit $**540** to complete the search fee.
- The application examination fee has not been paid. Applicant must submit $**220** to complete the examination fee for a non-small entity.

Replies should be mailed to:

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

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

For more information about EFS-Web please call the USPTO Electronic Business Center at **1-866-217-9197** or visit our website at http://www.uspto.gov/ebc.

If you are not using EFS-Web to submit your reply, you must include a copy of this notice.

/ddinh/

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

UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/726,786	03/18/2010		0.00	00802-32779.NP.CIP2	19	2

CONFIRMATION NO. 1959

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

FILING RECEIPT



Date Mailed: 04/12/2010

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

Applicant(s)
Power of Attorney: None

Domestic Priority data as claimed by applicant

This application is a CIP of 12/255,823 10/22/2008
which is a CIP of 12/168,110 07/05/2008
which claims benefit of 60/976,198 09/28/2007
and is a CIP of 11/560,817 11/16/2006

Foreign Applications

If Required, Foreign Filing License Granted: 04/07/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/726,786**

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

Non-Publication Request: No

Early Publication Request: No

Title

CMP Pad Dressers with Hybridized Abrasive Surface and Related Methods

Preliminary Class

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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

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

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

Applicants may wish to consult the USPTO booklet, "General Information Concerning Patents" (specifically, the section entitled "Treaties and Foreign Patents") for more information on timeframes and deadlines for filing foreign patent applications. The guide is available either by contacting the USPTO Contact Center at 800-786-9199, or it can be viewed on the USPTO website at http://www.uspto.gov/web/offices/pac/doc/general/index.html.

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

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

GRANTED

The applicant has been granted a license under 35 U.S.C. 184, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" followed by a date appears on this form. Such licenses are issued in all applications where the conditions for issuance of a license have been met, regardless of whether or not a license may be required as set forth in 37 CFR 5.15. The scope and limitations of this license are set forth in 37 CFR 5.15(a) unless an earlier

license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

No license under 35 U.S.C. 184 has been granted at this time, if the phrase "IF REQUIRED, FOREIGN FILING LICENSE GRANTED" DOES NOT appear on this form. Applicant may still petition for a license under 37 CFR 5.12, if a license is desired before the expiration of 6 months from the filing date of the application. If 6 months has lapsed from the filing date of this application and the licensee has not received any indication of a secrecy order under 35 U.S.C. 181, the licensee may foreign file the application pursuant to 37 CFR 5.15(b).

DECLARATION, POWER OF ATTORNEY AND PETITION

As a below named inventor, I hereby declare: that my residence, post office address, and citizenship are as stated below next to my name; that I verily believe I am the original, first, and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled CMP PAD DRESSERS WITH HYBRIDIZED ABRASIVE SURFACE AND RELATED METHODS, the specification of which was filed on March 18, 2010, as THORPE NORTH & WESTERN, LLP Docket No. 00802-32779.NP.CIP2, and given United States Application No. 12/726,786, and was amended on _____ (if applicable); that the subject matter of the attached amendment or amendment filed on _____ was part of my invention and was invented before the filing date of the original application, above identified for such invention; that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment specifically referred to above; and that I acknowledge the duty to disclose information which is material to patentability of this application as defined in §1.56 of Title 37 of the Code of Federal Regulations.

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

Application Number 12/255,823 filed October 22, 2008, status pending;

Application Number 12/168,110 filed July 5, 2008, status pending;

Application Number 60/976,198 filed September 28, 2007, status expired;

Application Number 11/560,817 filed November 16, 2006, status pending;

and insofar as the subject matter of each of the claims of this application is not disclosed in the earlier filed pending application in the manner provided by the first paragraph of §112 of Title 35 of

the United States code, we acknowledge the duty to disclose information which is material to this application, as defined in §1.56 of Title 37 of the Code of Federal Regulations, which occurred between the filing date of the earlier filed application and the filing date of this application.]]

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

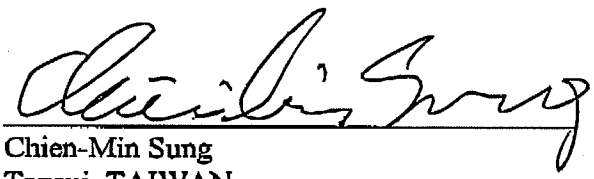
I hereby appoint as my attorneys and/or agents all registered patent practitioners/attorneys associated with Customer Number 20,551; all with full power of substitution and revocation, to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith.

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

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

Signed at Tansui, TAIWAN (City, State), this 24th day of March, 2010.

INVENTOR(S):



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

286189

Electronic Patent Application Fee Transmittal

Application Number:	12726786
Filing Date:	18-Mar-2010
Title of Invention:	CMP Pad Dressers with Hybridized Abrasive Surface and Related Methods
First Named Inventor/Applicant Name:	
Filer:	David William Osborne/Nicole Solomon
Attorney Docket Number:	00802-32779.NP.CIP2

Filed as Large Entity

Utility under 35 USC 111(a) Filing Fees

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Basic Filing:				
Utility application filing	1011	1	330	330
Utility Search Fee	1111	1	540	540
Utility Examination Fee	1311	1	220	220
Pages:				
Claims:				
Miscellaneous-Filing:				
Late filing fee for oath or declaration	1051	1	130	130
Petition:				

Description	Fee Code	Quantity	Amount	Sub-Total in USD($)
Patent-Appeals-and-Interference:				
Post-Allowance-and-Post-Issuance:				
Extension-of-Time:				
Miscellaneous:				
		Total in USD ($)		**1220**

Electronic Acknowledgement Receipt

EFS ID:	7804451
Application Number:	12726786
International Application Number:	
Confirmation Number:	1959
Title of Invention:	CMP Pad Dressers with Hybridized Abrasive Surface and Related Methods
First Named Inventor/Applicant Name:	
Customer Number:	20551
Filer:	David William Osborne/Nicole Solomon
Filer Authorized By:	David William Osborne
Attorney Docket Number:	00802-32779.NP.CIP2
Receipt Date:	14-JUN-2010
Filing Date:	18-MAR-2010
Time Stamp:	12:45:20
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	yes
Payment Type	Electronic Funds Transfer
Payment was successfully received in RAM	$1220
RAM confirmation Number	8849
Deposit Account	
Authorized User	

File Listing:

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

1	Oath or Declaration filed	32779NPCIP2declaration.pdf	102349 193fc045024bce912eca4c06439bef45d8435832	no	3
Warnings:					
Information:					
2	Fee Worksheet (PTO-875)	fee-info.pdf	37009 64ec2592572299b5931be1325bb50b32ccce0b79	no	2
Warnings:					
Information:					
			Total Files Size (in bytes):	139358	

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

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United States Patent and Trademark Office
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Alexandria, Virginia 22313-1450
www.uspto.gov

APPLICATION NUMBER	FILING or 371(c) DATE	GRP ART UNIT	FIL FEE REC'D	ATTY.DOCKET.NO	TOT CLAIMS	IND CLAIMS
12/726,786	03/18/2010		1220	00802-32779.NP.CIP2	19	2

CONFIRMATION NO. 1959

UPDATED FILING RECEIPT

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

OC000000042199192

Date Mailed: 06/22/2010

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

Applicant(s)

Chien-Min Sung, Tansui, TAIWAN;

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

Domestic Priority data as claimed by applicant

This application is a CIP of 12/255,823 10/22/2008
which is a CIP of 12/168,110 07/05/2008
which claims benefit of 60/976,198 09/28/2007
and is a CIP of 11/560,817 11/16/2006

Foreign Applications

If Required, Foreign Filing License Granted: 04/07/2010

The country code and number of your priority application, to be used for filing abroad under the Paris Convention, is **US 12/726,786**

Projected Publication Date: 09/30/2010

Non-Publication Request: No

Early Publication Request: No

Title

CMP Pad Dressers with Hybridized Abrasive Surface and Related Methods

Preliminary Class

PROTECTING YOUR INVENTION OUTSIDE THE UNITED STATES

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

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

LICENSE FOR FOREIGN FILING UNDER

Title 35, United States Code, Section 184

Title 37, Code of Federal Regulations, 5.11 & 5.15

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license has been issued under 37 CFR 5.15(b). The license is subject to revocation upon written notification. The date indicated is the effective date of the license, unless an earlier license of similar scope has been granted under 37 CFR 5.13 or 5.14.

This license is to be retained by the licensee and may be used at any time on or after the effective date thereof unless it is revoked. This license is automatically transferred to any related applications(s) filed under 37 CFR 1.53(d). This license is not retroactive.

The grant of a license does not in any way lessen the responsibility of a licensee for the security of the subject matter as imposed by any Government contract or the provisions of existing laws relating to espionage and the national security or the export of technical data. Licensees should apprise themselves of current regulations especially with respect to certain countries, of other agencies, particularly the Office of Defense Trade Controls, Department of State (with respect to Arms, Munitions and Implements of War (22 CFR 121-128)); the Bureau of Industry and Security, Department of Commerce (15 CFR parts 730-774); the Office of Foreign AssetsControl, Department of Treasury (31 CFR Parts 500+) and the Department of Energy.

NOT GRANTED

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UNITED STATES PATENT AND TRADEMARK OFFICE

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

APPLICATION NUMBER	FILING OR 371(C) DATE	FIRST NAMED APPLICANT	ATTY. DOCKET NO./TITLE
12/726,786	03/18/2010	Chien-Min Sung	00802-32779.NP.CIP2

CONFIRMATION NO. 1959

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

PUBLICATION NOTICE

OC00000043780741

Title:CMP Pad Dressers with Hybridized Abrasive Surface and Related Methods

Publication No.US-2010-0248596-A1
Publication Date:09/30/2010

NOTICE OF PUBLICATION OF APPLICATION

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

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

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

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

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

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

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

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Complete if Known	
Application Number	12/726,786
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First Named Inventor	Chien-Min Sung
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Examiner Name	
Attorney Docket Number	00802-32779.NP.CIP2

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Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
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EP1075898A2

Publication Title:

Dresser and dressing apparatus

Abstract:

Abstract of EP 1075898

(A2) Translate this text A dresser (21) for dressing a polishing pad used for polishing a material to be polished is disclosed, the dresser (21) comprising: a dresser principal (22) and a dressing-working part (23) which is provided as a body other than the dresser principal (22); and a holding means for holding the dressing-working part (23) in such a manner that the dressing-working part (23) can be attached to and detached from the dresser principal (22).

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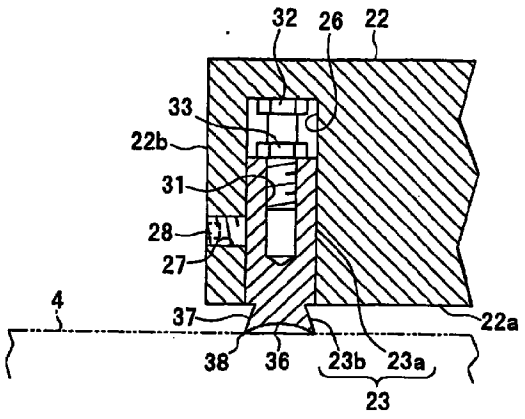
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(54) Dresser and dressing apparatus

(57) A dresser for dressing a polishing pad used for polishing a material to be polished is disclosed, the dresser comprising: a dresser principal and a dressing-working part which is provided as a body other than the dresser principal; and a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

FIG. 2



EP 1 075 898 A2

Description

BACKGROUND OF THE INVENTION

Field of the invention:

[0001] The present invention relates to a dresser and a dressing apparatus for dressing the surface of a polishing pad which is used for polishing materials to be polished, for example, semiconductor wafer or the like.

[0002] The present specification is based on Japanese patent applications (N0. HEI 11-229495, N0. HEI 11-271176, N0. 2000-131784 and N0. 2000-131785) and the contents of these applications are incorporated herein as a part of the present specification.

Description of the Related Art:

[0003] A chemical and mechanical polishing method (CMP method) which provides a high flatness is used for polishing the surface of materials to be polished for which excellent polishing accuracy is required, for example, for polishing semiconductor wafers or the like.

[0004] The CMP method is a method where the surface of wafer is polished chemically and mechanically to obtain a flatness of the surface, using an alkali slurry containing SiO_2, a neutral slurry containing CeO_2, an acid slurry containing Al_2O_3 or a slurry containing abrasive grains. For example, the following polishing apparatus is known as an apparatus for polishing the surfaces of wafers.

[0005] As schematically shown in Fig 17 of an enlarged perspective view of an important part, a polishing pad 4 comprising, for example, hard urethane, is provided on a disc-shaped platen 3 attached to a center shaft 2 in a polishing apparatus 1 and a wafer-polishing head 5 which holds a wafer 6 is disposed facing the polishing pad 4 and in a position eccentric from the center shaft 2 of the platen 3 to the polishing pad such that the head can be rotated on its own axis.

[0006] In the polishing apparatus 1, the polishing pad 4 and the wafer 6 are moved relatively each other while the wafer 6 is held in the state of being pressed against the polishing pad 4 by the wafer-polishing head 5 and the above-mentioned slurry S is interposed between the wafer 6 and the polishing pad 4, thereby to polish one surface of the wafer 6.

[0007] A lot of fine pores, channels or the like are provided on the polishing pad 4 for holding the slurry S, whereby the wafer 6 is polished by the slurry S hold on the polishing pad 4.

[0008] However, repeating the polishing causes the decrease of the surface flatness of the polishing pad 4 and causes clogging and dulling thereof with the result of bringing about a problem to decrease the polishing accuracy and efficiency of the wafer 6.

[0009] Accordingly, a dressing apparatus 7 has conventionally been arranged in a CPM apparatus as shown in Fig 17, thereby to dress the surface of the polishing pad 4.

[0010] In the above-mentioned dressing apparatus, a dresser 11 is, through an arm 9, attached to a rotary shaft 8 which is disposed outside a platen 3, while the dresser 11 is moved to perform a reciprocating and oscillatory motion on the rotating polishing pad 4 by rotating the arm 9 with the rotary shaft 8 to shave a slight amount of the surface of the polishing pad 4, whereby the surface flatness and the like of the polishing pad are recovered and maintained, and the clogging, dulling and the like are dissolved. The surface of the polishing pad is shaved off little by little in such a manner that while pressed against the surface of the polishing pad 4, the dresser 11 is rotated by a friction force between the dresser and the polishing pad or is rotated by being driven by a drive unit which is not shown in the drawing.

[0011] The conventional dresser 11 has a nearly circular shape having an opening in the center, for example, as shown in Fig.18 (a) of a side cross-sectional view and Fig.19 of a plane view and is provided with a dresser principal 11a wherein a projection 11b is formed in the outer peripheral portion of one end face. As shown in Fig.18 (b) of a partially enlarged side sectional view, the conventional dresser having a dressing-working part is used which comprises a diamond electrodeposited part 11d formed by electrodepositing on the projection 11b abrasive grains 11c (super abrasive grain) such as diamond or cBN. The dressing-working part shaves little by little the polishing pad 4 (such a dresser is called electrodeposited grindstone). Fig.19 is a plane view illustrating the under surface of the dresser 11. A dressing apparatus using this type of dresser is disclosed in, for example, JP-A 9-168961.

[0012] In the conventional dresser 11, there has been encountered the dropping off of the abrasive grains 11 such as diamond grain during dressing. In this case, a trouble is brought about due to scratching the surface of the wafer 6, when the wafer is polished while the dropped grains are filled up in the surface of the polishing pad.

[0013] In order to dissolve the above-mentioned problem, there was a proposal in JP-A 10-217103 as in Fig.20. A dresser 12 shown in Fig.20 has the following construction as a dressing-working part: a lot of projections 13 having a shape of pyramid are formed in the surface of a metal base 12a by machining and a surface 13a of the metal base 12a having the formed projections 13 was coated by a hard film. Dressing is carried out by pressing the projections 13 against a polishing cloth (polishing pad). There is no fear in the dressing apparatus having the dresser 12 for dropping of abrasive grains such as diamond grain with the result that there is little anxiety for suffering from a damage in the surface of materials to be polished.

[0014] However, in the dressers 11 and 12 as men-

EX1058, Page 69

tioned above, a cutting quality degreases due to reasons such as wear of the dressing-working part in proportion to repeated dressings. In this case, changing a dresser unit is required, which takes a high cost.

[0015] In addition, as shown in Fig.19, the dressing of the polishing pad 4 is carried out by the whole surface of the dressing-working part which is projected in a shape of ring in the under surface of the outer peripheral portion of a dresser principal 11a. Chatter is apt to be caused due to a force acting all over the whole surface of the dressing-working part. Further, if once the chatter is caused, the vibration of the dressing 11 continues due to reasons such as the resonance of the vibration, which causes cases leading to a failure to polish uniformly the surface of the polishing pad.

[0016] Further, chips generate from the polishing pad 4 shaved little by little during dressing with dresser 12. In the above-mentioned construction having a lot of projections 13, the chips clog the spaces between each projection, thereby to bring about a problem of degreasing the dressing performance.

[0017] Furthermore, it is difficult to maintain always a stable dressing performance, as it is difficult to estimate how much the wear of the hard film 14 proceeds with the passage of time and a criterion for use becomes unclear.

[0018] The Constitution of the dresser 11 is shown in a side sectional view illustrated in Fig.21 (a schematically illustrated view). A dresser 11 is attached to an arm 9 by the aid of a setting shaft 10 and on a dresser principal 11a connected to the setting shaft 10, there is formed a diamond-electrodepositing part 11d (an abrasive grain layer) including abrasive grains 11c, thereby to form a dressing-working face 15. The diamond-electro-depositing part 11d has the following construction: electroplating is carried out on a ground face positioned on the dresser principal 11a, whereby the abrasive grains 11c such as diamond, cBN or the like are fastened dispersedly on the ground face.

[0019] In the dresser 11, the dressing-working face 15 comprises the under surface of the diamond-electro-depositing part 11d (an abrasive grain layer). In Fig.21, the thickness of the diamond-electro-depositing part 11d and the size of abrasive grains are illustrated larger than actual ones so as to understand easily the shape of the dressing-working face 15.

[0020] If the dresser 11 contacts partially the polishing pad 4 during dressing the pad 4 with the dresser 11, the contact area of the dressing-working face 15 to the polishing pad 4 becomes small with the result that the dressing efficiency becomes lower and it takes a longer time to dress the pad than in unpartial contact cases, though the pad 4 can be dressed at any rate. Every time after polishing a wafer 6 has finished, the polishing pad 4 is dressed and it is carried out at every two and half to three minutes. Therefore, the working efficiency of polishing the wafer 6 becomes low when it takes a long time to dress the polishing pad 4.

[0021] Still further, when the dressing condition is unstable as mentioned above, the surface condition of the polishing pad varies widely and the polishing condition of the wafer 6 with the polishing pad 4 scatters. As the result, it becomes difficult to keep the rate of operation of CMP apparatus and the flatness of the wafer 6.

[0022] Because of the above-mentioned reasons, in order to stabilize the dressing condition, an arrangement is carried out such that the dressing-working face 15 is flat and the dressing-working face cross orthogonally the rotary axis of the dresser 11.

[0023] In a dresser having a prescribed shape formed by fixing abrasive grains by a binder, the above-mentioned arrangement is available by shaving the dressing-working face in the state that the dresser is attached to the setting shaft of a dressing apparatus 7 (this treatment is called "tooling"). However, the tooling can not be carried out in the case of an electrodeposited grindstone due to its own property.

[0024] Accordingly, in the case of using an electrodeposited grindstone for the dresser 11, it is necessary to increase the shape accuracy of the dresser principal 11a where the abrasive grain layer is formed and to increase the accuracy of attaching the dresser principal 11a to the setting shaft.

[0025] However, there are cases in the electrodeposited grindstone that the shape of the dresser principal 11a changes during the process of making thereof and the flatness of the dressing-working face 15 becomes inferior. The flatness of the dresser 11 is measured while contacing directly a dial gauge to the dressing-working face 15, and in the case of the electrodeposited grindstone, as the surface roughness of the dresser-working face is coarse which is a degree of #100, the measurement error is large and it is difficult to measure the flatness thereof accurately.

[0026] Further, there are cases during attaching the dresser 11 to the setting shaft that the dressing-working face 15 of the dresser 11 inclines against the rotary axis due to troubles such as an attaching error caused by a worker, dust interposed between the dresser 11 and the setting shaft, and so on. In order to detect the inclination, there is no way except measuring the deviation of the dressing-working face 15 while contacting directly the dial gauge to the dressing-working face, which has a problem in having a large measurement error. Therefore, it is difficult to obtain the attaching accuracy within a prescribed criterion.

[0027] In addition, as the polishing pad has a softness, it is difficult to detect the partial contact of the dresser 11 to the polishing pad 4 by observing the dressed state of the polishing pad 4, which is different from polishing materials having rigidity such as metal.

[0028] As mentioned above, it has been difficult to stabilize the dressing condition of the polishing pad 4 with the dresser 11.

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SUMMARY OF THE INVENTION

[0029] An object of the present invention is to provide a dresser which can be used economically and a dressing apparatus having the same.

[0030] In order to attain the above-mentioned object, the dresser of the present invention is one used for dressing a polishing pad for polishing materials to be polished and comprises a dresser principal, a dressing-working part which is provided as a body other than the dresser principal and a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

[0031] According to the dresser of the present invention, the dressing-working part can be attached and detached, and when a dressing performance thereof degreases due to reasons such as the wear of the dressing-working part, the dressing-working part is exchanged for a new one to recover the dressing performance. In this way, the dressing performance can be recovered only by exchanging a dressing-working part, thereby to degrease a cost for a dresser.

[0032] Another object of the present invention is to provide a dresser which enables a vibration hardly to take place, and which enables to suppress the vibration within a short time if the vibration takes place, and is to provide a dressing apparatus having the same.

[0033] In order to attain the above-mentioned object, the dresser of the present invention is one used for dressing a polishing pad for polishing materials to be polished and comprises a plurality of dressing-working parts which are disposed at unequal spaces in the circular direction of a dresser principal.

[0034] According to the dresser of the present invention, the dressing-working parts are disposed at unequal spaces in the circular direction of the dresser principal, whereby forces which cause the vibration of the dresser are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser.

[0035] As the result, a vibration hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0036] The interval between each dressing-working part can be decided by any way and for example, can be decided by using random numbers.

[0037] As another way, the interval can be unequal by arranging positions in such a manner that positions are designated as a standard position in the case of disposing dressing-working parts at an equal space each other, and each position is deviated from each standard position to the circular direction. In this case, the deviation of each dressing-working part from the corresponding standard position can be decided by using the random numbers or, for example, can be decided by designating as a starting point any position among each standard position, designating as θ an angle between the starting point and each standard position when looked from the center of axis, and specifying $x=\sin\theta$ as the deviation x of each dressing-working part from each standard position (or $x=\cos\theta$).

[0038] In the above-mentioned ways, when the deviation is too large, dressing-working parts having the too large deviation have a life shorter than the other dressing-working parts as a result of dressing more amount of a polishing pad. In contrast, when the deviation is too small, an effect on suppressing a resonance is lowered. Therefore, the deviation value is preferably by the absolute value within 10 to 30% of an interval between the corresponding standard positions.

[0039] The dresser is rotated in a position having an eccentric relation with the polishing pad, and the speed of the dresser relative to the polishing pad is lower in half a range of the circular direction (an inward peripheral side or an outward peripheral side of the polishing pad when looked from the center of axis of the dresser) than in the other half range and a load imposed on the dressing-working part is small. Therefore, it is estimated that the vibration of the dresser is hardly caused by a force imposed on a side which has a lower speed relative to the polishing pad. That is, dressing-working parts can be provided which are disposed in a same pattern every half a round.

[0040] A further object of the present invention is to provide a dresser which enables to always maintain an excellent dressing performance and can be used economically.

[0041] In order to attain the above-mentioned object, the dresser of the present invention is applied to an equipment which is used for polishing materials to be polished having a flat surface such as semiconductor wafer with a dressing pad, and is a dresser used for dressing the surface of the polishing pad, and is characterized by the following construction: the cutters are arranged in such a manner that the cutters are projected from the under surface of a dresser principal; the polishing pad surface is shaved by moving the edge of cutter which is a movement relative to and parallel to the polishing pad surface while the edge of the cutter is pressed against the polishing pad surface.

[0042] As the dressing pad is shaved with a cutter in the dresser of the present invention, the dresser is protected from the lowering of the dressing performance which is caused by clogging of the polishing pad with the shaved chips of the dressing pad in between abrasive grains, as compared with the conventional one, whereby a stable dressing performance is available. In addition, as an amount of wear can be decided from the flank of the cutter, a criterion for use is clear as compared with the conventional one, thereby to enable to maintain easily the dressing performance. Further, as a cutter is used, reusing the cutter is possible, which is different from the conventional one, with result of providing excellence in a cost for the dresser.

[0043] Still further object of the present invention is

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to provide a dresser wherein the polishing condition of the polishing pad can be stabilized.

[0044] In order to attain the above-mentioned object, the dresser of the present invention comprises: a dressing-working face formed by providing an abrasive grain layer including abrasive grains on the surface of a dresser principal, wherein the dresser principal comprises a ground face on which the abrasive grain layer is provided and a basic face which is disposed in a portion of the dresser principal more inward than the ground face and is formed in parallel to the ground face.

[0045] In the dresser of the present invention, as the basic face of the dresser principal is a plane parallel to the ground face, it is possible to predict the flatness of the ground face having the abrasive-grain layer formed thereon, that is, the flatness of the dressing-working face, by measuring the flatness of the basic face, whereby dressers can be selected which have a good flatness with regard to a dressing-working face.

[0046] In addition, when the dresser is attached to the dressing apparatus, the attaching situation can be confirmed according to the basic face as a basis, as the basic face is a plane parallel to the ground face.

BRIEF DESCRIPTION OF THE DRAWINGS

[0047]

Fig.1 is a plan view illustrating the under surface of the dresser of Example 1 of the present invention.

Fig.2 is a sectional view looking in the direction of the arrows A-A in the Fig.1.

Fig.3 (a) is a side sectional view showing another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.3 (b) is an end surface view showing another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.4 (a) is a side sectional view showing a further embodiment of the dresser-working part used in the dresser of Example 1.

Fig.4 (b) is a side sectional view showing still another embodiment of the dresser-working part used in the dresser of Example 1.

Fig.5 is a side sectional view illustrating another construction of the dresser in Example 1 of the present invention.

Fig.6 is an under surface view illustrating the shape of the dresser in Example 2 of the present invention.

Fig.7 (a) is a side sectional view illustrating the shape of the dresser in Example 2 of the present invention.

Fig.7 (b) is a side sectional view illustrating another shape of the dresser in Example 2 of the present invention.

Fig.8 is an under surface view illustrating the shape of the dresser in Example 3 of the present invention.

Fig.9 is a schematic view illustrating the dresser of Example 4 of the present invention, which is an enlarged side view of the important part of the dresser principal.

Fig.10 is a schematic view illustrating the dresser of Example 4 of the present invention, which is an under surface view of the dresser principal.

Fig.11 is a schematic view illustrating the dresser of Example 4 of the present invention, which is a side sectional view of the dresser principal.

Fig. 12 is an enlarged side view of a cutter used in the dresser shown in Figs.9 to 11.

Fig.13 is an enlarged under surface view of the cutter used in the dresser shown in Figs.9 to 11.

Fig.14 is a plan view showing a positional relationship between the dresser principal shown in Fig.9 to 13 and a platen to which a polishing pad is attached, when dressing is carried out.

Fig.15 is an enlarged side sectional view showing another embodiment of the cutter used in the dresser of Example 4.

Fig. 16 is a side sectional view illustrating the constitution and construction of the dresser in Example 5 of the present invention.

Fig.17 is an enlarged perspective view of the important part of the conventional polishing equipment and dressing apparatus, which is illustrating the schematic constitutions thereof.

Fig.18 (a) is a side sectional view illustrating the shape of the conventional dresser.

Fig. 18 (b) is a partially enlarged side sectional view of Fig. 18 (a).

Fig.19 is a plan view showing the under surface of the conventional dresser.

Fig.20 is an enlarged side sectional view of an important part illustrating the shape of the conventional dresser.

Fig.21 is a side sectional view illustrating the constitution and construction of the conventional dresser.

DESCRIPTION OF PREFERRED EMBODIMENTS

[0048] The dresser of the present invention and the dressing apparatus having the same are described in detail hereunder.

[0049] Fig.1 is a plan view illustrating the under surface of the dresser of Example 1 of the present invention. Fig.2 is a sectional view looking in the direction of the arrows A-A in the Fig.1.

[0050] The dressing apparatus of the present invention comprises a constitution almost similar to that of, for example, a dressing apparatus 7 shown Fig.17, and a dresser 21 of the present invention is used as a dresser in place of a dresser 11.

[0051] The dresser 21 of the present invention comprises a dresser principal 22 having an approximately circular shape and a plurality of dressing-working parts

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23 disposed in the circular direction in the under surface of the outer peripheral portion of the dresser principal 22. The dresser-working parts 23 which are provided as bodies other than the dresser principal 22 are arranged and are held to the dresser 22 by a means mentioned after in such a manner that the dresser-working parts 23 can be attached to and detached from the dresser principal 22. The number and disposition of the dressing-working parts 23 shown in Fig.1 is only an example. The dressing-working parts 23 can be disposed at equal spaces in the circular direction of the dresser principal or at irregular spaces in the circular direction. The dressing-working parts 23 can be arranged in a plurality of lines in the circular direction of the dresser principal 22, which is similar to that of the conventional dresser.

[0052] In the present example, the dresser principal 22 is composed of an approximately circular shape having an opening in the center thereof.

[0053] As shown in Fig.2, the dressing-working part 23 is composed of a member having an approximately pin-like shape. A receiving hole 26 for receiving a part of the dressing-working part 23 is formed from the under surface 22a to a predetermined depth in the dresser principal 22. In the dresser principal 22, a tapped hole 27 is formed which leads to the intermediate position of the receiving hole 26 from the outer periphery 22b thereof. In the tapped hole 27, a clamp screw 28 is screwed such that the end of the clamp screw can be advanced and retreated in the receiving hole 26.

[0054] The dressing-working part 23 is fixed in the receiving hole 26 by pressing the side of dressing-working part 23 received in the receiving hole 26 to the inner wall of the receiving hole with the end of the clamp screw 28 and is released from being fixed by releasing the pressing of dressing-working part 23 with the end of the clamp screw.

[0055] The present example comprises a holding means which hold dressing-working part 23 to the dresser principal 22 in such a manner that the dressing-working part 23 can be attached to and detached from the dresser principal 22 by the receiving hole 26, the tapped hole 27 and the clamp screw 28.

[0056] Here, in the present example, the receiving hole 26 is approximately parallel to the axis of the dresser principal 22 and the bottom surface thereof is a plane which approximately crosses orthogonally the axis of the dresser principal 22.

[0057] As shown in Fig.2, the dressing-working part 23 is a cutter having approximately a pin-like shape, and comprises a base 23a having an approximately columnar shape and a cutting edge 23b formed in the end of the base 23a.

[0058] The base 23a is received in the receiving hole 26 of the dresser 22 and the side of the base is subjected to the pressure given by the clamp screw 28. A position-adjusting screw hole 31 is formed in the base 23a, which has a prescribed depth along the axis from the end face of the base.

[0059] A position-adjusting screw 32 is screw-clamped to the position-adjusting screw hole 31 and an amount of projection of the position-adjusting screw 32 from the base 23a can be adjusted by controlling a screwed length to the position-adjusting screw hole 31.

[0060] The upper surface of the head of the position-adjusting screw 32 is pressed against the bottom surface of the receiving hole 26 when the dressing-working part 23 is received in the receiving hole 26. An amount of projection of the dressing-working part 23 from the receiving hole 26, that is, an amount of projection of the dressing-working part 23 from the dresser principal 22 can be adjusted by controlling an amount of projection of the position-adjusting screw 32 from the base 23a. In the present example, the upper surface of the head of the position-adjusting screw 32 is a plane crossing approximately orthogonally to the axis thereof.

[0061] Further, a fixing nut 33 is screw-clamped to the position-adjusting screw 32 which is positioned on the position-adjusting screw hole 31. The position-adjusting screw 32 is fixed in a state projected at any distance from the base 23a by screwing the fixing nut toward the edge of the position-adjusting screw 32 while pressed against the base 23a.

[0062] The present example comprises a projection adjusting means having the position-adjusting screw hole 31, the position-adjusting screw 32 and the fixing nut 33 for controlling an amount of projection of the dresser-working part 23 from the dresser principal 22.

[0063] The cutting edge portion 23b of the dressing-working part 23 comprises: a flank 36 which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face 37 comprising a cicumferential surface in the end portion of the cutter; and a cutting edge 38 which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion of the cutter. Namely, the cutting edge portion 23b has a nearly Japanese soup cup-like shape.

[0064] Here, ceramics, diamond, cBN and the like can be used for the cutting edge 38, and the surface of the cutting edge portion 23b can be covered by a hard film comprising hard materials such as diamond or the like.

[0065] Almost in the same manner as in the dressing apparatus shown in Fig. 17, the surface of a polishing pad 4 is dressed by the dressing apparatus of the present invention, which comprises the steps of: oscillating a dresser 21 while the dresser 21 is pressed against the surface of the polishing pad 4; rotating of the dresser owing to a friction force caused by friction with the polishing pad 4 or rotating the dresser by driving by a drive unit which is not shown in Figs while the dresser 21 is pressed against the surface of the polishing pad.

[0066] In the dresser 21, the surface of the polishing pad 4 is shaved little by little by the dresser 21 by providing to the dresser a relative movement to a direction parallel to the polishing pad 4, while the cutting edge 38 of the dressing-working part 23 is pressed

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against the surface of the polishing pad 4.

[0067] As an amount of projection of the dressing-working part 23 from the dresser principal 22 can be adjusted, the dressing performance of the dresser 21 is controlled by adjusting the depth of cut of the dressing-working part 23 into the dressing pad 4 according to the material and hardness of the dressing pad.

[0068] The dressing apparatus of the present invention can be composed of a constitution other than the above-mentioned one, in which the dresser 21 is connected to an arm 9 through a ball bearing, and the dresser can freely be inclined according to the surface of the polishing pad 4. In this case, in the dressing apparatus, the dresser is pressed against the dressing pad 4 by the dead weight thereof or by a force obtained by pressing the arm 9, and a depth of cut of the dressing-working part 23 into the polishing pad 4 is adjusted by controlling an amount of force of the pressing.

[0069] Adjusting an amount of projection of the dressing-working part 23 is carried out as follows: first, an amount of the position-adjusting screw 32 from the base 23a is adjusted by turning round the position-adjusting screw 32 which is screw-clamped to the base 23a to any of two directions in the state of detaching the dressing-working part 23 from the dresser principal 22 and the position-adjusting screw 32 is fixed to the base 23a by the fixing nut 33; then, the dressing-working part 23 is inserted into the receiving hole 26 of the dresser principal 22 and the clamp screw 28 is driven and tightened which is screw-clamped to the tapped hole 27, whereby the dressing-working part 23 is fixed in such a state that the cutting edge 38 of the dressing-working part 23 is projected from the under surface 22a of the dresser principal 22 by a prescribed amount.

[0070] In addition, as the dressing-working part 23 has the cutting edge 38 in the whole round thereof, the shaving of the polishing pad 4 can be carried out for any direction thereto, thereby to enable to increase a dressing performance.

[0071] And, as the dressing-working part 23 is a cutter, the dressing performance can be recovered by repolishing the cutter edge 38 when the dressing performance degreases, thereby to enable to lower a cost for the dresser.

[0072] Furthermore, though shaved chips generate due to shaving a little the polishing pad 4, the polishing pad 4 is hardly clogged with the shaved chips, which is different from a dresser having a dressing-working part comprising an abrasive grain layer and projections, thereby to obtain a stable dressing performance.

[0073] Still further, as the dressing performance can be judged from an amount of wear of the cutting edge 38 to clear a criterion for use, the stable dressing performance can always be obtained.

[0074] Yet further, there is no fear to scratch the surfaces of materials to be polished due the dropping of abrasive grains, as the abrasive grains are not used in the dressing-working part 23.

[0075] Still furthermore, if a dressing performance lowers due to reasons such as the wear of the dressing-working part 23, the dressing performance can be recovered by exchanging only the dressing-working part 23, thereby to enable to decrease a cost for a dresser.

[0076] The example is exemplified by a case wherein the dressing-working part 23 is used which comprises a cutting edge portion 23b having a Japanese soup cup-like shape and the example is not limited to the case. For another example, a dressing-working part 39 can be used which has a plurality of projections in the end thereof as shown in Fig.3 (a) of a side sectional view and Fig.3 (b) of an end surface view. The projection 40 of a dressing-working part 39 has a cross section approximately equal to an end face 40a from one end of the projection to near another end of the projection from which the projection is started and a cutting edge 40b is provided by a ridgeline formed by crossing of the end face 40a and the side surface of the projection. The projections are disposed in any way, regularly or irregularly. In addition, any shape can be provided to the end face 40a of the projection 40, for examples, the end face 40a can be nearly circular (the projection 40 is approximately columnar) or can be a polygon (the projection 40 is a square pillar having a polygonal section).

[0077] Further, ceramics, diamond, cBN and the like can be used for the cutting edge 40b, and the surface of the cutting edge 40b can be covered by a hard film comprising hard materials such as diamond.

[0078] In the dressing-working part 39 formed as mentioned above, the surface of the polishing pad 4 is dressed by the cutting edge 40b of each projection 40. Here, as the cutting edge 40b is formed in the wholly around of each projection 40, the polishing pad 4 can be dressed from any direction. The projection 40 has a cross section approximately equal to an end face 40a from one end of the projection to near another end of the projection from which the projection is started and the change of shape and area of the end face 40a is small when the projection 40 wears with the result that the dressing performance hardly changes and the stable dressing performance can be obtained.

[0079] Further, for example, as shown in Fig.4 (a) of a side sectional view, a dressing-working part 41 can be used which has a cutting edge 42 having a cutting edge portion 41b directed to one direction of the circular direction of dressing-working part. Here, ceramics, diamond, cBN and the like can be used for the cutting edge 42 and the surface of the cutting edge portion 41b can be covered by a hard film comprising hard materials such as diamond.

[0080] In addition, the polishing pad can be shaved from any direction, as a whole dresser, by providing to the dressing-working part 41 the cutting edges 42 which are directed in various directions each other.

[0081] Further, a dressing-working part 43 can be used as a dressing-working part, which comprises a grindstone 44 in the end of the base 43a which is

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approximately columnar as shown in Fig.4 (b). In this case, the grindstone 44 can be a grindstone which is conventionally used for dressing the polishing pad 4, for examples, can be a grindstone formed by an abrasive grain layer prepared by electrodepositing abrasive grains such as diamond or can be a metal bonded grindstone.

[0082] Further, a means for controlling an amount of projection can be composed of a constitution other than the above-mentioned one, in which a bolt inserting hole 29 leading to the upper surface of the dresser principal 22 is formed in the bottom face of a receiving hole 26 as shown in Fig.5 of a side sectional view and a position-adjusting screw 32 is inserted into the bolt inserting hole 29 from the upper surface of the dresser principal 22 and screw-clamped to a position-adjusting screw hole 31 (a fixing nut becomes unnecessary). Here, the position adjusting screw 32 is attached to the dresser principal 22 in such a manner that the screw is possible to turn around an axis while the head of the screw is received in the bolt inserting hole 29. When a means for controlling an amount of projection is provided as mentioned above, as the dressing-working part 23 can be moved along the position adjusting screw 32 by handling the position adjusting screw 32 in the state of attaching the dresser-working part 23 to the dresser principal 22, an amount of projection of the dressing-working part 23 can be controlled without detaching the dressing-working part 23 from the dresser principal 22.

Example 2:

[0083] The dresser of Example 2 of the present invention and the dressing apparatus having the same are described in detail hereunder, referring to Figs.

[0084] Fig.6 is an under surface view illustrating the shape of the dresser of Example 2. Fig.7 is a side sectional view illustrating the dresser.

[0085] The dressing apparatus of the present invention comprises a constitution almost similar to that of a dressing apparatus 7 shown Fig. 17, and the dresser 51 of the present invention is used as a dresser in place of a dresser 11.

[0086] A dresser 51 of the present invention comprises a dresser principal 52 having an approximately circular shape and a plurality of dressing-working parts B disposed in the circular direction in the under surface of the outer peripheral portion of the dresser principal 52. The dresser principal 22 of the present invention is composed of a shape having an opening in the center thereof in the same manner as in the conventional dresser. The dresser-working parts B are provided as bodies other than the dresser principal 52 and are fixed to the dresser principal 52 by, for examples, brazing, a clamp method, a blade method and so on.

[0087] In the present example, the dressing-working parts are members having a approximately pin-like shape.

[0088] The dressing-working parts B are disposed at unequal spaces in the circular direction of the dresser principal 52. A space between each dressing-working part B is decided by any way. In the present example, the positions in the case of disposing dressing-working parts B at equal spaces are designated as a standard position P and any one among the standard positions is designated as a starting point P_0 and an angle between each standard position P and the starting point P_0 when looked from the center of axis O of the dresser 52 is designated as θ , and $x=\sin\theta$ is specified as a deviation x of each dressing-working part B from each standard position P. Here, in Fig.6, accompanied characters are provided to standard positions P (and a dressing-working part B, angle θ and an amount of deviation x corresponding to each standard position P), in a counterclockwise order starting from the starting point P_0.

[0089] In the above-mentioned way, when the deviation x of a dressing-working part B from the corresponding standard position P is too large, a distance becomes large which is between one dressing-working part B and another dressing-working part B next to the former dressing-working part. In this case, the life of the dressing-working parts B become shorter as an amount of dressing of the polishing pad 4 carried out by the dressing-parts B becomes always too much as compared with the other dressing-working parts B. In contrast, when the deviation is too small, an effect on suppressing a resonance is lowered. Therefore, a deviation value of each dressing working part B from the corresponding standard position P is preferable by the absolute value within 10 to 30% of a space H between standard positions P.

[0090] The dressing-working part is approximately pin-like and can comprise any construction such as a dressing-working part having a diamond-electro-deposited part formed by electrodepositing abrasive grains such as diamond in the end which is directed to the under surface side of the dresser principal 52 or a dressing-working part having a cutter having a cutting edge formed in the end which is directed to the under surface side of the dresser principal 52 if dressing the polishing pad 4 is possible.

[0091] In the present example, as shown in Fig.7 (a), there is provided to the dresser principal 52 a receiving hole 56 having a prescribed depth from an under surface 52a and there is provided thereto a tapped hole 57 which leads to the intermediate position of the receiving hole 56 from the outer periphery 52b of the dresser principal 52 and to which a clamp screw 58 is clamped. The dressing-working part B is fixed to the receiving hole 56 by the following mechanism: the side thereof is pressed by the clamp screw 58 which is screw-clamped to the tapped hole 57, whereby the dressing-working part B is fixed to the receiving hole 56. And, as shown in Fig.7 (a), in the dressing-working part B, a position-adjusting screw hole 59 having a prescribed depth is formed along an axis from the end face

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of the base end thereof and a position-adjusting screw 60 is screw-clamped to the position-adjusting screw hole 59. An amount of projection of the dressing-working part B from the base end can be controlled by controlling a screw-clamping length of the position-adjusting screw 60 to the position-adjusting screw hole 59, and the upper face of head of the position adjusting screw 60 can be contacted to the bottom face of the receiving hole 56 when the dressing-working B is received in the receiving hole 56. Here, an amount of projection of the dressing-working part B from the receiving hole 56, that is, an amount of projection of the dressing working part B from the under surface 52a of the dresser principal 52a can be controlled by adjusting an amount of projection of the position-adjusting screw 60 from of the base end of the dressing-working part B.

[0092] In the present example, the dressing-working part B is a cutter having approximately a pin-like shape. A cutting edge portion 54 formed in one end of the cutter comprises: a flank 54a which is formed by concaving the end face of the cutting edge portion toward the base end of the cutter; a rake face 54b comprising a circumferential surface in the end portion of the cutting edge portion; and a cutting edge 54c which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion. Namely, the cutting edge 54 has a nearly Japanese soup cup-like shape and whole the round of the edge makes it possible to shave the polishing pad 4.

[0093] For example, as shown in Fig.7 (b) of a side sectional view, the dresser 51 can be composed of a constitution other than the above-mentioned one, in which a bolt inserting hole 53 is formed in the dresser principal 52 from the bottom face of a receiving hole 56 to the upper surface of the dresser principal 52 and a position-adjusting screw 60 is inserted into the bolt inserting hole 53 from the upper side of the dresser principal 52, thereby to screw-clamped the screw to a position adjusting screw hole 59. In this case, the position-adjusting screw 60 is attached to the dresser principal 52 in such a manner that the screw is possible to turn around an axis while the head of the screw is received in the bolt inserting hole 53. When the dresser 51 is constituted as mentioned above, as the dressing-working part B can be moved along the position adjusting screw 60 by handling the position-adjusting screw 60 in the state of attaching the dresser-working part B to the dresser principal 52, an amount of projection of the dressing-working part B can be controlled without detaching the dressing-working part B from the dresser principal 52.

[0094] Dressing the polishing pad 4 by using a dressing apparatus having the dresser 51 constructed as mentioned above is carried out in the same manner as in the conventional dressing apparatus.

[0095] In the present example, as the dressing-working parts B are disposed at unequal spaces in the circular direction of the dresser principal 52, forces which cause the vibration of the dresser 51 are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser 51.

[0096] Thus, according to the dresser 51 of the present invention and the dressing apparatus having the same, the vibration of the dresser 51 hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0097] The number and disposition of arranged dressing-parts B are not limited to the example shown in Fig.6 and any embodiment is available as long as the dressing-working parts B are disposed at unequal spaces in the circular direction of a dresser principal 52.

Example 3:

[0098] The dresser of Example 3 of the present invention and the dressing apparatus having the same are described in detail hereunder, referring to Fig.8 showing an under surface view.

[0099] A dresser 61 of the present example comprises a dresser principal 62 having an approximately circular shape and a dressing-working part C comprising a grindstone disposed along the circular direction in the under surface of the outer peripheral portion of the dresser principal 62.

[0100] Nicks N are provided to the dressing-working part C by forming a plurality of notches at unequal spaces in the circular direction of the dresser principal 62.

[0101] The arrangement of the nicks N can be decided in the same manner as in the dressing-working parts of Example 2. In the present example, the positions in the case of disposing dressing-working parts C at equal spaces are designated as a standard position P, and any one among the standard positions P is designated as a starting point P_0, and an angle between each standard position and the starting point when looked from the center of axis of the dresser principal 62 is designated as θ, and $x=\sin\theta$ is specified as a deviation x of each dressing-working part C from each standard position P. Here, in Fig.8, accompanied characters are provided to standard positions P (and a dressing-working part C, nick N, angle θ and an amount of deviation x corresponding to each standard position P), in a counterclockwise order starting from the starting point P_0.

[0102] Dressing a polishing pad 4 is carried out in the thus-constituted dresser 61 and a dressing apparatus having the same, in the same manner as in the dresser 51 of Example 2 and the dressing apparatus having the same.

[0103] In this example, as the nicks N are disposed at unequal spaces in the circular direction of the dresser principal 62, forces which cause the vibration of the dresser 61 are not brought about periodically and are brought about aperiodically to suppress the resonance of the dresser 61.

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[0104] Thus, according to the dresser 61 of the present invention and the dressing apparatus having the same, the vibration of the dresser 61 hardly takes place and the vibration can be suppressed within a short time if the vibration takes place.

[0105] The number and disposition of arranged nicks N are not limited to the example shown in Fig.8 and any embodiment is available as long as the nicks are disposed at unequal spaces in the circular direction of a dresser principal 62.

Example 4:

[0106] Example 4 of the present invention is described in detail hereunder, referring to Figs.

[0107] Fig.10 and 11 are schematically illustrating the present example. In the Figs., symbol 71 shows a dresser.

[0108] As shown in the Figs., the dresser 71 comprises a plurality f cutters 75 disposed at a prescribed spaces in the circular direction of a dresser principal 72, in a peripheral edge portion 74 of an under surface 73 of the dresser principal 72 having a circular shape.

[0109] The cutters 75 are arranged in the state that the cutter is projected from the under surface73 of the dresser principal 72 as shown in Fig.9 of an enlarged view (a view illustrating the vicinity of the cutter 75 when looked from a p direction in Fig.11). As further enlarged in Fig.12, the cutter 75 comprises an edge of cutter 76 having a flat surface 77 parallel to a polishing pad surface to be dressed (not show in Figs.). The width of the flat surface (a land width:1) is 0.001 to 0.5mm.

[0110] The rake angle D of the cutter 75 is 10° and the clearance angle E thereof is also 10°. The edge of cutter 76 of the cutter 75 is arranged in such a manner having a -15° of an inclined angle α, wherein, as shown in Fig.13, the inclined angle is defined as an angle of the edge of the cutter 76 inclined from a straight line L1 passing through an edge of end 76a in the edge of cutter 76 at the center side of the dresser principal 72 (not shown in the Fig.) and the center of the dresser principal 72 (not shown in the Fig.), and a movement direction of the cutter 75 relative to the polishing pad, that is, a rotational direction of the dresser principal 72 (mentioned after) is defined as positive (a q direction in Fig.13). In addition, nicks 78 are provide to the edge of cutter 76 of the cutter 75 as shown in Fig.13.

[0111] Hard materials such as diamond having a single crystal, cBN, sintered compact produced under a high pressure such as polycrystalline diamond, and materials coated by hard materials as mentioned above are used for the edge of cutter 76.

[0112] When a polishing pad is dressed by using the dresser 71, the polishing pad is shaved by the cutter 75 by rotating a platen 79 having the polishing pad attached thereto an h direction in the Fig.14 and rotating the dresser principal 72 to an i direction in the Fig.14 while pressing the under surface of the dresser principal 72 in such a manner that the flat surface 77 of the cutter 75 is pressed against the under surface of the dresser principal 72, thereby to dress the upper surface of the polishing pad. Here, the i direction is a movement direction of the cutter 75 mentioned above relative to the polishing pad (a q direction in Fig.13).

[0113] In the above-mentioned dresser 71, as the shaving of the polishing pad surface is carried out by providing to the edge of cutter 76 of the cutter 75 a movement relative to the polishing pad in a direction parallel to the polishing pad surface while the edge of cutter 76 is pressed against the polishing pad surface, the dresser is protected from the lowering of the dressing performance thereof which is caused by clogging of the polishing pad surface with the shaved chips in between abrasive grains, as compared with the conventional one, whereby a stable dressing performance is available. Further, as the polishing pad is shaved by using the cutter 75 as mentioned above, an amount of wear can be decided from the flank of the cutter 75 with result that the criterion for use is clear as compared with the conventional one, thereby to enable always to maintain easily a stable dressing performance. Furthermore, as the cutter 75 is used, reusing a cutter 75 which has worn is possible, which is different from the conventional one, with the result of providing excellence in a cost for the dresser.

[0114] In the dresser 71, as the flat surface 77 is formed in the edge of cutter 76 of the cutter 75, the edge of cutter 76 of the cutter 75 is disposed always at a settled position to the polishing pad without causing the vibration of the edge of cutter 76 of the cutter 75 when the dresser principal 72 is pressed against the polishing pad surface, whereby the flatness of the polishing pad can be obtained and in its turn, the polished performance of materials to polished such as semiconductor wafer can be increased.

[0115] Still further, in the dresser 71, the shaved chips of the polishing pad and the residues of slurries left in the polishing pad which have generated in polishing materials to be polished by methods such as a CMP method can be scooped up by the cutter 75 owing to providing a positive angle to a rake angle D of the cutter 75, whereby the dressing performance can be increased and the polishing pad can be easily cleaned.

[0116] In addition, in the dresser 71, the edge of cutter 76 of the cutter 75 is arranged in such a manner having a negative angle wherein a rotational direction of the dresser principal 72 (a q direction in Fig.13) is defined as positive to a straight line L1 passing through an edge of end 76a at the center side of the dresser principal 72 (not shown in the Fig.) and the center of the dresser principal 72. In such a construction, as a normal line L2 (refer to Fig.13) of the rank face 80 of the cutter 75 (refer to Figs.12 and 13) is always directed to the outward of the dresser principal, the shaved chips of the polishing pad scraped away and the residues left in the polishing pad of slurries which have generated in polish-

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ing materials to be polished by the CMP are scraped out by the edge of cutter 76 from the center side of the dresser 72 to the outward thereof. As mentioned above, as the shaved chips of the polishing pad and the residues of slurries left in the polishing pad which have generated in polishing materials to be polished by the CMP are scraped out to the outside by the cutter 75, the polishing pad can easily be cleaned.

[0117] It is to be understood that, within the spirit of the present invention, designs may be practiced otherwise than as specifically described in the present example.

[0118] For example, the rake angle D can be from -20 to 30°. Specifically, in case where channels having a embossed pattern or a latticed pattern are provide to the polishing pad, the rake angle D is preferably a negative angle such that the side wall of the channel can not be shaved off. In case where the polishing pad is too soft, a negative rake angle is also effective as the rake angle D in order to protect the polishing pad from an excessive shaving.

[0119] Further, in case where the rake angle D is from -5° to -15° , the mechanical strength of the cutter 75 can be ensured and it is useful for cases which require the strength of an edge of cutter.

[0120] Further, a width of land 1 can be within the range of 0.005 to 0.5mm and is preferably from 0.05 to 0.1mm. Further, the clearance angle can be from 3° to 15°. An amount of biting depth of the cutter to the polishing pad can be controlled by adjusting an amount of clearance angle E and a width of flank, as mentioned above. Thereby, an optimum shape can be adopted according to the materials and hardness of the polishing pads. Further, the angle α of inclination of the edge of cutter 76 of the cutter 75 can be within the rage of -10 to -30°. In addition, a construction is possible which has no nick 78.

[0121] Further, the edge of cutter 76 can be selected according to the materials of polishing pads to be dressed and slurry materials used in polishing materials to polished by a CMP method. With regard to a method for attaching the edge of cutter 75, brazing, a clamp method, a blade method and so on can be used.

[0122] Further, the clearance angle of the cutter 75 can comprise two steps as in shown in Fig.15 (for example, α 1=5° , β=15° ,in Fig.15). In this case, an amount of biting depth of the cutter 75 to the polishing pad is controlled by adjusting the clearance angle and the width of the first flank W, thereby to enable to obtain a pertinent dressing rate.

Example 5:

[0123] The dresser 81 of Example 5 of the present invention is described in detail hereunder, referring to Fig.16. The same symbols are provided to the same parts as those of the conventional dresser 11 described in the related art and the description thereon is omitted.

[0124] A dresser 81 is attached to an arm 9 of a dressing apparatus 7 by the aid of a setting shaft 82 in a CPM apparatus 1 shown in Fig.17, in the same manner as in the dresser 11.

[0125] Here, with regard to the setting shaft 82, one end of the setting shaft directed to a rotary shaft is connected to a drive unit (not shown in Figs.) by the aid of the arm and the setting shaft 82 is rotated around the rotary shaft. In the other end thereof, a flange 84 is formed for fixing the dresser 81 (refer to Fig.16 illustrating a side sectional view). In the flange 84, a plurality of bolt inserting holes 86 for bolts 85 for screw-clamping the dresser 81 to the flange 84 are disposed at appropriate spaces in the circular direction thereof (only one portion is illustrated in Fig. 16). Hereunder, in the present specification, the side of the dresser 81 contacting to the setting shaft 82 is defined as the upper side thereof and another side of the dresser 81 where a dressing-working part 15 is formed is defined as the lower side thereof.

[0126] The dresser 81 is an electrodeposited grindstone having a dressing-working face 15 formed by providing an abrasive grain layer 93 including abrasive grains 93 on the surface of a dresser principal 83 having a approximately annular shape, as shown in Fig.16, and the dresser is fixed to the setting shaft 82 while, the center of the dresser is matched with the center of the setting shaft 82.

[0127] The material of the dresser principal 83 comprises aluminum, stainless steel, steel or a combination of aluminum and steel and the section thereof is approximately a rectangle. A convex 87 of the outer peripheral side which is projected at the outer peripheral side of the under surface of the dresser principal 83 toward the lower side is formed all around the periphery, and the under surface of the convex 87 comprises a ground face 88 having an abrasive grain layer 93 formed thereon. The ground face is formed in such a manner that the face thereof is orthogonally crossed to a rotary axis AX of the dresser principal 83. In Fig.16, the thickness of the abrasive grain layer 93 is illustrated larger than the actual one so as to easily understand the shape of the dressing-working face 15.

[0128] A convex 89 of the inward peripheral side having an amount of projection to the lower side smaller than that of the convex 87 of the outer peripheral side is formed in a position closer to the center of rotation than the convex 87 of the outer peripheral side in such a manner that the convex 89 is concentric with the convex 87 and the under surface of the convex 89 comprises a basic face 90 which is parallel to the ground face 88. A recess 92 is formed between the convex 87 and the convex 89 so as to obtain the working accuracy thereof. A plurality of holes for bolt 91 for screw-clamping the bolts 85 are formed at appropriate spaces in the upper face of the dresser principal 83 all around the periphery (only one portion is illustrated in Fig.16).

[0129] Here, the dresser principal 83 is screw-

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clamped to the under surface of the flange 84 of the setting shaft 82 by screw-clamping the bolts 85 to the holes for bolt 91.

[0130] When the dressing of a polishing pad 4 is carried out with the dresser 81 constructed as mentioned above, the following operations are carried out so as to stabilize conditions for dressing the polishing pad 4.

[0131] First, dressers 81 are checked on whether or not a dresser 81 has a flatness of the dressing-working face 15 within a range which is proper to a use for the dressing apparatus 7, and dressers 81 are selected which have the proper flatness.

[0132] The flatness of a dressing-working face 15 can be predicted by inspecting the flatness of the ground face 88 for forming the dressing-working face 15, and the flatness of the ground face 88 can be predicted by inspecting the flatness of the basic face 90 parallel to the ground face 88.

[0133] Namely, if the flatness of a basic face 90 is within the range proper for a use in the dressing apparatus 7, the flatness of the corresponding ground face 88 and dressing-working face 15 can be predicted to be also within the range proper for the use, thereby to select dressers 81 which have the flatness of a basic face which is within the range proper for the use and to use the selected dressers.

[0134] Next, a dresser 81 which has been confirmed to have a flatness within the proper range is attached to the under surface of the flange 84 of the setting shaft 82 by the bolts 85.

[0135] Then, the deflection of the basic face 90 of the dresser 81 is measured with dial gauge, while rotating the setting shaft 82 together with the dresser 81 by a drive unit which is not shown in Figs., and the setting condition of the dresser is adjusted so as to attain a deflection having a proper range.

[0136] When the deflection is not within the proper range, it is considered as a reason that dust is contained in between the setting shaft 82 and the dresser 81, together with another reason due to an error in attaching the setting shaft 82. If the dust problem is considered, the dresser 81 is detached from the setting shaft 82 to confirm whether or not the dust is interposed in between. When the dust is interposed, the dust is removed, followed by attaching again the dresser 81 to the setting shaft 82.

[0137] According to the thus constructed dresser 81, as a ground face 88 having a dressing-working face 15 formed thereon can be predicted whether to be flat or not, dressers having a good flatness of the dressing-working face can be selected and used.

[0138] Further, the condition of attaching a dresser 81 to the setting shaft 82 of the dressing apparatus 7 is confirmed whether to be proper or not, the accuracy of attaching to the dressing apparatus 7 can be increased.

[0139] Thereby, the condition of dressing a polishing pad 4 with the dresser 81 can be stabilized.

[0140] Furthermore, as the basic face 90 is disposed in a position closer to the center of rotation as mentioned above than the ground face 88, that is, at the inward peripheral side of the dresser principal 83, a possibility of damaging the basic face 90 due to hitting the basic face 90 against something is decreased during delivering the dresser 81 or attaching the dresser 81 to the dressing apparatus 7, thereby to ensure an accuracy for predicting the flatness of the dressing-working face 15.

[0141] Still further, as the basic face 90 is disposed in a position close to the center of rotation, the outside diameter of the dresser 81 can be minimized and the dresser 81 can be easily handled.

[0142] In the above-mentioned example, a metal plating layer comprising the abrasive grain layer 93 can be formed by a metal which is not limited to Ni, and other metals can used. A method for forming the metal layer is not limited to electroplating, and the metal layer can be formed on the dresser principal 83 by PVD or CVD.

[0143] The present invention is not limited to the examples as mentioned above and various modified examples are included which contain the combinations of the examples (for examples, a combination of Example 1 and Example 2, and the combinations of any of Examples 1 to 4 and Example 5).

Claims

1. A dresser for dressing a polishing pad used for polishing a material to be polished, the dresser comprising:

   a dresser principal and a dressing-working part which is provided as a body other than the dresser principal; and
   a holding means for holding the dressing-working part in such a manner that the dressing-working part can be attached to and detached from the dresser principal.

2. The dresser as claimed in claim 1, wherein a projection adjusting means is provided for controlling an amount of projection of said dressing-working part from said dresser principal.

3. The dresser as claimed in claim 2, wherein said dressing-working part is a cutter.

4. The dresser as claimed in claim 3, wherein said cutter has an approximately columnar shape and comprises: a flank which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face comprising a circumferential surface in the end portion of the cutter; and a cutting edge which is a ridgeline formed by crossing of the end face and the circumferential surface in the end

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portion.

5. The dresser as claimed in claim 3, wherein said cutter comprises:

a plurality of projections formed in one end of the cutter;
said projection having a cross section approximately equal to an end face of the projection from one end of the projection to near another end of the projection from which the projection is started; and
a cutting edge which is a ridgeline formed by crossing of the end face of the projection and the side surface of the projection.

6. The dresser as claimed in claim 1, wherein said dressing-working part is a cutter.

7. The dresser as claimed in claim 6, wherein said cutter has an approximately columnar shape and comprises: a flank which is formed by concaving one end face of the cutter toward the base end of the cutter; a rake face comprising a circumferential surface in the end portion of the cutter; and a cutting edge which is a ridgeline formed by crossing of the end face and the circumferential surface in the end portion.

8. The dresser as claimed in claim 6, wherein said cutter comprises:

a plurality of projections formed in one end of the cutter;
said projection having a cross section approximately equal to an end face of the projection from one end of the projection to near another end of the projection from which the projection is started; and
a cutting edge which is a ridgeline formed by crossing of the end face of the projection and the side surface of the projection.

9. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 1.

10. A dresser for dressing a polishing pad used for polishing a material to be polished, said dresser comprising a plurality of dressing-working parts for dressing the polishing pad which are disposed at unequal spaces in the circular direction of a dresser principal.

11. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 10.

12. A dresser for dressing a polishing pad used for polishing a material to be polished, said dresser comprising: a dressing-working part for dressing the polishing pad along the circular direction of a dresser principal; and a plurality of nicks formed in the dressing-working part at unequal spaces in the circular direction of the dresser principal.

13. A dressing apparatus for dressing with a dresser the surface of a polishing pad used for polishing a material to be polished, said dresser comprising a dresser according to claim 12.

14. A dresser for dressing a polishing pad surface which is used for an apparatus for polishing, with the polishing pad, materials to be polished such as a semiconductor wafer having a flat surface, said dresser comprising at least one cutter projected from the under surface of a dresser principal,
wherein shaving the polishing pad surface is carried out by providing to the edge of cutter of the cutter a movement relative to the polishing pad surface in a direction parallel to the polishing pad surface, while the edge of cutter is pressed against the polishing pad surface.

15. The dresser as claimed in claim 14, wherein said edge of cutter comprises a flat surface which is parallel to the polishing pad surface and is pressed against the polishing pad surface.

16. The dresser as claimed in claim 14, wherein said cutter comprises a positive rake angle.

17. The dresser as claimed in claim 14, wherein said cutter comprises a rake angle having from -5° to -15°.

18. The dresser as claimed in claim 14, wherein said dresser principal has a circular shape and is constructed in such a manner that the dresser principal is rotated around a rotary shaft formed in the center thereof; and the edge of cutter of the cutter is arranged in such a manner that the edge of cutter has a negative angle wherein a rotational direction of the dresser principal is defined as positive to a straight line passing through the edge of end of the edge of cutter at the center side of the dresser principal and the center of the dresser principal.

19. A dresser which comprises a dresser principal and a dresser-working part having an abrasive grains layer including abrasive grains formed on the dresser principal,
wherein the dresser principal comprises a ground face on which the abrasive-grain layer is provided

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and a basic face which is disposed in a portion of the dresser principal more inward than the ground face and is formed in parallel to the ground face.

20. The dresser as claimed in claim 19, wherein said ground face comprises an approximately annular shape having a center which is the same as the center of rotation of said dresser principal; and the basic face is disposed in a position closer to the center of rotation than the ground face and is concentric with the ground face.

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FIG. 1

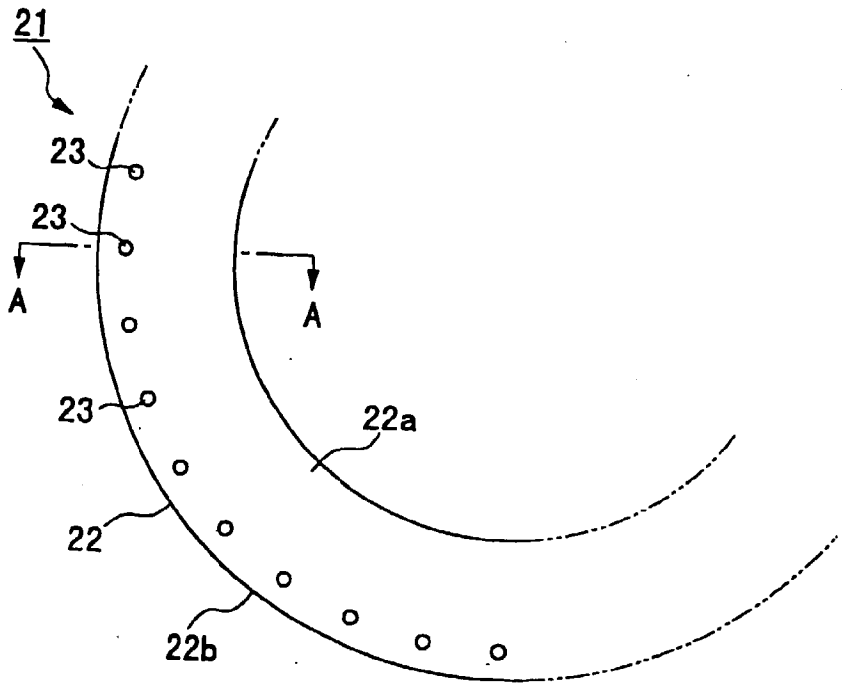


FIG. 2

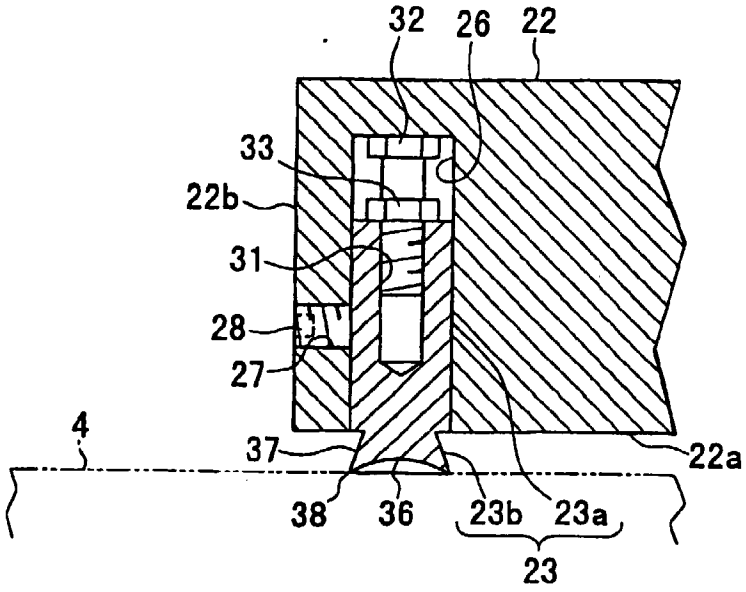

32
26
22
33
22b
31
28
27
4
37
22a
38
36
23b
23a
23

FIG. 3

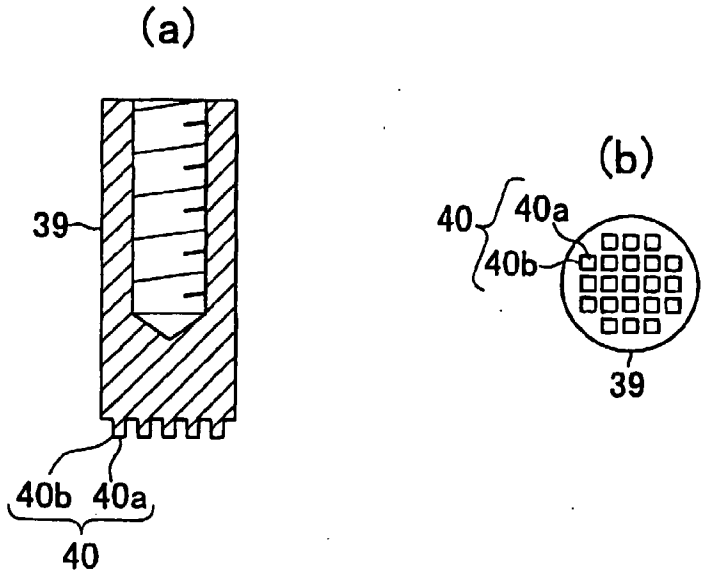

(a)
39
40b
40a
40
(b)
40
40a
40b
39

FIG. 4

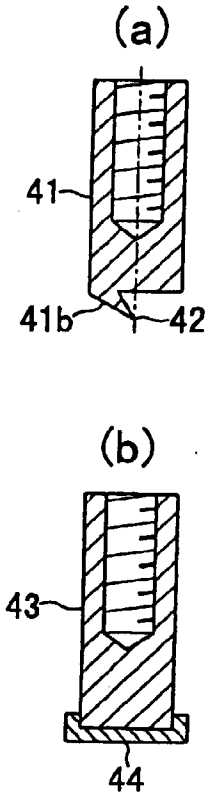


FIG. 5

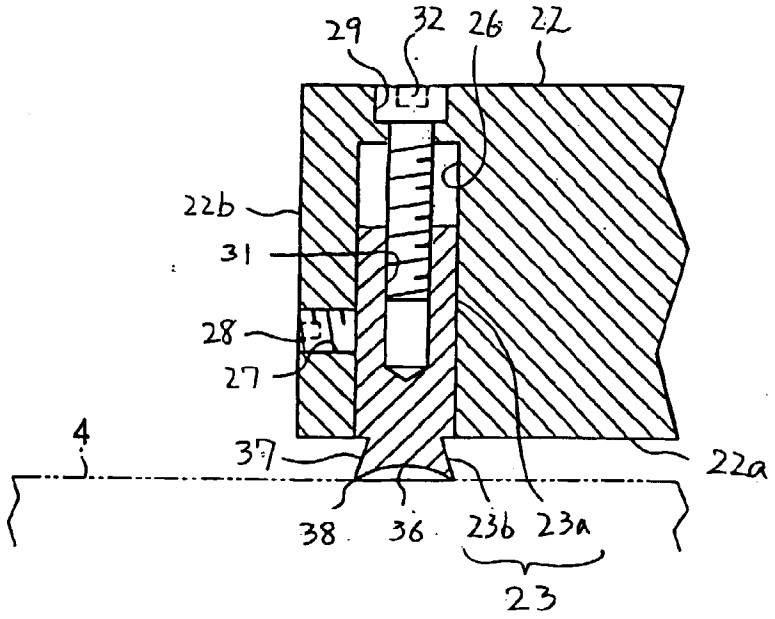


FIG. 6

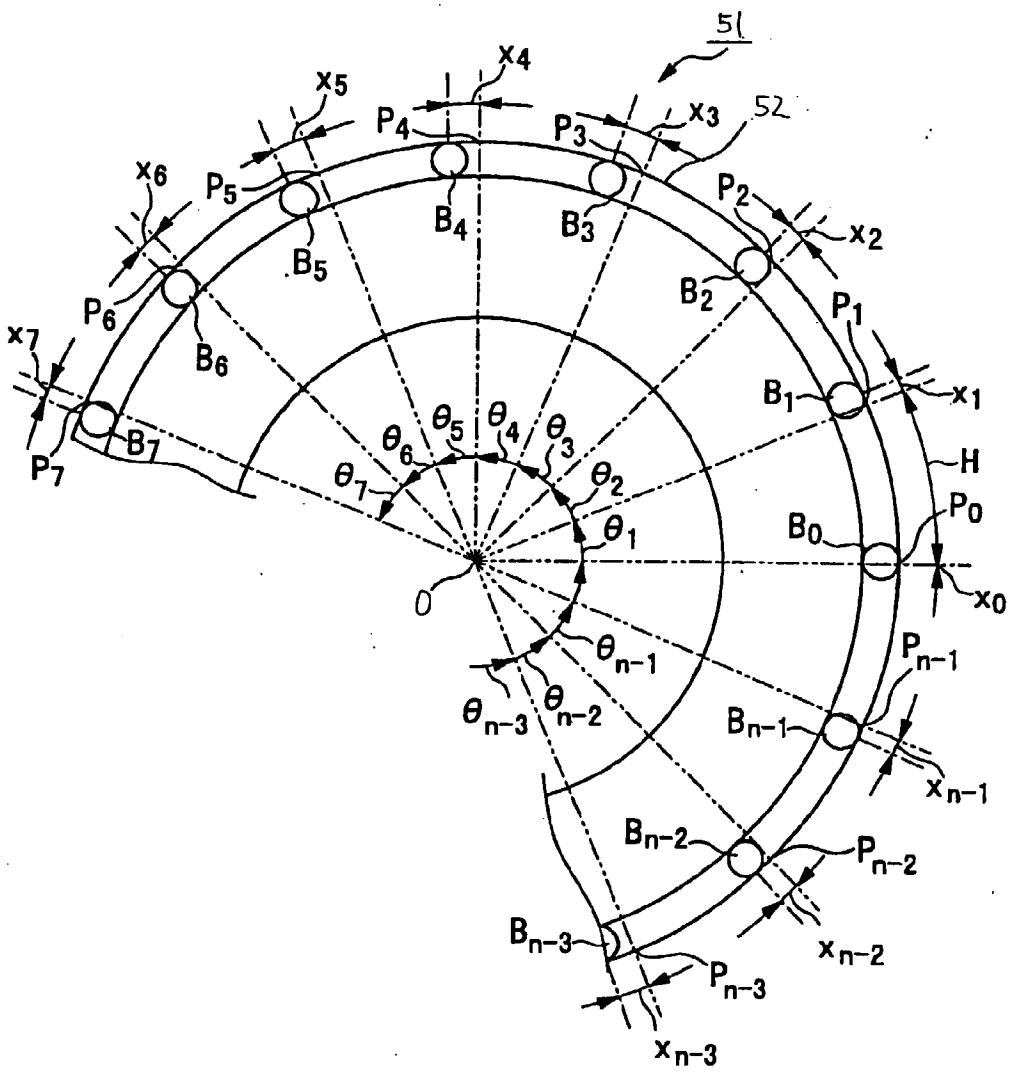

51
52
x_4
x_5
P_4
P_3
x_3
x_6
P_5
P_2
x_2
B_4
B_3
B_5
B_2
P_6
P_1
x_7
B_6
B_1
x_1
B_7
θ_5
θ_4
θ_3
θ_6
θ_2
H
P_7
θ_7
θ_1
B_0
P_0
0
x_0
θ_{n-1}
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B_{n-1}
x_{n-1}
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P_{n-2}
B_{n-3}
x_{n-2}
P_{n-3}
x_{n-3}

FIG. 7

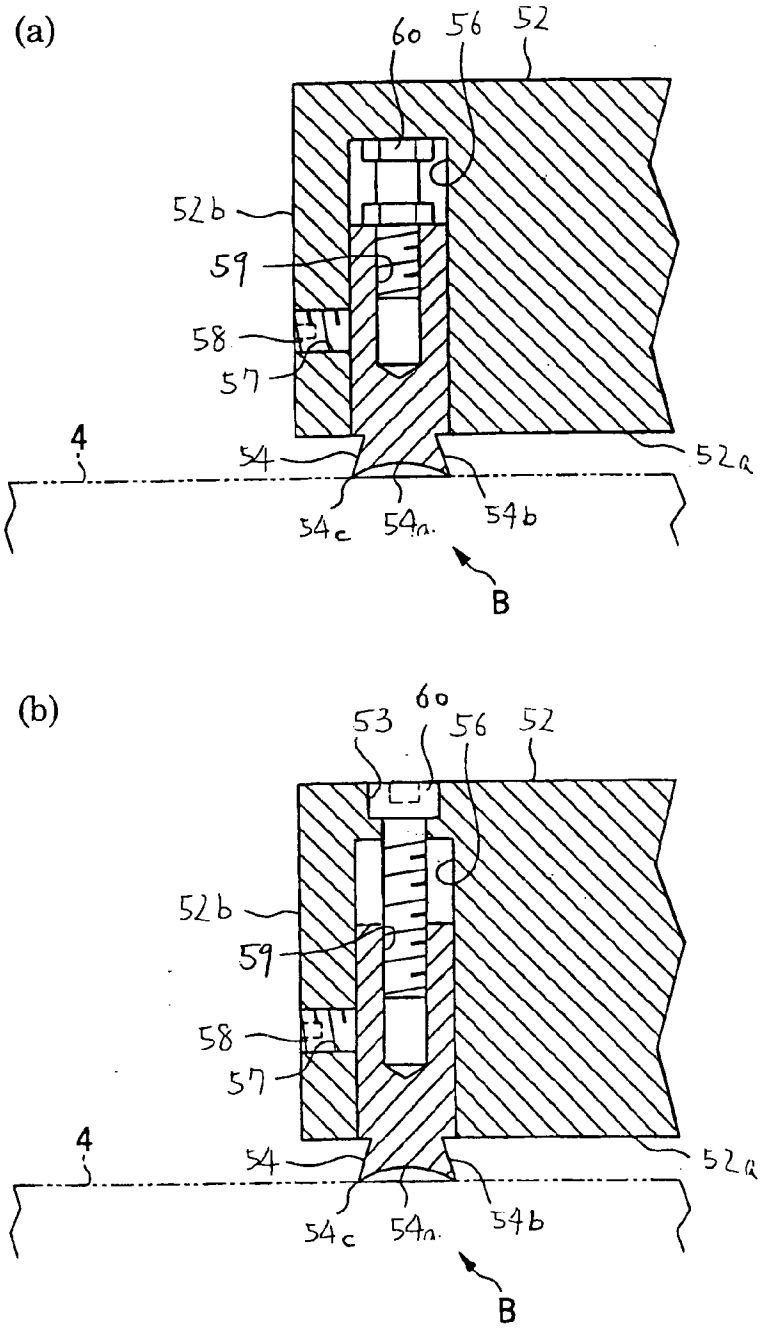

(a)
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B
(b)
53
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B

FIG. 8

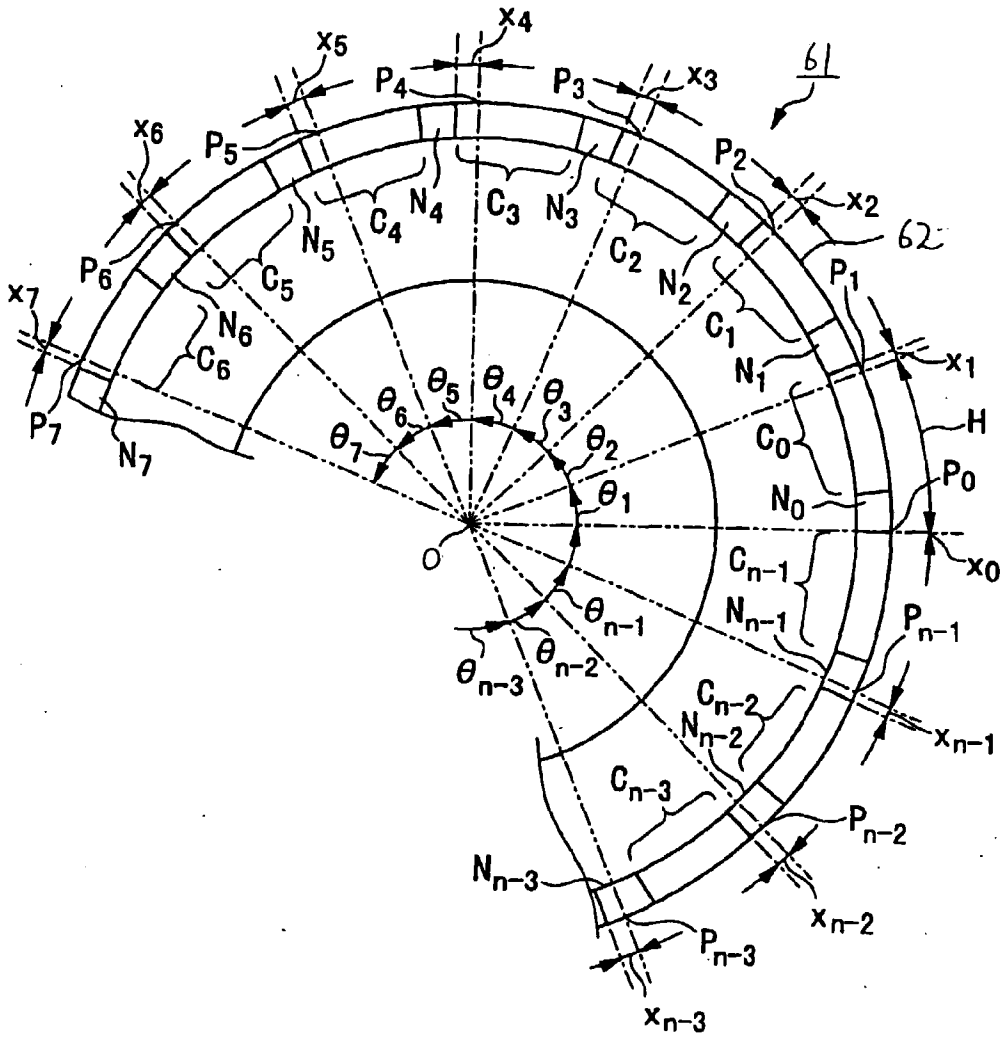

61
62
O
H
x_0 x_1 x_2 x_3 x_4 x_5 x_6 x_7 x_{n-1} x_{n-2} x_{n-3}
P_0 P_1 P_2 P_3 P_4 P_5 P_6 P_7 P_{n-1} P_{n-2} P_{n-3}
C_0 C_1 C_2 C_3 C_4 C_5 C_6 C_{n-1} C_{n-2} C_{n-3}
N_0 N_1 N_2 N_3 N_4 N_5 N_6 N_7 N_{n-1} N_{n-2} N_{n-3}
θ_1 θ_2 θ_3 θ_4 θ_5 θ_6 θ_7 θ_{n-1} θ_{n-2} θ_{n-3}

FIG. 9

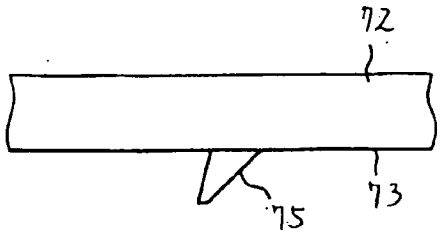


FIG. 10

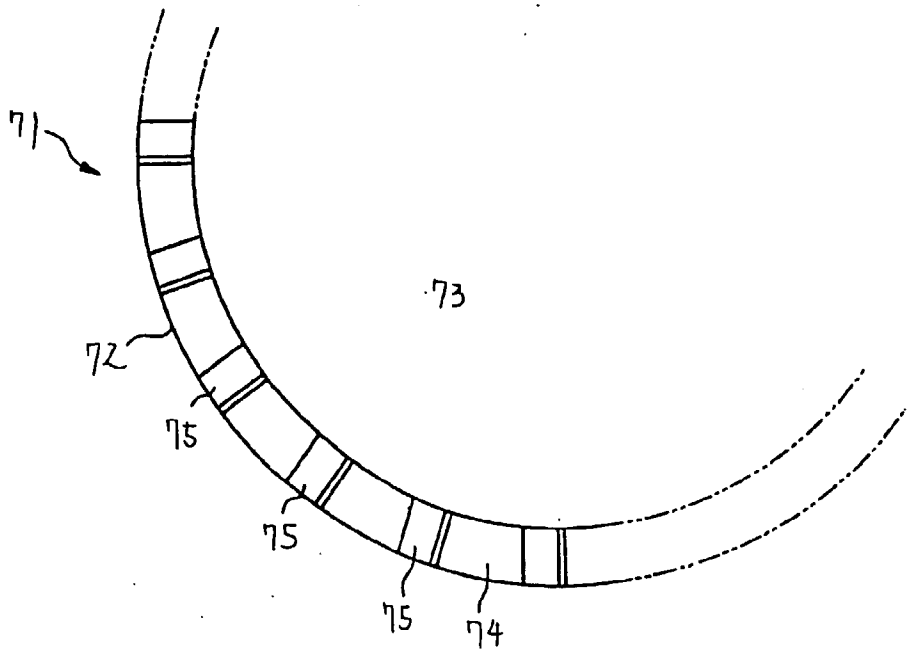


FIG. 11

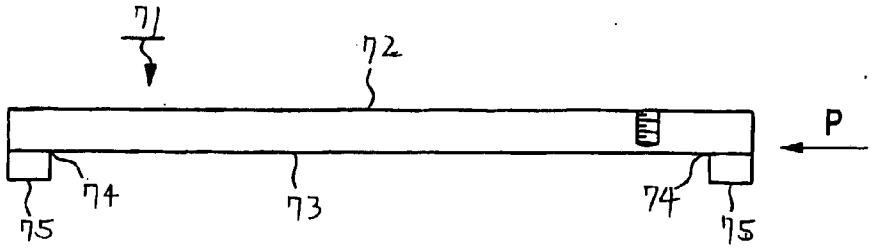


FIG. 12

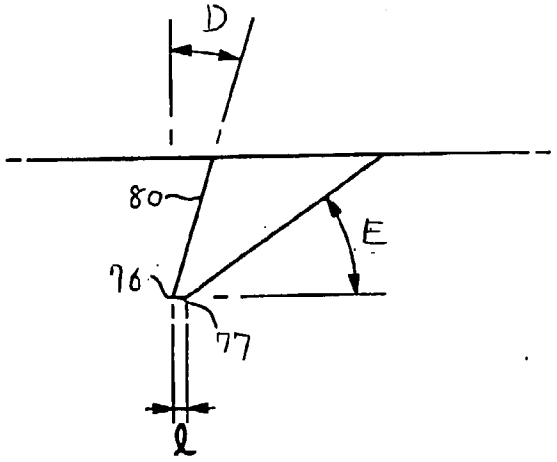


FIG. 13

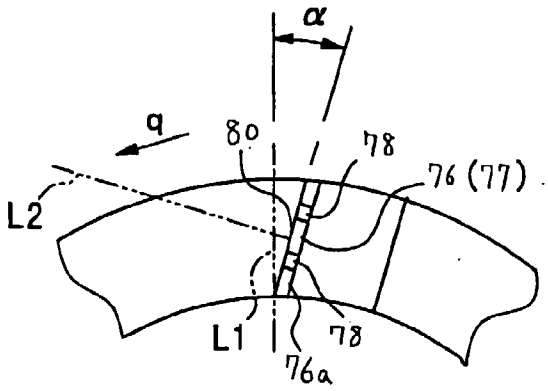


FIG. 14

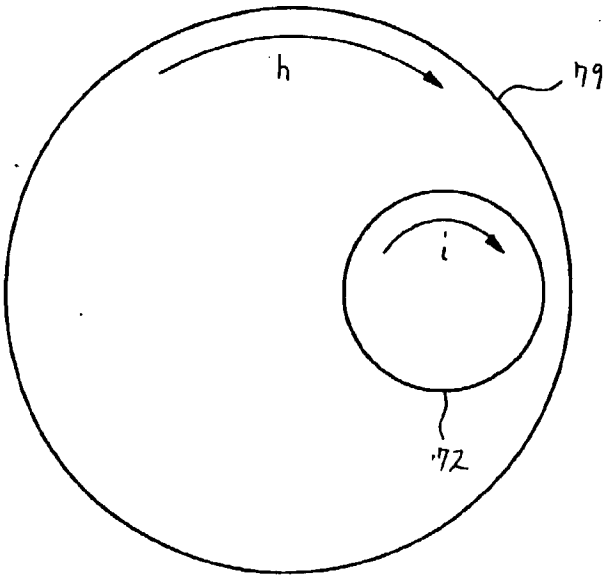


FIG. 15

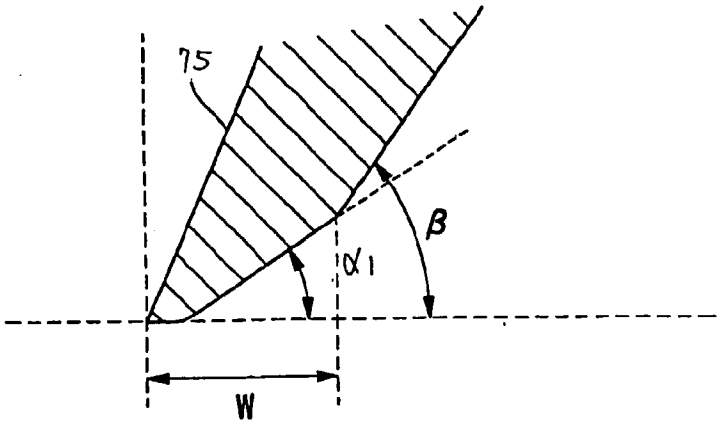


FIG. 16

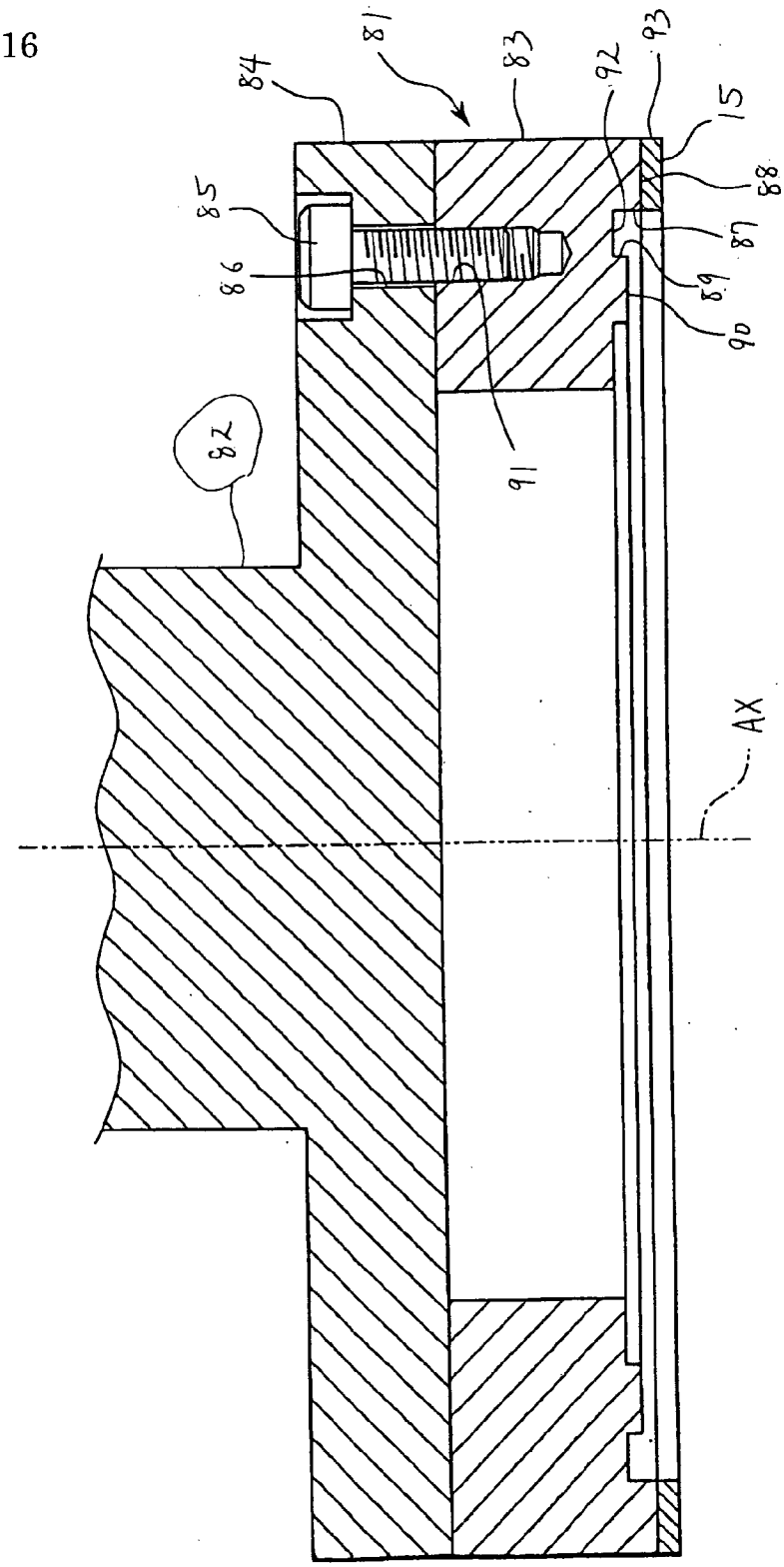


FIG. 17

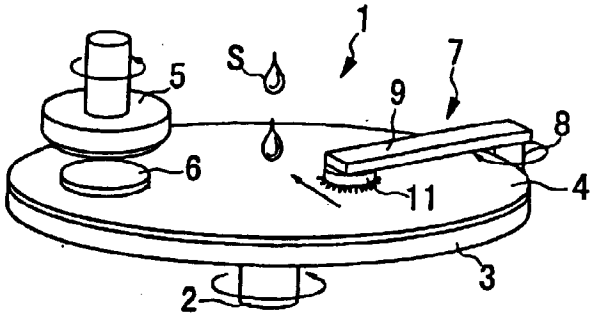


FIG. 18

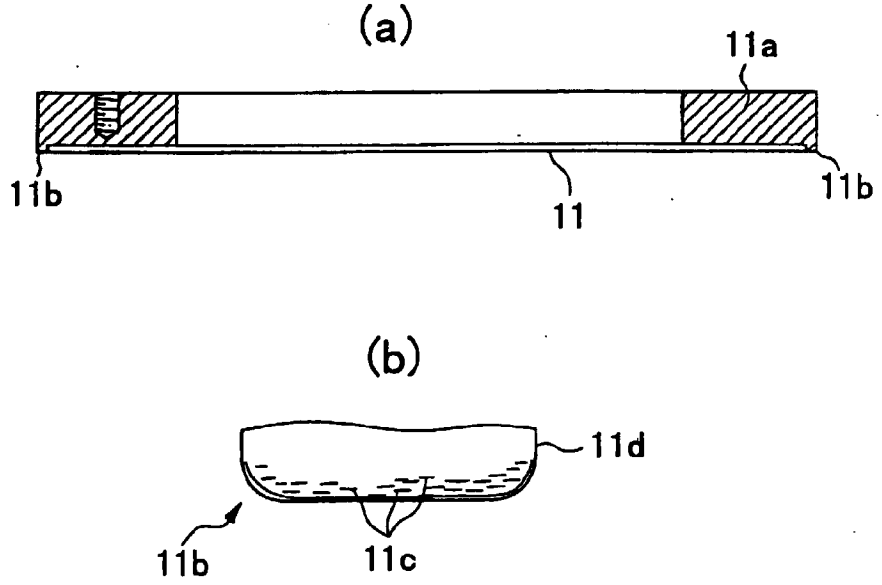


FIG. 19

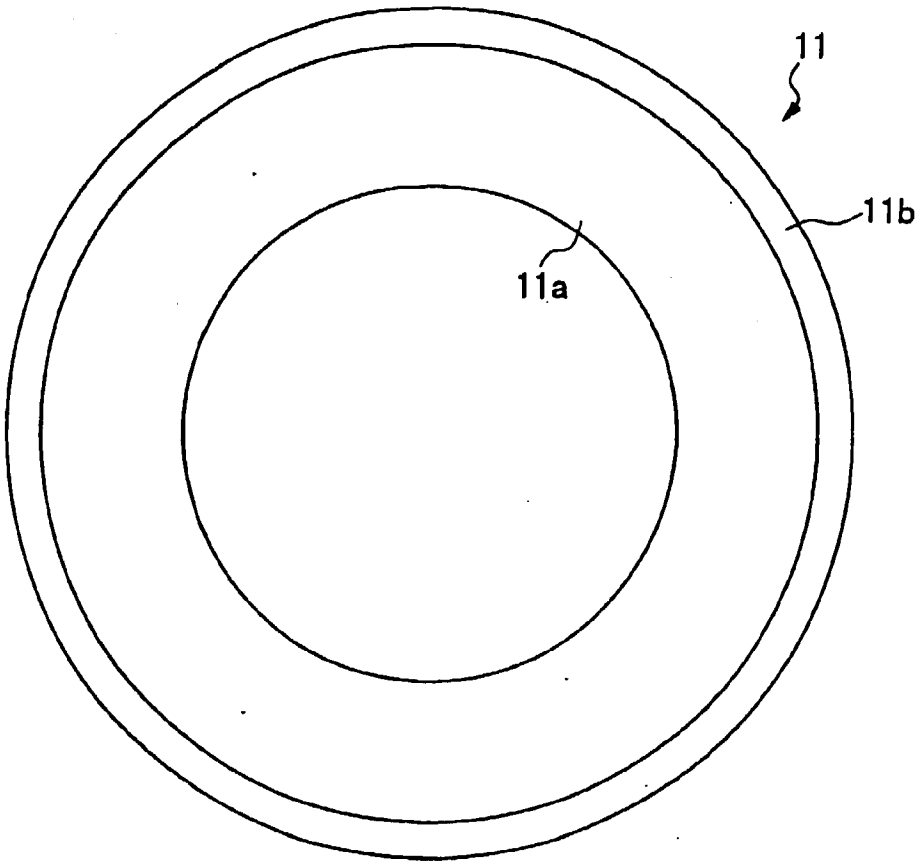


FIG. 20

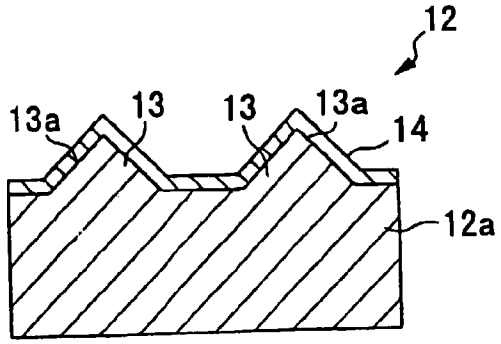
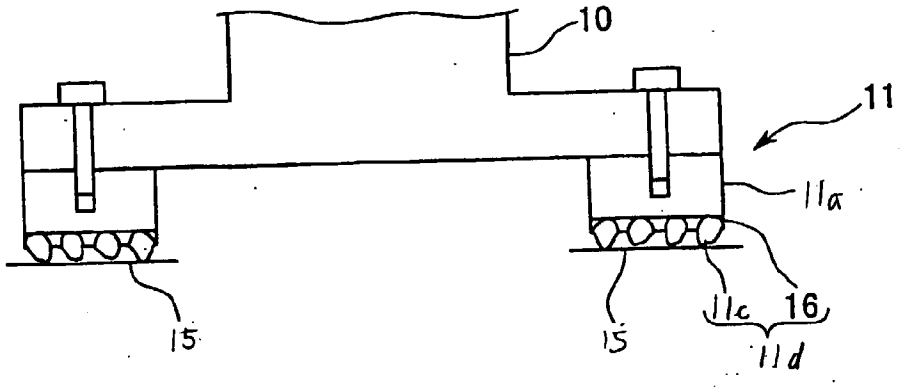


FIG. 21



GB2239011

Publication Title:

Single-crystal diamond of very high thermal conductivity

Abstract:

Abstract of GB 2239011

(A) Translate this text Single-crystal diamond consisting of isotopically pure carbon-12 or carbon-13 has been found to have a thermal conductivity higher than that of any substance previously known, typically at least 40% higher than that of naturally occurring IIA diamond. It may be prepared by a method comprising comminution of diamond of high isotopic purity, such as that obtained by low pressure chemical vapor deposition employing an isotopically pure hydrocarbon in combination with hydrogen, followed by conversion of the comminuted diamond to single-crystal diamond by diffusion under high pressure through a metallic catalyst-solvent material to a region containing a diamond seed crystal.

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(54) Single-crystal diamond of very high thermal conductivity

(57) Single-crystal diamond consisting of isotopically pure carbon-12 or carbon-13 has been found to have a thermal conductivity higher than that of any substance previously known, typically at least 40% higher than that of naturally occurring IIA diamond. It may be prepared by a method comprising comminution of diamond of high isotopic purity, such as that obtained by low pressure chemical vapor deposition employing an isotopically pure hydrocarbon in combination with hydrogen, followed by conversion of the comminuted diamond to single-crystal diamond by diffusion under high pressure through a metallic catalyst-solvent material to a region containing a diamond seed crystal.

GB 2 239 011 A

SINGLE-CRYSTAL DIAMOND OF VERY HIGH THERMAL CONDUCTIVITY

This invention relates to the preparation of single crystal diamond of extremely high thermal conductivity.

Diamond substances with high thermal conductivity are known in the art. For example, type IIA natural diamond, characterized by a very high degree of purity, has a thermal conductivity at 25°C (298°K) on the order of 21 watts/cm.°K, the highest of any material known prior to the present invention. Its electrical conductivity, on the other hand, is so low as to be negligible.

These properties make diamond an excellent material for conducting heat away from heat-generating objects or units. It may be used as a heat sink or as a conductor/spreader to conduct heat from the heat-generating object or unit to a heat sink of some other material.

Various areas exist in which heat conductors of very high thermal conductivity are necessary. One example is in repeating stations for fiber optic networks. Signals are transmitted by laser light over the fibers of such networks for very great distances. Since these signals decrease substantially in intensity over several kilometers, it is necessary to construct "repeating stations" periodically along the network, for the purpose of increasing the intensity of the light transmitted along the network. In a typical repeating station of this type, a photodetector is employed to convert the weakened signal transmitted by fiber optics to an electrical signal, which is then magnified, reconverted to a light signal by a light-emitting diode, and transmitted in turn along the next segment of the network.

In order to minimize the requisite number of repeating stations, optimum magnification of the signal in any station is desirable. However, the amount of radiant energy of any kind generated electrically is proportional to the fourth power of the current employed. While a portion of such radiant energy is in the form of light, the remainder thereof is lost as heat. In any individual station, therefore, very large amounts of heat are generated, requiring efficient heat conductors to maintain the operativeness of the repeating station.

The use of natural type IIA diamond as a conductor of heat in these areas has not been foreclosed despite its very high cost since the operative heat-conducting units are very small, typically about 1 mm. on a side. When larger heat-conducting elements are required, expense considerations become important and the use of natural diamond may accordingly be foreclosed.

Conventionally produced high-pressure synthetic diamond of gem quality is lower in cost than natural diamond. However, synthetic diamond of this type having high thermal conductivity cannot effectively be produced directly from graphite because a profound contraction in volume occurs in the conversion and introduces imperfections into the crystalline structure. For the most part, diamond prepared by low-pressure chemical vapor deposition (hereinafter sometimes "CVD") processes are not single crystal diamond and have substantially lower thermal conductivities, typically on the order of 12 watts/cm.°K at about 300°K (hereinafter sometimes "room temperature conductivity").

In U.S. Patent 3,895,313, there are disclosed various diamond materials which allegedly have very high thermal conductivities, and which allegedly are useful as optical elements for very high-power laser beams. In particular, it is stated that synthetic diamond grown from

isotopically pure carbon-12 or carbon-13 would be useful in this way, with room temperature conductivity values in the range of 10-20 watts/cm.°K being mentioned. This is, of course, the order of magnitude of natural type IIA diamond and also of diamond produced by chemical vapor deposition. It is further suggested that at a temperature of 70°K (-203°C), below the temperature of liquid nitrogen, a thermal conductivity exceeding 200 watts/cm.°K may be obtained, perhaps in diamond which has high isotopic purity and "relevant properties which closely approach the limits predicted by the theory of the perfect solid state" (i.e., are in single-crystal form). However, no methods for the preparation of such diamond are suggested, and the state of the art has hitherto been inadequate to put them in the possession of the public.

The present invention provides a method for preparing single-crystal diamond of very high chemical and isotopic purity. The raw material for such diamond is itself diamond, which eliminates the volume contraction encountered in the high-pressure conversion of graphite to diamond. The thermal conductivity of the diamond so produced has been found to be higher than that of any substance presently known including natural type IIA diamond, and also higher than the values in the aforementioned U.S. Patent 3,895,313. Accordingly, it is eminently suitable for use as a conductor of heat and also in numerous other areas.

In one of its aspects, the invention is a method for preparing single-crystal diamond of high isotopic purity which comprises the steps of:

(A) preparing diamond consisting of isotopically pure carbon-12 or carbon-13; and

(B) converting said diamond to single-crystal diamond by diffusion under high pressure through a metallic

catalyst-solvent material to a region containing a diamond seed crystal.

An essential feature of the method of this invention is the employment of isotopically pure carbon-12 or carbon-13. As explained hereinafter, it has been found that the increase in thermal conductivity resulting from the employment of chemically and isotopically pure carbon is vastly greater than would be expected based on theoretical considerations. In general, the isotopic purity of the hydrocarbon should be at least 99.2% by weight; that is, the other isotope should be present in a maximum amount of 8 parts per 1000. An isotopic purity of at least 99.9% by weight is preferred. The hydrocarbon should also have a high degree of chemical purity.

Various methods may be employed in step A for the preparation of diamond in isotopically pure form. For example, a gaseous carbon compound such as carbon monoxide may be separated into carbon-12 and carbon-13 species via differences in diffusivity and then converted to solid carbon by art-recognized means, such as combustion in a reducing flame in the case of carbon monoxide. The carbon thus formed may then be converted to diamond under conventional conditions, including high temperature and high pressure conditions or CVD conditions.

Alternatively, other methods may be employed including shock formation and CVD processes under conditions which produce a mixture of diamond and graphite. In processes of the latter type, the carbon-13 species will concentrate in the diamond phase and the carbon-12 species in the graphite phase. Other diamond precursors which may be employed in enriched form include pyrolytic graphite, amorphous or glassy carbon, liquid hydrocarbons and polymers.

It is usually found that conventional methods of CVD diamond formation are most convenient for the preparation of isotopically pure diamond. In such methods, a layer of diamond is deposited on at least one substrate. Any substrate material suitable for diamond deposition thereon may be employed; examples of such materials are boron, boron nitride, platinum, graphite, molybdenum, copper, aluminum nitride, silver, iron, nickel, silicon, alumina and silica, as well as combinations thereof. Metallic molybdenum substrates are particularly suitable under many conditions and are often preferred.

The method of chemical vapor deposition of diamond on a substrate is known, and the details need not be repeated herein. In brief, it requires high-energy activation of a mixture of hydrogen and a hydrocarbon, typically methane, whereupon the hydrogen gas is converted to atomic hydrogen which reacts with the hydrocarbon to form elemental carbon. Said carbon then deposits on the substrate in the form of diamond. Activation may be achieved by conventional means involving high-energy activation which produces atomic hydrogen from molecular hydrogen; such means include thermal means typically involving heated filaments, flame means, D.C. discharge means and radiation means involving microwave or radio-frequency radiation or the like.

Thermal and especially filament methods, employing one or more resistance heating units including heated wires or filaments, are often preferred for the purposes of this invention. In such methods, the filaments are typically of metallic tungsten, tantalum, molybdenum and rhenium; because of its relatively low cost and particular suitability, tungsten is often preferred. Filament diameters of about 0.2-1.0 mm. are typical, with about 0.8 mm. frequently being preferred. Distances from filaments to substrate(s) are generally on the order of 5-10 mm.

Said filaments are typically heated at temperatures of at least 2000°C and the optimum substrate temperature is in the range of 900-1000°C. The pressure in the deposition vessel is maintained up to about 760 torr, typically on the order of 10 torr. The hydrogen-hydrocarbon mixture generally contains hydrocarbon in an amount up to about 2% by volume based on total gases. For a description of illustrative CVD methods of diamond preparation, reference is made to copending, commonly owned applications U.S. Serial Nos. 07/389,210 and 07/389,212.

Isotopically pure hydrocarbon is employed in the CVD method, when used. In order to avoid contamination thereof, it is essential to employ equipment which does not contain natural carbon as an impurity. For this purpose, the CVD chamber should be constructed of materials substantially incapable of dissolving carbon. Typical materials of this type are quartz and copper.

As between carbon-12 and carbon-13, the former is usually preferred for various reasons. In the first place, carbon-12 is present in nature in much higher proportions than carbon-13, the latter typically occurring in amounts no higher than about 1% by weight; therefore, the use of carbon-12 involves minimum expense. In the second place, thermal conductivity is inversely proportional to the square of the mass number of the isotope, and diamond prepared from carbon-12 can therefore be expected to have a thermal conductivity about 17% greater than those prepared from carbon-13. In some applications, however, carbon-13 is preferred and its preparation and use are part of the invention.

The thickness of the CVD diamond layer deposited on the substrate is not critical. In general, it is convenient to deposit at least as much diamond as will be needed to produce a single crystal of the desired size. Of course, the

production of a larger amount of CVD diamond for use to make several crystals is also contemplated.

It is possible to convert the product of the CVD process directly to diamond of high thermal conductivity by high pressure means, as described hereinafter, employing the same in the form of a slab, sheet or broken pieces thereof. However, the method of this invention is most efficiently conducted if the isotopically pure diamond is first comminuted.

Comminution may be achieved by art-recognized means such as crushing and powdering. The particle size thereof is not critical so long as a sufficient degree of comminution is attained; the form known in the art as "grit diamond" is suitable.

Step B, the production of single crystal diamond, is conventional except that the isotopically pure diamond produced in step A is the raw material employed. Two things are achieved by using diamond rather than graphite or some other allotrope of carbon as the raw material: an easily obtained isotopically pure material may be employed, and the contraction in volume encountered in the conversion of graphite and other allotropes to diamond is avoided, permitting production of a single crystal of regular structure and high quality.

The process for producing single-crystal diamond under high pressure is also known in the art, and a detailed description thereof is not deemed necessary. Reference is made, for example, to Encyclopedia of Physical Science & Technology, vol. 6, pp. 492-506 (Academic Press, Inc., 1987); Strong, The Physics Teacher, January 1975, pp. 7-13; and U.S. Patents 4,073,380 and 4,082,185, for general descriptions of the process. It generally involves diffusion of the carbon employed as a source material through a liquid bath of a metallic catalyst-solvent material, at pressures on the order

of 50,000-60,000 atmospheres and temperatures in the range of about 1300-1500°C. A negative temperature gradient, typically of about 50°C, is preferably maintained between the material being converted and the deposition region, which contains a diamond seed on which crystal growth can begin.

Catalyst-solvent materials useful in step B are known in the art. They include, for example, iron; mixtures thereof with nickel, aluminum, nickel and cobalt, nickel and aluminum, and nickel, cobalt and aluminum; and mixtures of nickel and aluminum. Iron-aluminum mixtures are frequently preferred for the production of single-crystal diamond, with a material consisting of 95% (by weight) iron and 5% aluminum being particularly preferred for the purposes of the invention.

Following preparation of the single-crystal diamond by the method of this invention, it is often preferred to remove the portion attributable to the seed crystal by polishing. This is particularly true if the seed crystal is not isotopically pure.

Studies on single-crystal diamond prepared according to the invention and having various degrees of isotopic purity have shown that at carbon-12 purity levels of 99.2%, 99.5% and 99.9% by weight, the room temperature conductivities are, respectively, 10%, 25% and 40% greater than that of natural type IIA diamond. At lower temperatures, even higher differences in thermal conductivity are to be expected. Such thermal conductivities are higher than those of any material previously known. Single-crystal diamond of this type is another aspect of the invention, as is diamond prepared by the method described herein.

The reasons for the extremely high thermal conductivity of the single-crystal diamond of this invention are not fully understood. It is assumed, however, that the phenomenon is principally a function of the mean free path of

the phonons (i.e., lattice vibration modes) in the diamond crystals. Thermal conductivity is directly proportional to specific heat, sound velocity in and phonon mean free path of the crystal, and isotope effects on specific heat and sound velocity are negligible.

In a simplified calculation, the reciprocal of the phonon mean free path can be considered as equal to the sums of the reciprocals of the mean free paths attributable to phonon-phonon scattering and to isotope effects. It has been calculated that the isotope-related mean free path is 34,000 Angstroms and the phonon scattering-related path is 1900 Angstroms; consequently, the isotope effect would account for a decrease in mean free path on the order of only about 5.2%. One possible reason for the substantially greater observed isotope effect on thermal conductivity is that contrary to theory, the isotopic constitution of the diamond has a direct effect on the mean free path attributable to phonon-phonon scattering. This effect has apparently not been previously recognized.

By reason of the aforementioned high thermal conductivity value and essentially non-existent electrical conductivity, the isotopically pure single crystal diamond of the present invention is singularly useful as a conductor of heat from electronic devices and similar heat-generating sources. Articles comprising such a source in contact with said diamond as a thermal conductor are another aspect of the invention.

A further aspect is abrasive articles comprising said diamond. Such articles can be expected to have extraordinarily long life by reason of their ability to dissipate frictional heat generated during their use. Typical areas of application include abrasive grit, diamond compacts, wire drawing dies, saw blades, scribing tools, drills, tool sharpeners, and polishing tools for optical

items, stone and precious stones including diamonds and articles made therefrom.

Still another aspect is light-filtering articles comprising said diamond with a pinhole aperture therein. They are useful, for example, as spatial filters for laser beams and the like. Articles of this type fabricated from natural diamond are subject to radiation-induced damage, probably thermal in nature. The substantially higher thermal conductivity of the diamond of this invention may be expected to greatly minimize damage of this kind.

The invention is illustrated by an example in which a layer of CVD diamond was first deposited on a molybdenum substrate in a chamber constructed of quartz and copper, neither of which dissolves substantial amounts of carbon. The substrate was vertically disposed in a plane parallel to and 8-9 mm. distant from the plane of a tungsten filament about 0.8 mm. in diameter. The vessel was evacuated to a pressure of about 10 torr, the filament was heated to about 2000°C by passage of an electric current and a mixture of 98.5% (by volume) hydrogen and 1.5% methane was passed into the vessel. The methane employed was substantially impurity-free and 99.9% thereof contained the carbon-12 isotope. Upon removal and mass spectroscopic analysis of the diamond thus obtained, it was found that 99.91% of the carbon therein was carbon-12.

Thermal conductivity of the isotopically pure CVD diamond was measured by the mirage detection of thermal waves generated by a modulated argon-ion beam impinging on the diamond crystals, in accordance with a conventional method. The room temperature conductivity was shown to be about 12 watts/cm.°K. A control sample of similar CVD diamond prepared from methane having the naturally occurring isotope distribution (98.96% C-12, 1.04% C-13) had essentially the same conductivity.

The isotopically pure CVD diamond was crushed and powdered, and was used as a source of carbon for the growth of a single-crystal diamond under high pressure and high temperature conditions. Specifically, a conventional belt apparatus was employed at 52,000 atmospheres and 1400°C, employing a catalyst-solvent mixture of 95% (by weight) iron and 5% aluminum. A small (0.005 carat) single-crystal diamond seed of normal isotopic distribution was used to initiate growth, and a negative temperature gradient of about 50°C was maintained between the CVD diamond and the seed crystal. The process was continued until a single crystal of 0.95 carat had been produced. It was shown by analysis that 99.93% of the carbon therein was the C-12 isotope.

The diamond was polished on a standard diamond scaife to remove the seed crystal, and its room temperature conductivity was compared with those of several other materials, including a control single-crystal diamond prepared from the CVD diamond with normal isotope distribution. The results were as follows, all values being in watts/cm.°K:

Isotopically pure C-12 diamond (this invention)	31.5
Control	21.18
Naturally occurring type IIA diamond	21.2
CVD diamond	12.0
Cubic boron nitride	7.6
Silicon carbide	4.9
Copper	4.0
Beryllium oxide	3.7
Boron phosphide	3.6
Aluminum nitride	3.2
Silicon	1.6
Aluminum oxide	0.2

Thus, the room temperature conductivity of the diamond of this invention is 48.7% greater than that of the control. It is also much higher than the room temperature conductivity of any other diamond or non-diamond material which has been measured.

At 70°K, below the boiling point of liquid nitrogen, the diamond of the present invention is theoretically predicted to have a conductivity of about 2675 watts/cm.°K, more than 13 times the minimum value predicted in the aforementioned U.S. Patent 3,895,313.

CLAIMS

1. A method for preparing single-crystal diamond of high isotopic purity which comprises the steps of:

(A) preparing diamond consisting of isotopically pure carbon-12 or carbon-13; and

(B) converting said diamond to single-crystal diamond by diffusion under high pressure through a metallic catalyst-solvent material to a region containing a diamond seed crystal.

2. A method as claimed in claim 1 wherein the carbon in the hydrocarbon is carbon-12.

3. A method as claimed in claim 1 or claim 2 wherein the product of step A is comminuted.

4. A method as claimed in any of the preceding claims wherein the carbon in the hydrocarbon is at least 99.2% isotopically pure.

5. A method as claimed in any of the preceding claims wherein the diamond of step A is prepared by chemical vapor deposition.

6. A method as claimed in any of the preceding claims wherein the equipment employed in step A is constructed of materials substantially incapable of dissolving carbon.

7. A method as claimed in claim 4 wherein the particle size achieved by comminution is that of grit diamond.

8. A method as claimed in claim 7 or claim 4 wherein step A is conducted at a filament temperature of at least 2000°C, a substrate temperature in the range of 900-1000°C and a pressure of about 10 torr.

9. A method as claimed in claim 7 or claim 8 wherein the filaments are of tungsten and the substrate is molybdenum.

10. A method as claimed in claim 6 wherein the carbon in the hydrocarbon is at least 99.9% isotopically pure.

11. A method asclaimed in claim 10 wherein the catalyst-solvent material employed in step B is an iron-aluminum mixture.

12. A method as claimed in claim 11 wherein a negative temperature gradient is maintained in step B between the material being converted and the deposition region.

13. A method as claimed in claim 12 wherein the catalyst-solvent material employed in step B is a mixture of 95% iron and 5% aluminum by weight.

14. A method as claimed in claim 13 wherein the temperature gradient is about 50°C.

15. A method as claimed in claim 12 wherein the pressure in step B is in the range of 50,000-60,000

atmospheres and the temperature is in the range of 1300-1500°C.

16. A method as claimed in claim 15 wherein the seed crystal is single-crystal diamond of normal isotopic distribution.

17. A method as claimed in claim 16 wherein the portion of the product diamond attributable to the seed crystal is removed by polishing.

18. Single-crystal diamond consisting of at least 99.2% by weight isotopically pure carbon-12 or carbon-13, said diamond having a thermal conductivity at 300°K at least 10% greater than that of natural type IIA diamond.

19. Diamond as claimed in claim 18 which consists of carbon-12.

20. An article comprising a heat-generating source in contact with the diamond of claim 18 as a thermal conductor.

21. An abrasive article comprising the diamond of claim 18.

22. A light-filtering article comprising the diamond of claim 18 with a pinhole aperture therein.

23. Single-crystal diamond consisting of at least 99.5% by weight isotopically pure carbon-12 or carbon-13, said diamond having a thermal conductivity at 300°K at

least 25% greater than that of natural type IIA diamond.

24. Single-crystal diamond consisting of at least 99.9% by weight isotopically pure carbon-12 or carbon-13, said diamond having a thermal conductivity at 300°K at least 40% greater than that of natural type IIA diamond.

25. Single-crystal diamond prepared by the method of claim 1.

26. Single-crystal diamond prepared by the method of claim 2.

27. Single-crystal diamond prepared by the method of claim 4.

28. Single-crystal diamond prepared by the method of claim 10.

29. Single-crystal diamond prepared by the method of claim 17.

30. A method as claimed in claim 1 substantially as hereinbefore described in any one of the examples.

31. A single crystal diamond as claimed in claim 18 substantially as hereinbefore described in any one of the examples.

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Publication Title:

Cast diamond tools and their formation by chemical vapor deposition

Abstract:

Abstract of GB 2366804

(A) Translate this text A method and design of cast diamond tools includes a mold that contains a negative body shape and surface finish of an intended diamond tool. Diamond deposited by a vapor phase, such as by chemical vapor deposition, is applied to the mold. After depositing diamond to a certain thickness, the mold is dissolved in acid or another suitable solvent, leaving behind the diamond cast that duplicates the intended body shape and surface finish. The diamond cast is then used to fabricate suitable tools, such as a cutting insert, or a wire-drawing die. In addition pad conditioners for polishing silicon wafers may be manufactured using this process, where the soluble mold is formed of silicon. In a variation a diamond hose is formed by overcoating a twisted wire with diamond after which the central metal core is dissolved leaving a hollow diamond hose which is then cast in an epoxy resin.

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C7F FHE FP861 FP862 FP864 FR902
B3D DMN
C7D DB704
U1S S1578 S1645 S1652 S1660

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(58) Field of Search
UK CL (Edition R) **B3D DEN DMN , B5A AB18 AB19 ANA ATXP AT3P , C7D DB702 DB704 DB706 DB708 , C7F FHB FHE FHX**
INT CL[7] **B22F 7/04 , B24B 53/12 , B29C 33/42 39/02 39/10 41/08 41/20 45/37 , B29D 31/00 , C23C 16/00 16/27 16/44**
Online: WPI, EPODOC, JAPIO

(54) Abstract Title
Cast diamond tools and their formation by chemical vapor deposition; diamond hoses

(57) A method and design of cast diamond tools includes a mold that contains a negative body shape and surface finish of an intended diamond tool. Diamond deposited by a vapor phase, such as by chemical vapor deposition, is applied to the mold. After depositing diamond to a certain thickness, the mold is dissolved in acid or another suitable solvent, leaving behind the diamond cast that duplicates the intended body shape and surface finish. The diamond cast is then used to fabricate suitable tools, such as a cutting insert, or a wire-drawing die. In addition pad conditioners for polishing silicon wafers may be manufactured using this process, where the soluble mold is formed of silicon. In a variation a diamond hose is formed by overcoating a twisted wire with diamond after which the central metal core is dissolved leaving a hollow diamond hose which is then cast in an epoxy resin.

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FIG. 1a

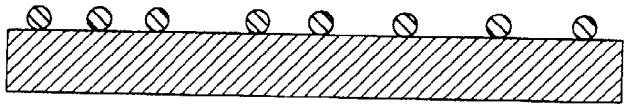


FIG. 1b

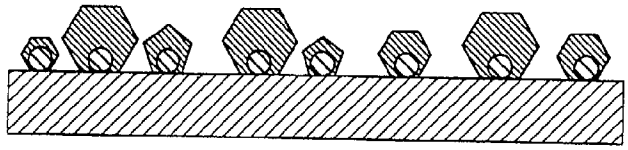
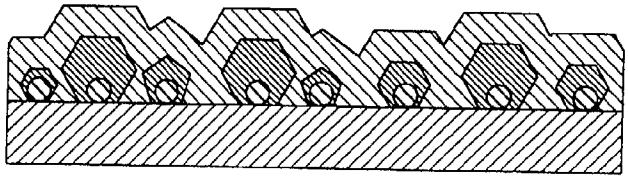


FIG. 1c



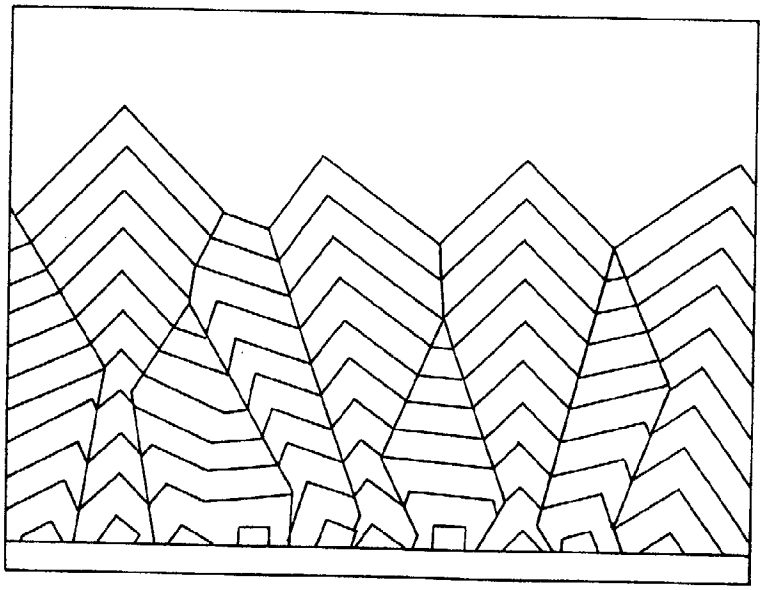


FIG. 1d

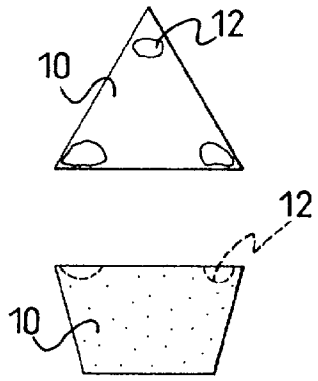


FIG. 2
PRIOR ART

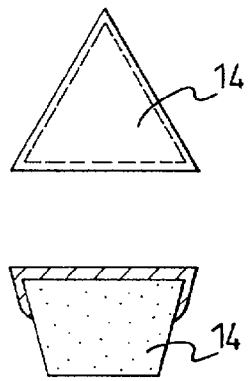


FIG. 3
PRIOR ART

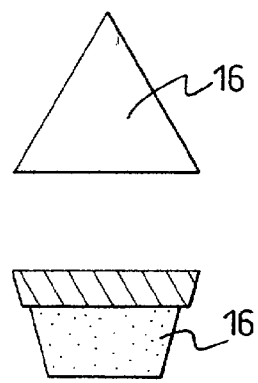


FIG. 4
PRIOR ART

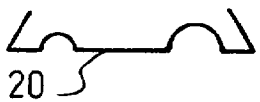


FIG. 5

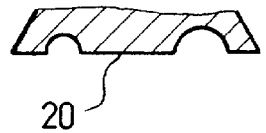


FIG. 6

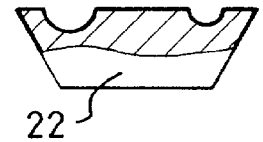


FIG. 7

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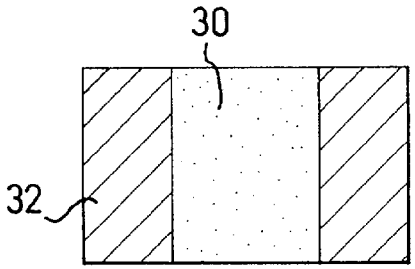


FIG. 8
PRIOR ART

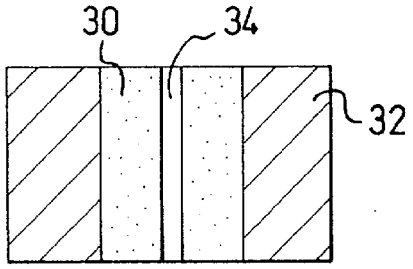


FIG. 9
PRIOR ART

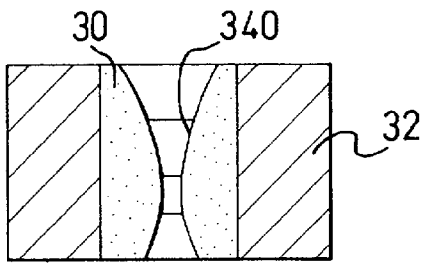


FIG.10
PRIOR ART

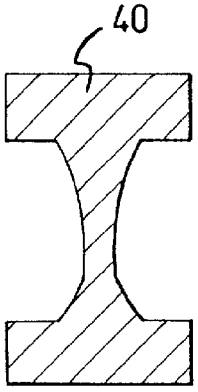


FIG.11

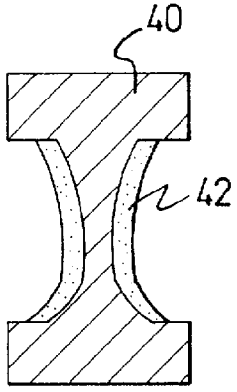


FIG.12

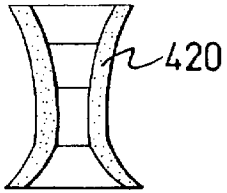


FIG.13

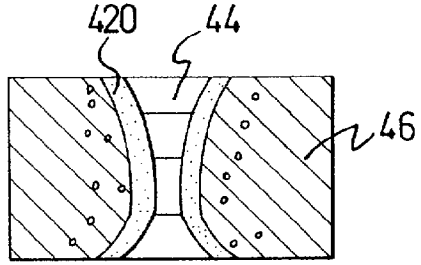


FIG.14

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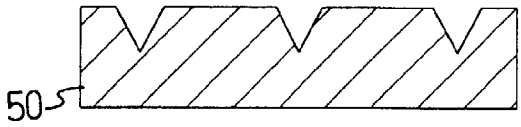


FIG. 15

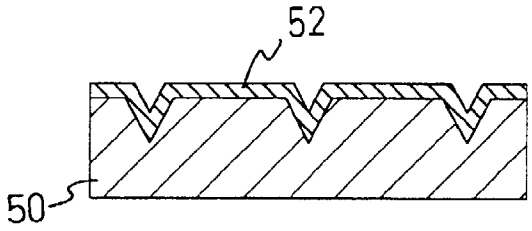


FIG. 16

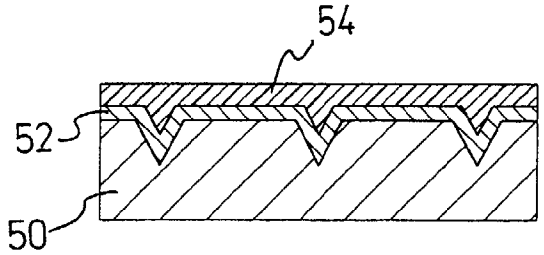


FIG. 17

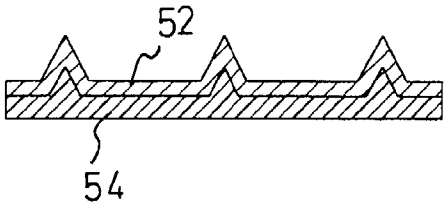


FIG. 18

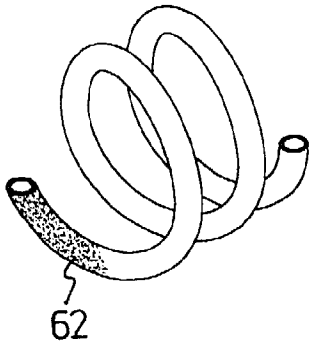


FIG. 21

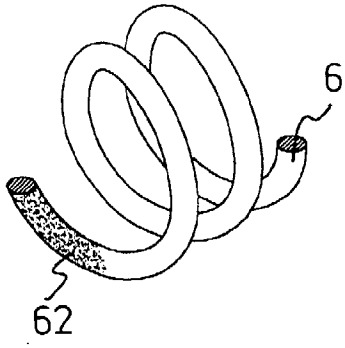


FIG. 20

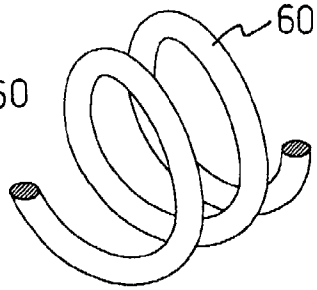


FIG. 19

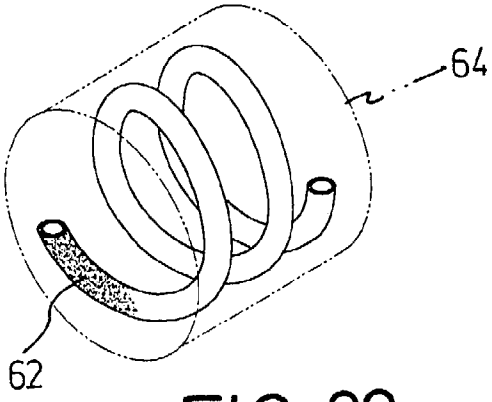


FIG. 22

CAST DIAMOND TOOLS AND THEIR FORMATION BY CHEMICAL VAPOR DEPOSITION

1. Field of the Invention

The present invention relates to a manufacturing method and design of cast diamond tools.

2. Description of Related Art

As a material, diamond has many extreme properties, such as high wear resistance, high thermal conductivity, rapid transmission of sound waves, and corrosion inertness. These superior properties have made diamond the ideal material for many advanced applications. For example, diamonds have been used widely as superabrasives, heat spreaders, acoustic devices, and chemical barriers. Conventionally, diamonds are synthesized under high pressure (more than fifty times atmospheric pressure), but such diamonds are typically in grit form. Although they are ideal for superabrasives (e.g., for diamond saws), they are not suitable for non-mechanical applications (e.g., heat spreaders).

In recent years, diamond films up to 1mm in thickness have also been deposited commercially. These films are deposited by CVD methods using gas reactants. The gases included typically a small amount (<5%) carbonaceous material, e.g., methane (CH4), that is diluted in an ample amount of

hydrogen (H2). During the process, the gases are heated to a high temperature so the carbonaceous gas will decompose to free up carbon atoms. At the same time, hydrogen molecules will dissociate to form atoms. Normally, carbon atoms will deposit as either amorphous carbon or graphite, but with the surrounding of hydrogen atoms, they will maintain the diamond structure (sp3 bond), as in the case of methane, and precipitate out as diamond. Even with the formation of non-diamond carbon, the ready presence of hydrogen will convert the carbon back to methane. Hence, hydrogen atoms play a key role in catalyzing the formation of diamond. Hence, the higher the concentration of hydrogen atoms, the better the quality of diamond that is formed.

There are various ways to heat the gas mixture, among them hot filament (e.g., using tungsten), microwave agitation, oxyacetylene flame, and direct current (DC) arc are commonly used. Although the temperature for diamond deposition is typically in the range of 800 ℃ to 900 ℃, the reaction temperature for the gases is much higher. In fact, the higher the reaction temperature is, the more complete the decomposition of the gases to form carbon and hydrogen atoms, and the faster the deposition rate of the diamond. Thus, the hot filament method can only reach 2000 ℃ or slightly over, so its

deposition is the slowest (about 1 micron per hour). The microwave agitation can heat the gases to a higher temperature, so the deposition rate is intermediate (about 10 microns per hour). The oxyacetylene can attain an even higher plasma temperature, so its deposition rate is quite high (e.g., 30 microns per hour). The DC arc method can surpass the gases to the highest temperature (about 6000 ℃) and hence it can deposit diamond at the highest rate (e.g., 50 microns per hour) of the above methods. However, the higher the deposition rate, the smaller the area of the deposition, and the less uniform the diamond film produced. Hence, there is a tradeoff between deposition rate and deposition area.

CVD diamond films contain polycrystalline diamond grains. Diamond nuclei are first formed on the surface of the substrate, and these nuclei will grow with ever increasing coarseness, as shown in Figs. 1a to 1d. Hence, the film on the nucleation side tends to show the same surface finish as the substrate material, but the growing side becomes ever-increasingly rough with the coarsening of the grain. For most applications (e.g., heat spreader), the rough surface must be ground and polished. However, as diamond is the hardest material known, the machining of the coarse diamond is extremely difficult and tedious. As a result, the cost associated with the finishing of a

diamond film is often higher than that for its deposition.Fig. 1 shows the nucleation and growth of a diamond film. Note the nucleation surface is a negative of the substrate surface, and the growing surface is becoming more and more rough with the deposition time.

Moreover, certain machining procedures, such as to cut a curved groove on the diamond surface, or to drill a square hole through diamond are almost impossible to achieve. Such limitations have severely constrained diamond films' potential applications.

For example, CVD diamond films have been used as a premium cutting insert. When it is used to cut ductile material (e.g., copper alloy), the long cutting thread must be interrupted from time to time. This is conveniently done by providing a trough near the cutting edge, as commonly done with other cutting tools, to bend and break the material being removed during the thread cutting operation. However, it is not possible to make such a trough on the flat diamond film. Hence, CVD diamond cutters, although extremely durable, are not suitable to cut ductile materials.

As another example, many advanced applications, e.g., circuitry in the electronics industry, would require using triangular, square, or irregularly-shaped shaped metal wires.

These wires cannot be drawn with conventional diamond wiredrawing dies that contain only circular holes. Hence, there is no suitable product to serve this significant demand from the market.

Furthermore, most applications use the surface (e.g., an extruding die) of diamond films, hence the property of the bulk body may not be critical. However, the conventional CVD method must produce the diamond film from the bottom up. Hence, if the top surface is required, the entire film must be grown slowly to reach the top portion. Such a tedious growth process can be very costly.

Example 1- Cutting Inserts Made of Diamond

Conventional diamond cutting inserts include two main types. The first type is to coat a WC insert with thin diamond film (e.g., 30 microns). The problem of this design is that the deposited diamond surface is rough, so the cutting surface does not have a fine finish. Alternatively, a thick diamond film (e.g., 300 microns) can be grown. The diamond film can then be ground and polished by a laser to form a triangular cutting tip. This tip is then brazed onto a WC insert. This method is tedious and expensive. In addition to the above described drawbacks, these diamond film cutting inserts suffer another deficiency which is that their top faces are always flat. Hence,

they do not possess chip breakers for efficiently cutting ductile materials.

Fig. 2 shows a conventional WC insert (10) with a depressed chip breaker (12) near each cutting corner. Fig. 3 shows a diamond coated WC insert (14) without a chip breaker. Fig. 4 illustrates a thick diamond brazed onto a WC insert (16), again without a chip breaker.

Example 2 - Wire Drawing Dies Made of Diamond

Many metal wires are drawn by using polycrystalline diamond (PCD) tools. The PCD (30) is enclosed by WC (32) (Fig. 8), and a hole (34) is drilled through the PCD (30) (Fig. 9), typically by a laser. The hole (34) is then enlarged to form a flare (340), as shown in Fig. 10, and the surface is polished by using fine diamond paste. Although there is much laborious finishing work involved, such PCD dies are still the best tools used for drawing metal wires. Even so, PCD dies contain only round holes, hence, it is not possible to draw polygonal wires, such as those with square cross-sections.

All PCDs contain more than 10% cobalt. As cobalt can reconvert diamond to amorphous carbon or graphite, so the PCD must be kept below a temperature of about 700 ℃. Hence, the lubrication and cooling by water or other liquid is critical.

However, during the drawing process, the metal wire tends to press against the PCD and it may weld with cobalt embedded in the PCD. As a result, excessive heating is inevitable and the PCD may deteriorate rapidly due to the reconversion to amorphopus carbon or graphite. Moreover, the dragging may damage the surface of the metal wire by causing weld spots and burn marks.

Example 3 - Pad Conditioners Made of Diamond

Chemical Mechanical Polishing (CMP) is an essential step for manufacture silicon chips with sophisticated architecture. During the CMP process, silicon wafers are pressed against a rotating pad typically made of polyurethane. The table is fed with a stream of slurry that contains ultrafine (less than 0.2 microns) abrasive (e.g., silica or alumina). The wafers are therefore polished by the abrasive to reach a certain flatness and smoothness. However, the polished debris can coat the pad and make the latter unusable, so a diamond conditioner is required to scrape off the deposited debris from time to time.

The pad conditioner contains a plurality of diamond grits that are attached to a metal substrate (e.g., stainless steel). These grits are used to rake the pad to prevent its top from glazing. The effectiveness in cleaning the pad, and the durability of the conditioner are dependent on two critical

factors: the separation of diamond grits, and the leveling of their tops. These two factors are notoriously difficult to control. Hence, almost all diamond conditioners used commercially contain randomly distributed diamond grits with a high variability of the top height.

The object of this invention to make diamond film products that either eliminate or minimize the expensive post-synthesis operations.

It is another object of this invention to produce diamond film products with irregular and novel body shapes and surface finishes.

It is yet another object of this invention to simplify the diamond manufacture process by casting only the critical part of the diamond film, and then filling in the non-critical part with fast grown diamond or other material.

In the drawings

Figs. 1 shows stages of diamond nuclei formed on a surface of a substrate;

Fig. 2 shows a conventional tungsten carbide tool insert;

Fig. 3 shows a conventional diamond coated tungssten carbide tool insert without a chip breaker;

Fig. 4 shows conventional tungsten carbide with a thick diamond film but without a chip breaker;

Fig. 5 shows a thin metal mold for use in the present invention;

Fig. 6 shows the mold of Fig. 5 filled with diamond film deposition, in accordance with the present invention;

Fig.7 shows the mold of Fig. 5 dissolved away;

Fig. 8 shows a prior art polycrystalline diamond (PCD) enclosed by tungsten carbide;

Fig. 9 shows the PCD of Fig. 8 with a hole drilled therethrough;

Fig. 10 shows the PCD of Fig. 9 with the hole enlarged;

Fig. 11 shows a mold for use with the present invention;

Fig. 12 shows the mold of Fig. 11with diamond deposition ;

Fig. 13 shows the diamond deposition of Fig. 12 formed as a die, with the mold dissolved away;

Fig. 14 shows the diamond of Fig. 13 with the diamond die encased by a metal;

Fig. 15 shows a silicon wafer in accordance with the present invention;

Fig. 16 shows the silicon wafer of Fig. 15 cast with chemical vapor deposition (CVD) diamond;

Fig. 17 shows the silicon wafer of Fig. 16 with an epoxy resin layer;

Fig. 18 shows a disk with diamond pyramids after the the

silicon has been dissolved away;

Fig. 19 shows a wire having been twisted, in accordance with the present invention;

Fig. 20 shows the wire of Fig. 19 coated with chemical vapor deposition diamond;

Fig. 21 shows the wire of Fig. 19 dissolved away, leaving a diamond hose; and

Fig. 22 shows the diamond hose of Fig. 21 encased in resin.

This invention reverses the common practice of growing diamond film to form a body and then machining it to a required shape. Instead, a diamond film is cast in a mold to form the body shape and surface finish it in a single process. A remaining portion can then be filled in at a later stage using a much less expensive material or method. This novel concept can produce the cast that duplicates the body shape and surface finish of the mold, hence, expensive post-synthesis machining works are eliminated. Moreover, the complicated body shape or delicate surface finish can both be achieved from the mold. As a result, diamond film products with novel and unique geometries can now be produced for the first time.

A key ingredient of this invention is the ability to reproduce a surface finish of the mold to the deposited diamond cast and experiments have been performed to test this

feasibility. Many materials with different surface finishes have been used as the substrate for depositing CVD diamond. The CVD reactor used is a large production system manufactured by sp3, Inc. of California. The reactor is a hot filament system with a deposition area of 30 cm x 40 cm. It has been discovered that if the substrate material is suitable (e.g., copper, tungsten carbide), and the surface treatment is proper (i.e., thoroughly cleaned), diamond films so deposited can faithfully reproduce the surface feature of the substrate. Hence, the concept of reverse deposition was proven.

Conventional diamond films have their growing sides used as appropriate tool surfaces. This invention relies on using a nucleation side for the application. The nucleation side contains diamond microcrystals that have been formed on the substrate. These newly formed nuclei may not be chemically pure, nor structurally sound. Moreover, amorphous carbon or pyrolitic graphite may be co-deposited there. As the nucleation side will be used as the tool surface, it is critical to make this side contain as much diamond as possible.

Several techniques have been applied to improve the diamond quality of the nucleation side. For example, during the early phase of diamond deposition, the methane flow rate is reduced and the gas pressure is increased. In this way, the

decomposition rate of carbon will decrease, but the concentration of hydrogen atoms will increase. The slow deposition rate coupled with the increased amount of catalyst can assure that diamond nuclei formed are of high quality.

Moreover, the nucleation rate must be increased to fill up the minute crevices of the substrate. The nucleation rate can be effectively boosted (up to one million times) by applying a negative bias (e.g., 100 V) on the substrate. Alternatively, the substrate can be polished by using a fine diamond paste. After polishing, the embedded diamond micron powders can serve as effective seeds for diamond nucleation. If the nucleation rate can be raised, the diamond quality on the nucleation side will increase, and the substrate finish can be faithfully translated onto the nucleated surface.

Certain metals, e.g., iron, cobalt, nickel and their alloys, can catalyze at a high temperature (>700 degrees Celsius) diamond back to amorphous carbon or graphite. It is important that the substrate material contains as little as possible of such metals. For example, a good substrate material for diamond deposition is cobalt cemented tungsten carbide (WC). If WC is used for diamond deposition, the mount of cobalt should be limited to 4% or less. In recent years, binder free WC materials have been available. These materials are suitable to

make molds (e.g., the hole for a wire-drawing die). If the WC grain is ultrafine (submicron), the diamond nucleation will further increase. The result is a very smooth surface of high diamond content, which is ideal for many applications.

Fig. 5 shows a thin metal mold (20) that has the negative geometry of a conventional cutting insert with chip breakers. The metal can be W, Mo, Ta, Zr, Ti, Cr, V, Cu, Si or other suitable material. Fig. 6 shows that this metal mold (20) is filled up by the deposition of diamond film. Fig. 7 shows that the metal mold (20) is dissolved away, e.g., by soaking in acid. A bottom part (22) of the remaining diamond film contains the same geometrical form of the metal mold (20). A top part is then packed with WC particles or other refractory grains (e.g., SiC) and infiltrated with an alloy (e.g., copper-manganese alloy). The solidified alloy can then serve as the substrate of the cutting insert as shown in Fig. 7. This diamond insert contains the original surface of the metal mold (20), including the chip breaker. This diamond cutting tool does not require expensive mechanical finishing work.

This invention can solve all the above mentioned problems of the prior art.

Referring to Fig. 11, a center column (40) made of a binderless WC (or W metal) is first fabricated with the

appropriate geometry and surface finish. As shown in Fig. 12, this center column (40) is then coated with CVD diamond (42) to a thickness of 50 to 100 microns. The center column (40) is subsequently dissolved in acid, leaving a diamond tube cast in the same geometry of the center column (40), as seen in Fig. 13. This diamond tube is placed at the center of a stainless steel ring (46), and a space between them is packed with WC particles or SiC grains. A pile of copper-manganese-nickel alloy is placed on top of these particles. The set up is next placed in a vacuum furnace and heated to cause the melting of the copper alloy. The copper alloy will then infiltrate into the powder and consolidated the assembly. This rigid assembly contains a stainless steel outer ring and a diamond inner tube (44). Moreover, the diamond tube is compressed by the shrinking copper alloy that reduces the volume significantly during the solidification process. This compression is highly desirable as it will protect the tube from expansion due to the outward pushing force exerted by the drawing wire. Furthermore, this compressional force is adjustable in that may be varied to suit the type of wire to be drawn (e.g., low for drawing copper and high for drawing tungsten). The compressional force can be varied simply by adjusting the powder/metal ration. the more metal used, the higher the

compression force is.

The above described novel technology not only eliminates the expensive finishing operation, and hence greatly reduces the production cost. but also it improves the quality of the wire drawing die in many aspects. For example, unlike PCD that contains less than 90% in volume of diamond, CVDD is made entirely of diamond, hence, its wear life can be much higher than PCD (the service life is not linearly proportional to the diamond content, but is an exponential function).

CVDD is much more slippery than PCD that contains metal adhering cobalt, hence the heat generated during wire drawing would be significantly less. Moreover, CVDD can stand a temperature of 1200 ℃ that is much higher than 700 ℃ for PCD. Hence, the use of liquid lubrication may not be necessary. The elimination of liquid lubricant not only pays for the cost of the wire drawing die itself, but also it avoids environmental contamination associated with the lubricant. Concern about protecting the environment is forcing the machining industry to operate "dry", so this invention anticipates such a world trend.

Furthermore, the elimination of cobalt in the contact surface can improve greatly the surface finish of the wire, e.g., to make it have a reflective finish. Such a high quality wire is

highly welcomed by the electronics industry (e.g., contamination-free copper wires) and the jewelry business (e.g., shinning gold wires).

An even more significant breakthrough based on this invention is that wire drawing with non-circular holes can be performed as easily as circular holes. Hence, wires with triangular or square cross sections can be produced readily. The introduction of non-circular wires currently unavailable can allow new designs of products for certain fields (e.g., in the electronics industry), hence it may spur the creation of a new industry.

Using the cast diamond concept as taught by this invention, an extremely high quality diamond conditioner can be fabricated with strict control of diamond separation and top height. Firstly, a silicon wafer (50) is machined with impressions of identical pyramids that are placed in specific locations (e.g., with a fixed distance from the neighbor) as shown in Fig. 15. Secondly, the engraved silicon wafer is cast with CVD diamond (52), as shown in Fig. 16. Thirdly, an epoxy resin (54) is then attached on the top, as shown in Fig. 17. The entire assembly is then dipped in hydrofluoric acid to dissolve the silicon substrate. The remaining disk, when inverted, will show identical diamond pyramids protruding to the same height,

as shown in Fig. 18. Such a diamond layout is ideal for making a CMP pad conditioner. This method can also allow new designs of pad conditioners. For example, the distribution of the pyramids may be such that they follow a spiral pattern. In this way, the slurry may be guided to follow the pattern so as to improve the distribution of the abrasive. The result can be an increased polishing rate of the wafer and a reduced consumption of the expensive slurry. Moreover, the uniformity and flatness of the wafer may also be improved.

Diamond Hose

This invention can allow the manufacture of novel and unique diamond devices, such as a diamond hose that can be used to transmit corrosive fluid. The manufacturing steps follow the same procedures as described above. Firstly, the hose is fabricated using a metal (e.g., by twisting a W wire (60)), as shown in Fig. 19. Secondly, the twisted wire (60) is overcoated by CVDD (62), as shown in Fig. 20, to form a center metal core. Thirdly, the center metal core is dissolved, leaving a hollow diamond hose, as shown in Fig. 21. Finally, this diamond hose is cast in an epoxy resin (64) to form an easily handled tool, as shown in Fig 22.

The same idea may be applied to manufacture of other novel objects, such as a diamond flask or a diamond gear.

There is no limitation of the type of shape that may be produced by CVD diamond.

The above few examples are merely used to illustrate the flexibility of applying this invention.

It is to be understood, however, that even though numerous characteristics and advantages of the present invention have been set forth in the foregoing description, together with details of the structure and function of the invention, the disclosure is illustrative only, and changes may be made in detail, especially in matters of shape, size, and arrangement of parts within the principles of the invention to the full extent indicated by the broad general meaning of the terms in which the appended claims are expressed.

CLAIMS:

1. A CVD diamond product cast by a mold with the surface features determined by contact interface of the mold.

2. The product as described in Claim 1, wherein the mold is made of metal.

3. The product as described in Claim 2, wherein the metal is essentially any metal selected from the group of W, Mo, Ta, Ti, Zr, V, Cr, or any of its carbides, and Cu.

4. The product as described in Claim 1, wherein the mold has a concave shape.

5. The product as described in Claim 4, wherein the concave shape is a cup.

6. The product as described in Claim 1, wherein the mold has a convex shape.

7. The product as described in Claim 6, wherein the convex shape is cylindrical.

8. The product as described in Claim 1, wherein the CVD diamond has a thickness of 30 to 200 microns.

9. The product as described in Claim 1, wherein the product is one of a cutting tool made of diamond, a wire drawing die made of diamond, a pad conditioner made of diamond, a diamond diaphragm, or a diamond pipe.

10. The product as described in Claim 9, wherein the

cutting tool contains chip breakers.

11. The product as described in claim 9, wherein the wire drawing die has a nonspherical hole.

12. The product as described in Claim 9, wherein the wire drawing die is produced by infiltrating molten alloy around a CVD diamond tube.

13. A method to make a CVD diamond product, comprising the following steps:

a. making a negative mold that contains a shape and a surface of an intended product;

b. depositing a CVD diamond to a desired thickness at an interface of the mold:

c. dissolving the mold by acid or another solvent; and

d. mounting a remaining diamond object in a suitable holder.

14. The method according to Claim 12, wherein the CVD diamond is deposited by a method using hot filament, microwave plasma, oxyacetylene flame, or DC arc to heat gas used therein.

15. The method according to Claim 13, wherein the gas contains methane and hydrogen.

Application No: GB 0022947.6 **Examiner:** Pete Beddoe
Claims searched: 1-15 **Date of search:** 19 December 2000

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Databases searched:

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Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
A	US 5507987 (SAINT GOBAIN) see whole doc	
X	US 4774991 (SMIT) see esp col2 line 52 - col3 line 39 & figs	1,13 at least
X	CH 684249 A & WPI Accession no 94-249735 (REISHAUER) see esp figs & abstract	1,13 at least
X	JP 2256464 A & WPI Accession no 90-357429 (ASAHI) see esp figs & abstract	1,13 at least
X	JP 5890465 A & Japio abstract of JP 5890465 A (OOSAKA) see esp figs & abstract	1,13 at least

X	Document indicating lack of novelty or inventive step	A	Document indicating technological background and/or state of the art.
Y	Document indicating lack of inventive step if combined with one or more other documents of same category.	P	Document published on or after the declared priority date but before the filing date of this invention.
&	Member of the same patent family	E	Patent document published on or after, but with priority date earlier than, the filing date of this application.

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POLYCRYSTALLINE ABRASIVE GRIT

Abstract:

Abstract of WO 0231078

(A2) A method is provided for producing a plurality of polycrystalline ultra-hard abrasive grit. The method includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of crystalline abrasive grit. The ultra-hard abrasive is generally diamond or cubic boron nitride.

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(54) Title: POLYCRYSTALLINE ABRASIVE GRIT

(57) Abstract: A method is provided for producing a plurality of polycrystalline ultra-hard abrasive grit. The method includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of crystalline abrasive grit. The ultra-hard abrasive is generally diamond or cubic boron nitride.

POLYCRYSTALLINE ABRASIVE GRIT

BACKGROUND OF THE INVENTION

This invention relates to polycrystalline abrasive grit.

Ultra-hard abrasive bodies in the form of either abrasive compacts or individual crystals are well known in the art. The abrasive compact will generally be a diamond compact, also known as polycrystalline diamond or PCD, or a cubic boron nitride compact, also known as polycrystalline cubic boron nitride or PCBN. These abrasive compacts have wide application in cutting, drilling, boring, milling and other abrasive applications.

Such ultra-hard abrasive bodies are produced under conditions of elevated temperature and pressure at which the ultra-hard abrasive is crystallographically stable. Polycrystalline diamond or polycrystalline boron nitride can be produced with or without a second phase or bonding matrix. The second phase, when provided, may be in the case of diamond a solvent/catalyst such as cobalt, or it may be a carbide-forming element such as silicon. Similar sintering mechanisms are utilised in PCBN synthesis with various carbides, nitrides and borides being common second phases.

CONFIRMATION COPY

Abrasive compacts are generally produced in the form of a disc, either free-standing or bonded to a support, which may be cut into smaller segments for use.

Single crystal ultra-hard abrasives in the form of either diamond or cubic boron nitride crystals, also referred to as "grit", are used in loose or bonded form for a variety of abrasive applications such as lapping, drilling, grinding and sawing.

Examples of abrasive tools which utilise single crystal ultra-hard abrasives are grinding wheels and saw segments. Bond types for such abrasives can be a metal, resin or a ceramic.

Diamond or CBN grits are typically produced through a high pressure/high temperature process where graphite or hexagonal boron nitride is converted in the presence of a suitable catalyst to, respectively, diamond or cubic boron nitride. In some cases natural diamond crystals are also employed.

The concepts of abrasive compacts and grits have been combined and have led to the development of polycrystalline grit. For instance United States Patent 4,776,861 describes a process for generating polycrystalline grit containing ultra-hard material. This is achieved by leaching non-diamond material from polycrystalline diamond or cubic boron nitride compacts obtained through a high pressure/high temperature process and subsequently crushing the leached product.

The process of high pressure/high temperature sintering followed by subsequent crushing is not ideal as a high amount of energy is consumed in crushing sintered PCD and control over the shape and size of the final product is limited. Hence yield and quality tend to be low.

SUMMARY OF THE INVENTION

According to the present invention, a method of producing a plurality of polycrystalline ultra-hard abrasive grit includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions at which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of polycrystalline abrasive grit.

The method of the invention involves, as a first step, the forming of the mass of ultra-hard abrasive particles or of combination of a precursor for such particles and solvent/catalyst into a plurality of green state granules. The term "green state granules" means a coherent mass of any suitable shape or size and which is produced, for example, by known granulation or pelletising techniques.

The green state granules will generally be produced in the presence of a second (or binder) phase. The second phase may be provided by a material which participates in or contributes to the formation of the polycrystalline ultra-hard abrasive grit, e.g. a solvent/catalyst for the ultra-hard abrasive. The second phase may also be a binder, organic or inorganic, which may be removed prior to subjecting the granules to the high temperature/high pressure sintering conditions. The second phase can also consist of a combination of these two second phases.

If a precursor for the ultra-hard abrasive is used, then a solvent/catalyst for that ultra-hard abrasive must also be present. Examples of suitable solvent/catalysts for such particles, particularly when the particles are diamond or cubic boron nitride, are well known in the art. The solvent/catalysts may be precursors which can be converted to the solvent/catalyst, e.g. metal oxides which on heating are converted to the metal. Such precursors are included in the term "solvent/catalyst".

Examples of combinations, generally in the form of mixtures, of ultra-hard abrasive particles or precursor particles and second phases which are useful in the practice of the invention are:

1. Diamond and a diamond solvent/catalyst which may be a transition metal such as cobalt, nickel, iron or manganese or non-metallic solvent/catalyst such as a carbonate or sulphate to produce a sintered, intergrown polycrystalline diamond grit material.

2. Graphite and a diamond solvent/catalyst which may be a transition metal such as cobalt, nickel, iron or manganese or a non-metallic solvent/catalyst such as a carbonate or sulphate to produce a sintered, intergrown polycrystalline diamond grit. In producing the grit, the graphite is converted to diamond.

3. A combination of 1 and 2.

4. Diamond and a carbide forming metal such as silicon or titanium to produce a grit which is a sintered polycrystalline diamond/ SiC or TiC composite.

5. A combination of 1 and 4 or 2 and 4.

6. Cubic boron nitride together with a boride or nitride forming metal such as aluminium, titanium, zirconium, hafnium, tantalum, molybdenum, niobium, chromium or tungsten or mixtures thereof introduced either in metallic form or as a substoichiometric or stoichiometric carbide, boride or nitride. The polycrystalline cubic boron nitride grit produced consists of cubic boron nitride and metal nitrides or borides.

7. A combination of 6 and cobalt, nickel, iron or manganese.

8. A combination of cubic boron nitride and alumina or a combination of diamond and alumina.

9. Hexagonal boron nitride and a suitable solvent/catalyst for cubic boron nitride such as magnesium, lithium or calcium in either metallic form, as a nitride or in the form of a boronitride to produce a sintered, intergrown polycrystalline cubic boron nitride grit. In producing the grit, the hexagonal boron nitride is converted to cubic boron nitride.

The green state granules are placed in the reaction zone of a standard high pressure/high temperature apparatus for the high pressure/high temperature sintering. Generally, the granules will be placed in a capsule which itself is placed in the reaction zone.

A separating medium separates individual granules in the reaction zone. The separating medium is preferably provided as a coating on individual granules. A particularly suitable method of coating individual granules is spray coating in a fluidised medium.

The separating medium, in one form of the invention, may be a metal or alloy which does not interfere with the high pressure/high temperature sintering of the green state granules. For example, molybdenum is a suitable coating

where the ultra-hard abrasive is diamond or a precursor for diamond, e.g. graphite.

The separating medium may also be an inert medium which adequately transmits pressure, e.g. a salt such as a chloride or a carbonate, graphite, hexagonal boron nitride or an oxide.

A chemical barrier layer may be applied to the green state granules , generally to coat the granules completely, prior to the separation medium being interposed between adjacent granules. Examples of suitable chemical barrier layers are niobium, molybdenum, tantalum, titanium or other transition metal. The chemical barrier layer may be left on the polycrystalline abrasive grit produced from the green state granules.

The separating medium and chemical barrier layers may be applied to the green state granules by spraying in the form of an aqueous or non-aqueous suspension. The granules will generally be in a fluidised state during spraying. Alternatively, the granules may be dipped into a suspension of the separation medium and/or chemical barrier layer, or these layers may be coated mechanically on to the granules.

In one particular form of the invention, the green state granules are placed in a container, the separating medium in powdered or liquid form poured into the container and the granules and the separating medium mixed. If necessary, good dispersion and mixing can be assisted by some mechanical agitation or vibration to ensure that there are no gaps and the green state granules are all embedded in or enclosed by the separating medium.

Before subjecting the green state granules to the elevated temperature and pressure sintering, any removable binder, e.g. an organic binder which is present is preferably removed, for example, by a pressureless heat treatment.

The heat treatment conditions will vary according to the nature of the granules and its content. Typical heat treatment or outgassing conditions are 500°C in an argon atmosphere or 400°C in air or 1100°C in a vacuum. A slow heating cycle is preferred.

The green state granules may optionally be densified. Densification can be achieved by uniaxial compaction or cold isostatic pressing. Some deformation of the granules will take place during this compaction. When the green state granules contain a binder which is removed, the densification may take place before or after the binder is removed.

The elevated temperature and pressure sintering conditions to which the green state granules are subjected are known in the art. Typical pressures are 3 to 9 GPa and typical temperatures are 1000 to 2500°C.

The sintered material is removed from the reaction zone of the high temperature/high pressure apparatus using known techniques. The material which is recovered is sintered and coherent and consists of a plurality of sintered granules separated by the separating medium and a chemical barrier layer, when provided. The individual sintered granules or polycrystalline ultra-hard abrasive grit can be released by removing the separating medium. For example, if the separating medium is a metal such as molybdenum, the material may be placed in a hot boiling acid such as 3 parts of boiling hydrofluoric acid and one part nitric acid. This will dissolve the molybdenum leaving a plurality of polycrystalline diamond grit. When the separating medium is hexagonal boron nitride, removal of the separating medium may be achieved by placing the sintered material in an ultrasonic bath filled with water. Hexagonal boron nitride is hydrolysed by the water and the sonification breaks up or disintegrates the hexagonal boron nitride.

The polycrystalline ultra-hard abrasive grit produced by the method of the invention will typically have a particle size less than 5 mm and typically less than 2 mm. This grit may be used in a variety of abrasive applications, depending on the content and composition of the grit. The polycrystalline nature of the grit provides for a better bond retention in the bonding matrix of an abrasive tool when compared with single crystal grit. Further, controlled fracture of the grit can occur resulting in sharp edges or points being continuously produced, in use. The invention provides a particularly effective and economic method of producing polycrystalline abrasive grit. Further, the method is versatile in that polycrystalline abrasive grit may be produced with or without a second (binder) phase and contain more than one type of ultra-abrasive. The method allows for the production of polycrystalline abrasive grit of controlled shape and size.

EXAMPLE 1

A solvent based suspension with a 80 weight percent diamond (average particle diameter approximately 10 microns) and 20 weight percent of submicron cobalt powder was prepared and approximately 1 volume percent of organic binder added. The suspension was processed using a combination of spray drying and fluidised bed technology to produce strong green state spherical granules of approximately 1mm diameter and a porosity of approximately 42%. A solvent based suspension was formulated using submicron molybdenum powder. The diamond/cobalt granules were fluidised and a thin layer of molybdenum of approximately 100 microns thickness was spray dried on to the granules, using the molybdenum suspension.

The coated green state granules were placed into a die set and uniaxially compacted to yield a green compact of approximately 60% density. Binder removal from the green state granules was achieved by heat treatment at 1100°C for 2 hours in vacuum. The outgassed green state granules were then

loaded into a metal canister. The canister was loaded into the reaction capsule of a standard high pressure/high temperature apparatus and the loaded capsule placed into the reaction centre of this apparatus. The contents of the canister were exposed to a temperature of approximately 1450°C and a pressure of 5 GPa. These conditions were maintained for 10 minutes. After completion of the treatment a densely sintered compact was recovered from the canister. A polished cross-section showed sintered polycrystalline diamond grit separated by a honeycomb structure of thin molybdenum veins. The compact was placed into a beaker with 3 parts of boiling hydrofluoric acid and 1 part nitric acid. After a few minutes of treatment the compact separated into a plurality of roundish particles of approximately 0,5 to 0,7 mm diameter. Closer examination showed these particles to consist of hard sintered polycrystalline diamond with the cobalt leached out of the surface region of the particles.

EXAMPLE 2

An organic suspension of hexagonal boron nitride containing a small amount of dissolved organic binder was prepared. The molybdenum clad green state granules described in Example 1 were fluidised and spray coated with a second approximately 100 micron thick coating of hexagonal boron nitride, using the hexagonal boron nitride suspension. Repeating the same compaction, outgassing and high temperature/high pressure treatment as described in Example 1 resulted in a coherent sintered compact recovered from the canister. The compact was placed into an ultrasonic bath filled with water. After a few minutes of sonification the compact separated into a plurality of roundish particles of approximately 0,6 to 0,8 mm diameter. Closer examination revealed the particles to consist of sintered polycrystalline diamond grit clad with a thin sintered molybdenum metal coating.

EXAMPLE 3

The procedure in Example 2 was repeated replacing the hexagonal boron nitride layer with a spray deposited sodium chloride layer. The binder removal temperature was lowered to 500°C in argon so as to prevent volatilisation of the chloride. Repeating the same compaction, outgassing and high temperature/high pressure treatment as described in Example 1 resulted in a coherent sintered compact recovered from the canister. The compact was placed into an ultrasonic bath filled with water. After a few minutes of sonification the compact separated into a plurality of roundish particles of approximately 0,6 to 0,8 mm diameter. Closer examination revealed the particles to consist of sintered polycrystalline diamond grit clad with a thin sintered molybdenum metal coating.

CLAIMS

1 A method of producing a plurality of polycrystalline ultra-hard abrasive grit includes the steps of providing a mass of ultra-hard abrasive particles or a mass of a combination of a precursor for such particles and a suitable solvent/catalyst, forming the mass into a plurality of green state granules, placing the granules with a separating medium between adjacent granules in the reaction zone of a high pressure/high temperature apparatus, subjecting the contents of the reaction zone to elevated temperature and pressure conditions at which the ultra-hard abrasive particle is crystallographically stable, recovering the thus sintered material from the reaction zone and removing the separating medium in the sintered material to produce a plurality of polycrystalline abrasive grit.

2 A method according to claim 1 wherein the green state granules are produced by granulation or pelletising.

3 A method according to claim 1 or claim 2 wherein the green state granules contain a second phase which is an organic or inorganic binder, such binder being removed prior to subjecting the granules to the high temperature/high pressure conditions.

4 A method according to claim 1 or claim 2 wherein the green state granules contain a second phase which participates in or contributes to the formation of the polycrystalline ultra-hard abrasive grit.

5 A method according to claim 4 wherein the second phase is a solvent/catalyst for the ultra-hard abrasive.

6 A method according to any one of the preceding claims wherein the green state granules contain diamond and a metal solvent/catalyst.

7 A method according to any one of claims 1 to 5 wherein the green state granules contain graphite and a diamond solvent/catalyst.

8 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond, graphite and a diamond solvent/catalyst.

9 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond and a carbide forming metal.

10 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond, a diamond solvent/catalyst and a carbide forming metal.

11 A method according to any one of claims 1 to 5 wherein the green state granules contain cubic boron nitride and a boride or nitride forming metal.

12 A method according to any one of claims 1 to 5 wherein the green state granules contain a combination of cubic boron nitride, a boride or nitride forming metal, and a metal selected from cobalt, nickel, iron and manganese.

13 A method according to any one of claims 1 to 5 wherein the green state granules contain cubic boron nitride and alumina.

14 A method according to any one of claims 1 to 5 wherein the green state granules contain diamond and alumina.

15 A method according to any one of claims 1 to 5 wherein the green state granules contain hexagonal boron nitride and a solvent/catalyst for cubic boron nitride.

16 A method according to any one of the preceding claims wherein the separating medium is provided as a coating on individual granules.

17 A method according to any one of the preceding claims wherein the ultra-hard abrasive for the green state granules is diamond or a precursor for diamond, and the separating medium is molybdenum.

18 A method according to any one of the preceding claims wherein the separating medium is selected from a salt, graphite, hexagonal boron nitride and an oxide.

19 A method according to any one of the claims 1 to 16 wherein a chemical barrier layer is applied to the green state granules prior to the separation medium being interposed between adjacent granules.

20 A method according to claim 19 wherein the chemical barrier layer coats the granules completely.

21 A method according to 19 or claim 20 wherein the chemical barrier layer is selected from niobium, molybdenum, tantalum, titanium or other transition metal.

22 A method according to any one of claims 19 to 21 wherein the chemical barrier layer is left on the polycrystalline abrasive grit produced from the green state granules.

23 A method according to any one of the preceding claims wherein the elevated temperature conditions are a pressure in the range 3 to 9 GPa and a temperature in the range 1000 to 2500°C.

24 A method according to claim 1 substantially as herein described with reference to any one of the examples.

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DIAMOND CONDITIONING OF SOFT CHEMICAL MECHANICAL PLANARIZATION/POLISHING (CMP) POLISHING PADS

Abstract:

Abstract of WO 2004094106

(A1) Translate this text Conditioning of chemical mechanical planarization (CMP) using conventional diamond-embedded abrasive strips are well suited to condition conventional "hard" polishing but not soft polishing pads because the diamonds not only remove waste material, but they also damage the polishing surface of the pad. Embodiments of the present invention condition soft polishing pads using diamond strips without damaging the soft polishing pad (108).

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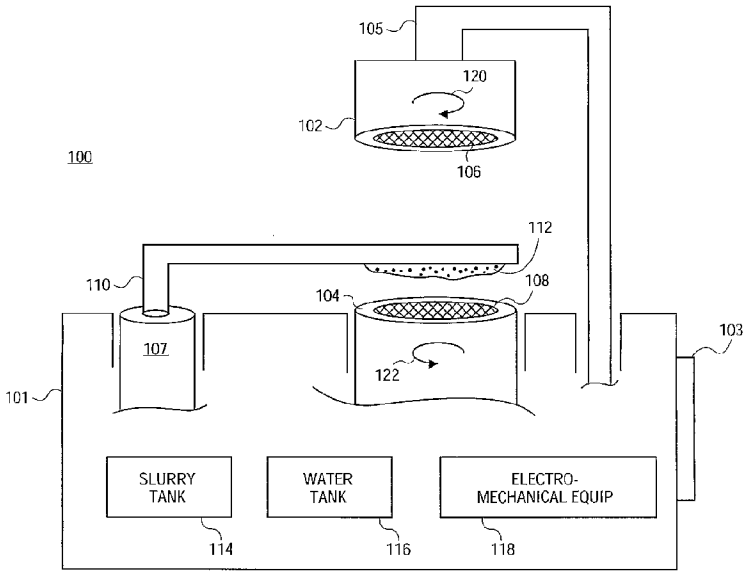
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(54) Title: DIAMOND CONDITIONING OF SOFT CHEMICAL MECHANICAL PLANARIZATION/POLISHING (CMP) POLISHING PADS



(57) Abstract: Conditioning of chemical mechanical planarization (CMP) using conventional diamond-embedded abrasive strips are well suited to condition conventional "hard" polishing but not soft polishing pads because the diamonds not only remove waste material, but they also damage the polishing surface of the pad. Embodiments of the present invention condition soft polishing pads using diamond strips without damaging the soft polishing pad (108).

WO 2004/094106 A1

DIAMOND CONDITIONING OF SOFT CHEMICAL MECHANICAL PLANARIZATION/POLISHING (CMP) POLISHING PADS

BACKGROUND

1. Field

[0001] Embodiments of the present invention relate to chemical mechanical planarization/polishing (CMP) and, in particular, to conditioning of CMP polishing pads.

2. Discussion of Related Art

[0002] Chemical mechanical planarization/polishing (CMP) is a process technology first developed in the mid-1980s to enable production of integrated circuits on substrates or wafers. CMP processes are used prepare wafers and to fabricate semiconductor devices or structures on the wafers. A CMP process may be used to planarize (*i.e.*, make flat) a semiconductor layer on a wafer, an insulating layer on the semiconductor layer, and a conductive layer on the insulating layer in predetermined patterns.

[0003] A typical CMP system includes a wafer carrier and a platen mounted in a housing. A polishing pad is secured to the platen and the wafer to be polished is secured in the wafer carrier. A typical CMP process operates as follows. The wafer carrier rotates the wafer and/or the platen rotates the polishing pad. Chemical slurry is applied to the surface of the polishing pad and the wafer is brought into contact with the polishing pad and is polished (or planarized). The combination of applying the chemical slurry and the mechanical rotation leads to the term "chemical-mechanical planarization."

[0004] As the wafer is polished, the chemical slurry and materials removed from the wafer tend to glaze the surface of the polishing pad, making the polishing pad slick and reducing the polishing rate and efficiency. It is thus important that the polishing pad surface be clean and free of surface irregularities. The process of cleaning the polishing pad is sometimes referred to a "conditioning" or "refreshing."

[0005] One method of conditioning polishing pads is to abrade them with a conventional diamond-embedded abrasive disk or strip. Although conventional diamond-embedded abrasive strips are well suited to condition "hard" polishing pads used for rough polishing,

they are not well suited to condition "soft" polishing pads used for fine polishing. When a soft polishing pad is conditioned with a diamond-embedded abrasive disk, the diamonds not only remove waste material, but they also damage the polishing surface of the pad.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] In the drawings, like reference numbers generally indicate identical, functionally similar, and/or structurally equivalent elements. The drawing in which an element first appears is indicated by the leftmost digit(s) in the reference number, in which:

[0007] Figure 1 is schematic diagram of a chemical mechanical planarization/polishing (CMP) polishing system according to an embodiment of the present invention;

[0008] Figure 2 is a flowchart illustrating a process performed by a CMP polishing system in according to embodiments of the present invention;

[0009] Figure 3 illustrates an example soft polishing pad according to an embodiment of the present invention;

[0010] Figure 4 illustrates operation of a conditioning arm according to an embodiment of the present invention; and

[0011] Figure 5 illustrates a diamond conditioner according to an embodiment of the present invention.

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

[0012] Figure 1 is schematic diagram of a chemical mechanical planarization (CMP) polishing system 100 according to an embodiment of the present invention. The CMP polishing system 100 includes a housing 101, a polishing head 102, a control panel 103, a platen 104, a spindle 105, a wafer 106, a base 107, a soft polishing pad 108, a conditioning arm 110, a diamond (or artificial diamond) conditioner 112, a slurry tank 114, a spindle 115, a water tank 116, and electromechanical equipment 118. The slurry tank 114 and/or the water tank 116 may be located in or separate from the housing 101. The electromechanical equipment 118 may include vertical drivers, rotational drivers,

controllers, or other equipment generally used to operate arms, motors, and other devices in CMP polishing systems.

[0013] The platen 104 is mounted in the housing 101 and may be rotated by a motor (not shown) in the electromechanical equipment 118. The polishing head 102 is mounted on the spindle 105 and may be rotated by a motor (not shown) in the electromechanical equipment 118. The wafer 106 is mounted with the surface to be polished face down and away from the polishing head 102. The soft polishing pad 108 mounted to the platen using an adhesive. During polishing of the wafer 106, the polishing head 102 may be rotated in a direction opposite to the rotation of the polishing pad 108 may be, as shown by arrows 120 and 122. Alternatively, the polishing head 102 may rotate while the platen 104 remains stationary. Alternatively still, the polishing head 102 may be stationary while the platen 104 rotates. The slurry tank 114 delivers slurry to the surface of the soft polishing pad 108 during wafer 106 polishing.

[0014] The conditioning arm 110 pivots in its base 107 when conditioning the soft polishing pad 108. A motor (not shown) in the electromechanical equipment 118 may move the conditioning arm 110. The water tank 116 may dispense a rinsing solution, such as potable water or de-ionized (DI) water, to the surface of the soft polishing pad 108 during conditioning of the soft polishing pad 108.

[0015] Figure 2 is a flowchart illustrating a process 200 performed by the CMP polishing system 100 according to embodiments of the present invention. A machine-readable medium with machine-readable instructions thereon may be used to cause a processor to perform the process 200. Of course, the process 200 is only an example process and other processes may be used. The example process 200 may be used to remove metal, oxides, glass, silicon, etc. Although the example process 200 is described with reference to wafers, the example process 200 may be used for semiconductors, memory disks, or other suitable objects requiring smoothness, planarity, fine polishing, etc., such as lenses and mirrors.

[0016] In a block 202 the head 102 holds the wafer 106 and rotates the wafer 106 against the soft polishing pad 108 as slurry from the slurry tank 114 is applied to the surface of the

soft polishing pad 108 and the platen 104 applies a force to the wafer 106. In a block 204, the head 102 disengages the wafer 106 from contact with the soft polishing pad 108 and the slurry stops flowing to the surface of the soft polishing pad 108.

[0017] In a block 206, the soft polishing pad 108 is conditioned using the diamond conditioner 112. In one embodiment of the present invention, the platen 104 rotates the soft polishing pad 108, rising solution from the water tank 116 rinses the soft polishing pad 108, e.g., by supplying DI water to the surface of the soft polishing pad 108, and the conditioning arm 110 with the diamond conditioner 112 sweeps across (e.g., back and forth) the soft polishing pad 108. Although polishing of the soft polishing pad 108 may be described in some embodiments as being performed *ex situ* (between wafer 106 polishings), polishing of the soft pat 108 in other embodiments may be performed *in situ* (while wafers 106 are being polished), or some combination of both. Of course, the soft polishing pad 108 may be conditioned according to embodiments of the present invention prior to polishing any wafers 106.

[0018] One or a combination of the following process parameters may be modified to improve the process for soft pad 108 conditioning using the diamond conditioner 112 to ensure that the conditioning arm 110 with the diamond conditioner 112 do not destroy or significantly reduce the lifetime of the soft polishing pad 108. In fact, according to embodiments of the present invention, the lifetime of the soft polishing pad 108 is significantly increased. Increased soft polishing pad 108 lifetime results in reduced labor costs and costs of parts, as well as improved processes, (*e.g.*, soft polishing pads 108 do not have to be changed as often).

[0019] In one embodiment, the conditioning arm 110 applies approximately 0.25 psi to the soft polishing pad 108 through the diamond conditioner 112 as opposed to approximately three psi applied using conventional hard polishing pad techniques..

[0020] In known soft polishing pad conditioning methods, the platen and thus the soft polishing pad does not rotate. In embodiments of the present invention, the rotational speed of the platen 104 and thus the soft polishing pad 108 may be approximately one hundred revolutions per minute 100 (rpm)

[0021] In known soft polishing pad conditioning methods, there may be no DI water flowing to the soft conditioning pad. In one embodiment of the present invention, the volumetric flow rate of DI water from the DI water tank 116 may may be one gallon per minute (gpm). Alternatively, the volumetric flow rate may be anywhere from zero to approximately seven gallons per minute.

[0022] In known soft polishing pad conditioning methods, there is no diamond conditioner used, thus no down force applied to a soft polishing pad In one embodiment, the down force applied to the soft polishing pad by the diamond conditioner 112 may be 0.25 psi.

[0023] In known soft polishing pad conditioning methods, no diamond conditioner is used. n known hard polishing pad conditioning methods, the diamond conditioner makes at least ten sweeps. In one embodiment, the diamond conditioner 112 makes one sweep across the soft polishing pad.

[0024] Figure 3 illustrates the example soft polishing pad 108 according to an embodiment of the present invention. The example soft polishing pad 108 includes several pores 302 and may be made from napped poromerics-porous urethane layers on a mylar or compressible urethane substrate. In an alternative embodiment, the example soft polishing pad 108 may be a soft pad made with tangled polyester fibers coated with polyurethane. In another embodiment, the example soft polishing pad 108 may be a felt sheet of fibers impregnated with micro porous elastomer. Alternatively still, the example soft polishing pad 108 may be a porous thermoplastic resin matrix, typically polyurethane, reinforced with a fibrous network such as a felted mat of polyester fibers. An example of a suitable soft pad includes any of the Politex® Series polishing pads available from Rodel Holdings in Wilmington, Delaware.

[0025] The soft polishing pads 108 according to embodiments of the present invention are to be distinguished from known hard polishing pads, which include micro porous polyurethane polishing pads that are relatively hard and not as compressible when compared to other types of polishing pads and polyurethane impregnated felt polishing

pads. Examples of hard pads include the SUBA 1000 Series polishing pads and the SUBA® Pads available from Rodel in Phoenix, Arizona.

[0026] Figure 4 illustrates operation of the conditioning arm 110 according to an embodiment of the present invention. When the soft polishing pad 108 is moving and a wafer 106 is being polished, the conditioning arm 110 (and the diamond conditioner 112) remain in the position 402 situated adjacent to the perimeter of the soft polishing pad 108. After a predetermined number of wafers have been polished by the soft polishing pad 108, or when the polishing rate has been decreased due to build up of slurry and other debris, the conditioning arm 110 is pivoted at one end by the base 107, lowered onto the soft polishing pad 108, and swept along an arc indicated by the arrows 408 from the position 402 across the surface of the soft polishing pad 108 (as shown by phantom lines) to a second position 406 adjacent to the other side of the perimeter of the soft polishing pad 108 (also shown by phantom lines).

[0027] Figure 5 illustrates the diamond conditioner 112 according to an embodiment of the present invention. The diamond conditioner 112 includes a base 502 having diamonds 504. The base 502 may be any suitable rigid substrate. The diamonds 504 may be synthetic diamonds, natural diamonds, etc.

[0028] The diamonds 504 may be placed on the base 502 using chemical vapor deposition (CVD). Alternatively, the diamonds 404 may be embedded in the base 502. For example, the diamond conditioner 112 may be formed by embedding diamond particles in nickel coated on the surface of a rigid substrate according to well-known or proprietary techniques.

[0029] Embodiments of the invention can be implemented using hardware, software, firmware, or a combination of hardware and software. In implementations using software, the software may be stored on a computer program product (such as an optical disk, a magnetic disk, a floppy disk, etc.) or a program storage device (such as an optical disk drive, a magnetic disk drive, a floppy disk drive, etc.).

[0030] The above description of illustrated embodiments of the invention is not intended

to be exhaustive or to limit the invention to the precise forms disclosed. While specific embodiments of, and examples for, the invention are described herein for illustrative purposes, various equivalent modifications are possible within the scope of the invention, as those skilled in the relevant art will recognize. These modifications can be made to the invention in light of the above detailed description.

[0031] In the above description, numerous specific details, such as particular processes, materials, devices, and so forth, are presented to provide a thorough understanding of embodiments of the invention. One skilled in the relevant art will recognize, however, that the embodiments of the present invention can be practiced without one or more of the specific details, or with other methods, components, etc. In other instances, well-known structures or operations are not shown or described in detail to avoid obscuring the understanding of this description.

[0032] Various operations have been described as multiple discrete operations performed in turn in a manner that is most helpful in understanding embodiments of the invention. However, the order in which they are described should not be construed to imply that these operations are necessarily order dependent or that the operations be performed in the order in which the operations are presented.

[0033] Reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure, process, block, or characteristic described in connection with the embodiment is included in at least one embodiment of the present invention. Thus, the appearances of the phrases "in one embodiment" or "in an embodiment" in various places throughout this specification are not necessarily all referring to the same embodiment. Furthermore, the particular features, structures, or characteristics may be combined in any suitable manner in one or more embodiments.

[0034] The terms used in the following claims should not be construed to limit the invention to the specific embodiments disclosed in the specification and the claims. Rather, the scope of embodiments of the invention is to be determined entirely by the following claims, which are to be construed in accordance with established doctrines of claim interpretation.

CLAIMS

What is claimed is:

1. A method of conditioning a chemical mechanical planarization (CMP) polishing pad, comprising:

conditioning a soft polishing pad using diamond conditioner.

2. The method of claim 1, further comprising:

rotating a soft polishing pad on a platen;

rinsing the soft polishing pad; and

passing a diamond conditioner over the soft polishing pad.

3. The method of claim 2, further comprising:

applying zero pounds per square inch (psi) to the soft polishing pad from the platen.

4. The method of claim 1, wherein passing the conditioning arm having the diamond conditioner thereon over the soft polishing pad comprises passing the diamond conditioner over the soft polishing pad during wafer polishing.

5. The method of claim 1, wherein passing the conditioning arm having the diamond conditioner thereon over the soft polishing pad comprises passing the diamond conditioner over the soft polishing pad between wafer polishings.

6. The method of claim 1, further comprising rotating a wafer against the soft polishing pad.

7. The method of claim 6, further comprising applying a slurry to the surface of the soft polishing pad.

8. A chemical mechanical planarization (CMP) system, comprising:

a head mounted in a housing;

a wafer mounted to the head;

a platen mounted in the housing;

a soft polishing pad mounted to the platen;

a pad conditioning arm mounted in the housing; and

a diamond conditioner mounted to the pad conditioning arm.

9. The system of claim 8, further comprising a slurry tank mounted in the housing.

10. The system of claim 9, further comprising a water tank mounted in the housing.

11. The system of claim 8, further comprising electromechanical equipment mounted in the housing.

12. A chemical mechanical planarization (CMP) apparatus, comprising:

a soft polishing pad adhered to a platen in a housing; and

a pad conditioning arm mounted in the housing, the pad conditioning arm having a diamond conditioner attached thereto.

13. The CMP apparatus of claim 12, wherein the soft polishing pad comprises napped poromerics-porous urethane layers on a substantially compressible substrate.

14. The CMP apparatus of claim 13, wherein the soft polishing pad comprises napped poromerics-porous urethane layers on a mylar substrate.

15. The CMP apparatus of claim 12, wherein the soft polishing pad comprises napped poromerics-porous urethane layers on a substantially compressible urethane substrate.

16. The CMP apparatus of claim 12, wherein the diamond conditioner comprises a diamond strip.

17. The CMP apparatus of claim 12, wherein the diamond strip comprises synthetic diamonds embedded in a base.

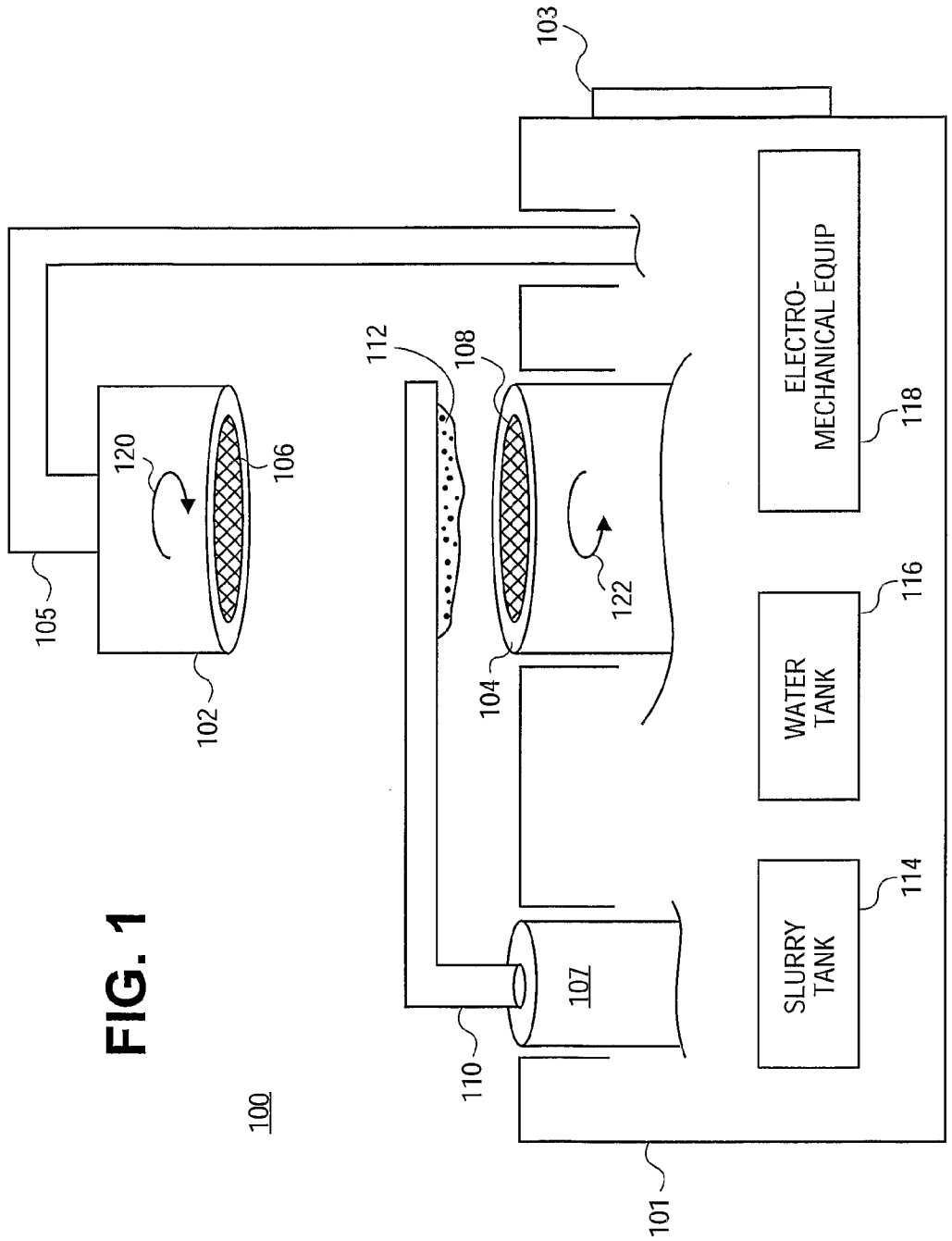

103
ELECTRO-MECHANICAL EQUIP
118
112
108
120
106
105
102
104
122
WATER TANK
116
SLURRY TANK
114
107
110
101
100

FIG. 1

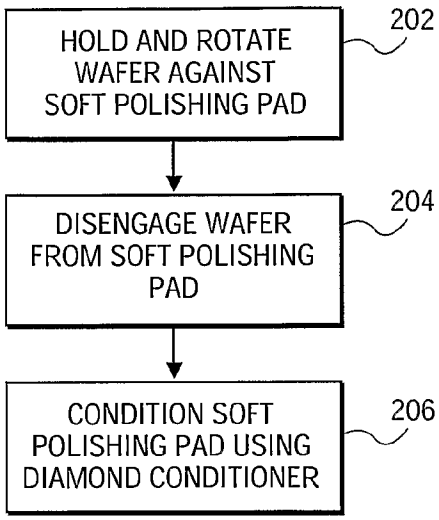

HOLD AND ROTATE WAFER AGAINST SOFT POLISHING PAD
202
DISENGAGE WAFER FROM SOFT POLISHING PAD
204
CONDITION SOFT POLISHING PAD USING DIAMOND CONDITIONER
206

FIG. 2

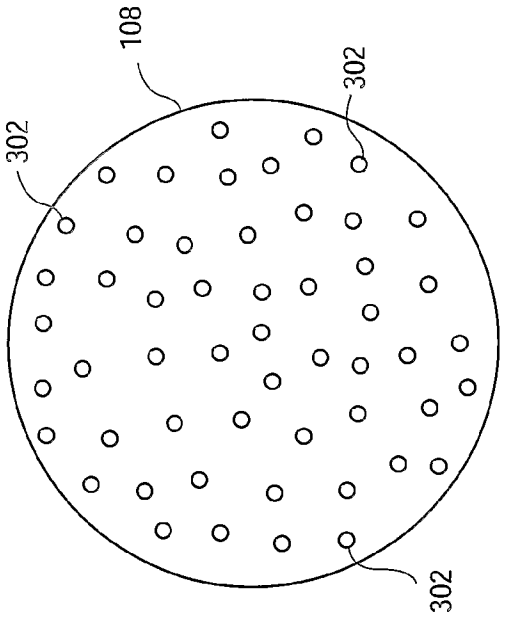


FIG. 3

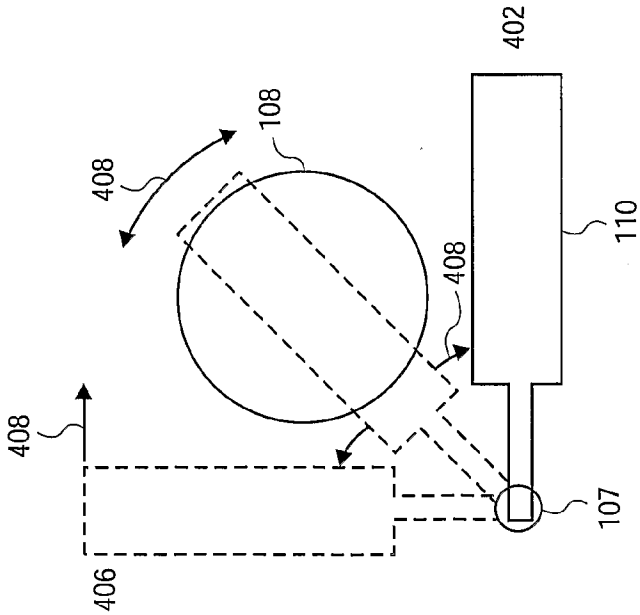


FIG. 4

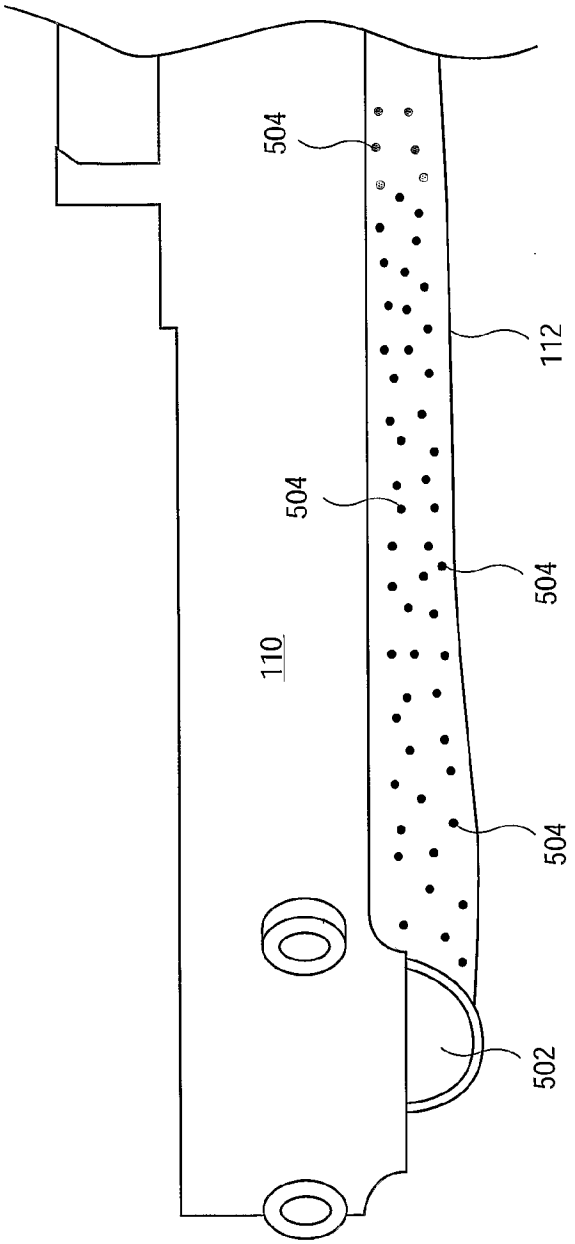


FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B24B37/04 B24B53/007

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 B24B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2001/029155 A1 (LI JUI-LUNG ET AL) 11 October 2001 (2001-10-11) paragraphs '0034!,'0035!,'0043!; claim 1; figure 3	1-17
A	US 2002/137436 A1 (GOTKIS YEHIEL ET AL) 26 September 2002 (2002-09-26) paragraph '0024!; figure 5C	16,17

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

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
13 May 2004	25/05/2004

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	Do Huu Duc, J

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 03/39969

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2001029155 A1	11-10-2001	NONE	
US 2002137436 A1	26-09-2002	US 6340326 B1	22-01-2002
		AU 2940301 A	07-08-2001
		EP 1250215 A1	23-10-2002
		JP 2003521117 T	08-07-2003
		TW 471994 B	11-01-2002
		WO 0154862 A1	02-08-2001
		US 2001012751 A1	09-08-2001

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Publication Title:

SUPERHARD CUTTERS AND ASSOCIATED METHODS

Abstract:

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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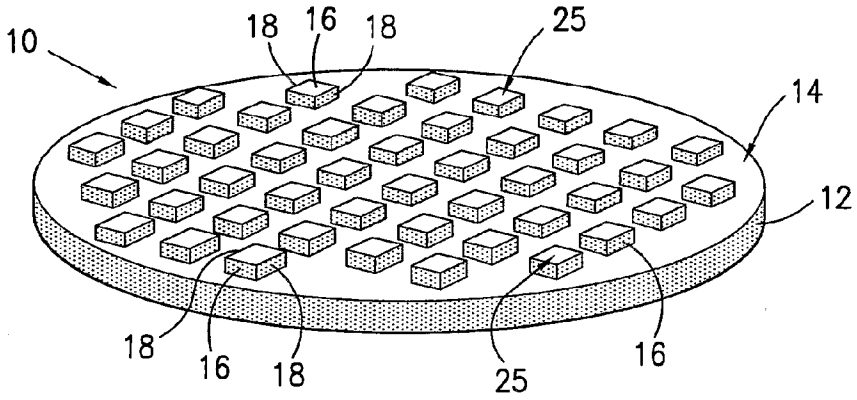
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— *without international search report and to be republished upon receipt of that report*

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(54) Title: SUPERHARD CUTTERS AND ASSOCIATED METHODS



(57) Abstract: A cutting device (10) comprises a base (12) having a working side (14) that is oriented to face a workpiece (19) from which material is to be removed. A plurality of individual cutting elements (16) are arranged on the working side of the base, with each cutting element having a peak that comprises at least one cutting edge (18) that is formed from a polycrystalline superhard material. The peaks of the cutting elements are aligned in a common plane (20).

WO 2006/124792 A2

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.

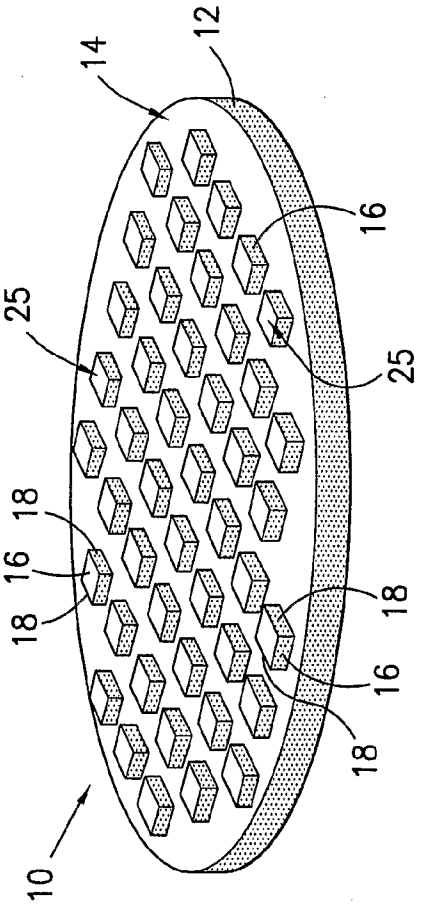


FIG. 1

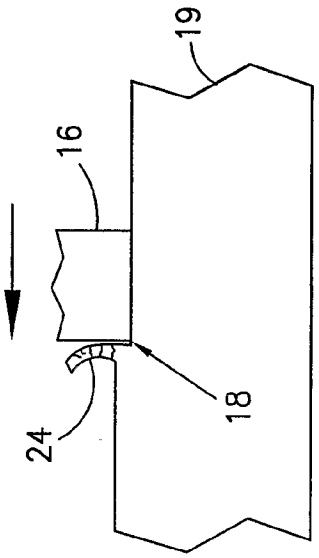


FIG. 3

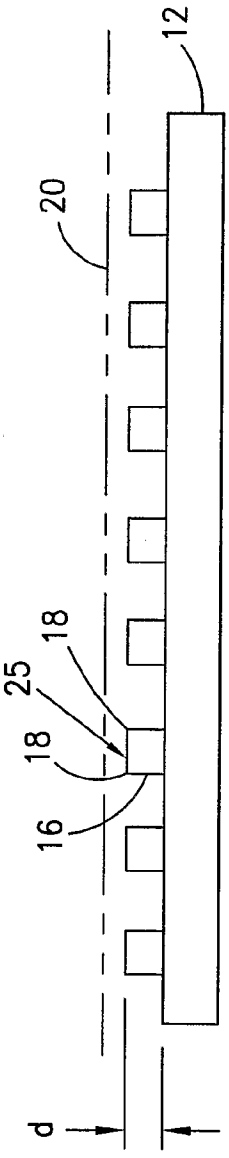


FIG. 2

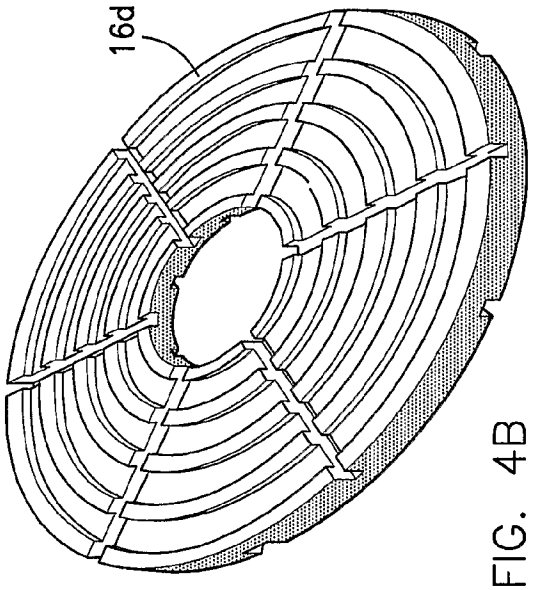


FIG. 4B

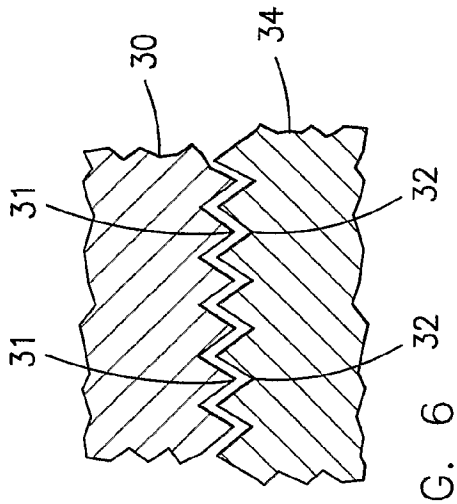


FIG. 6

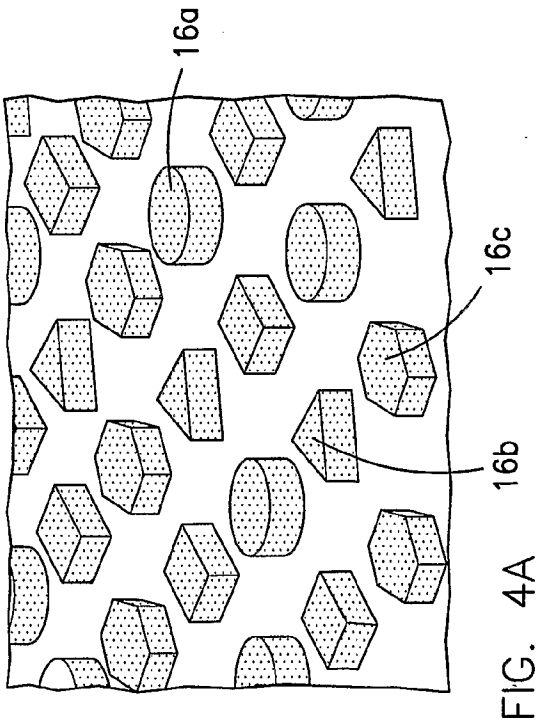


FIG. 4A

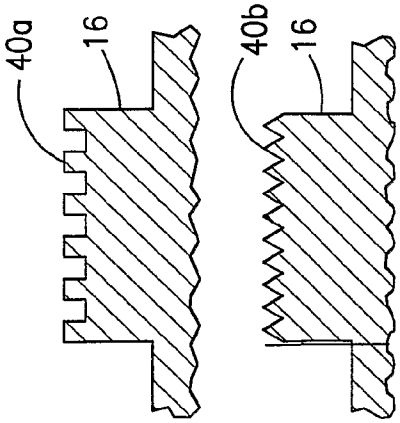


FIG. 5

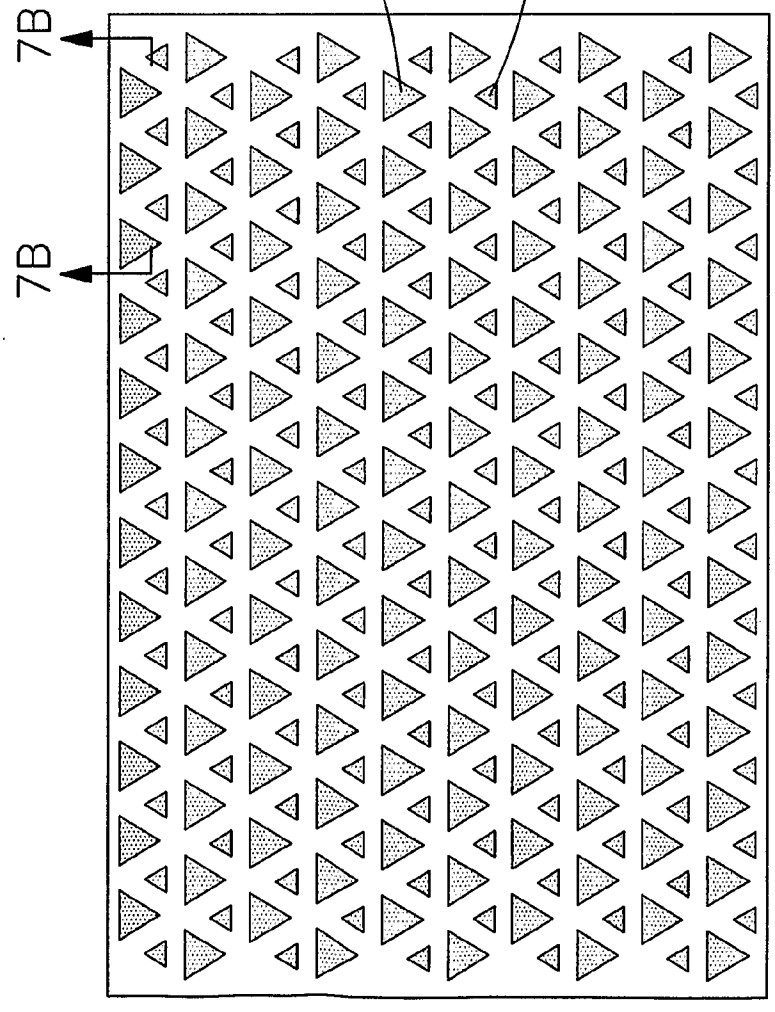


FIG. 7A

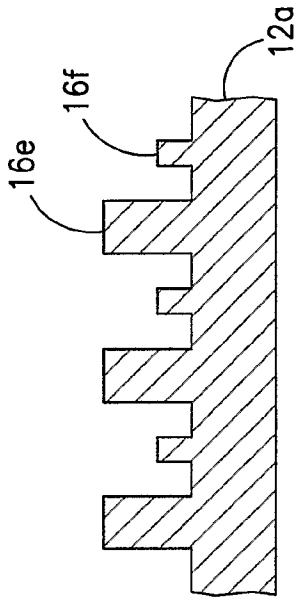


FIG. 7B

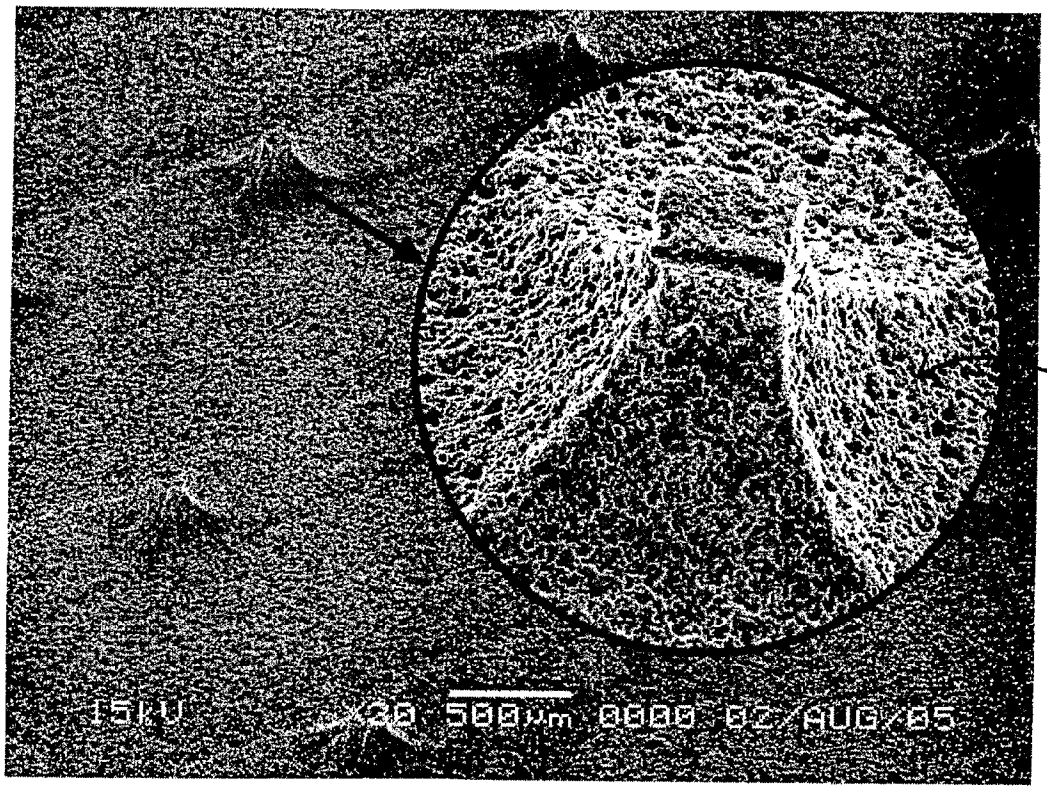


FIG. 8

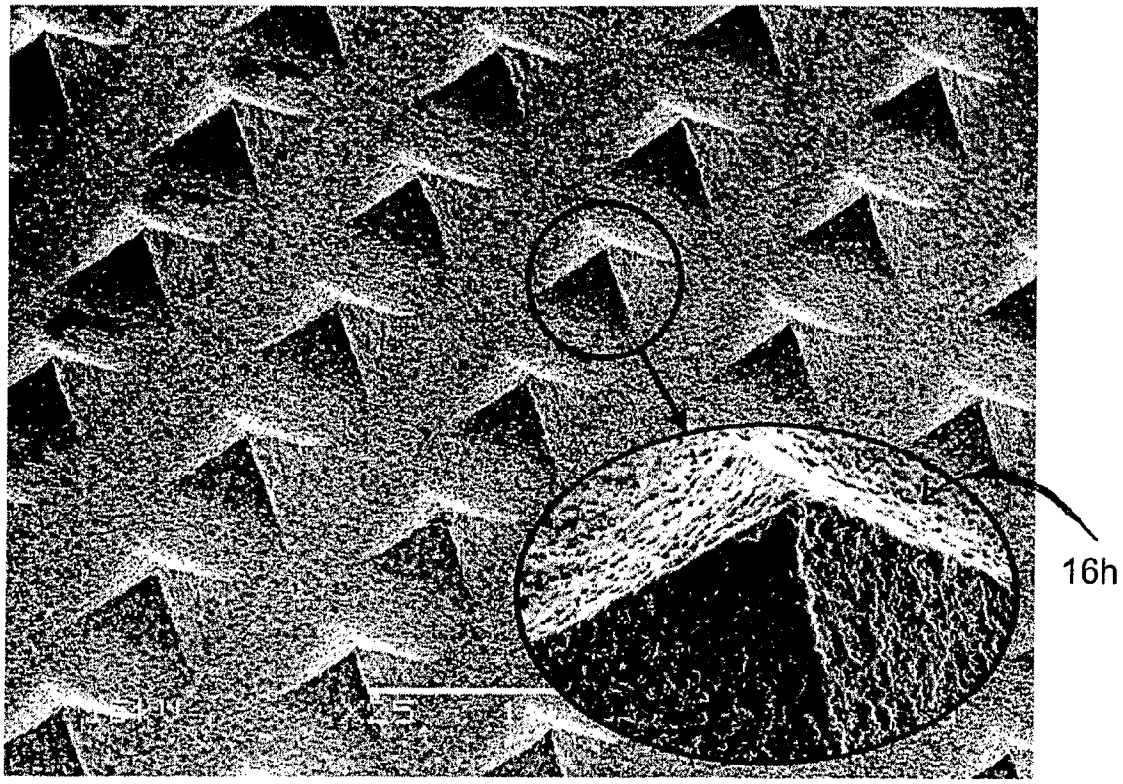


FIG. 9

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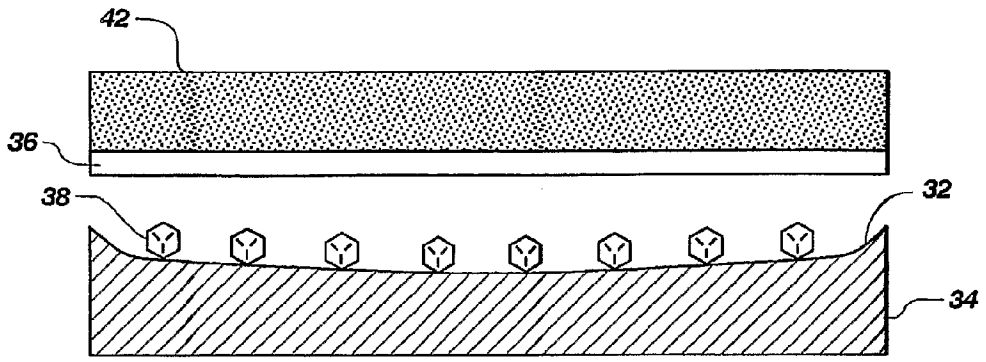
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(54) **Title:** METHODS OF BONDING SUPERABRASIVE PARTICLES IN AN ORGANIC MATRIX



(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.

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.

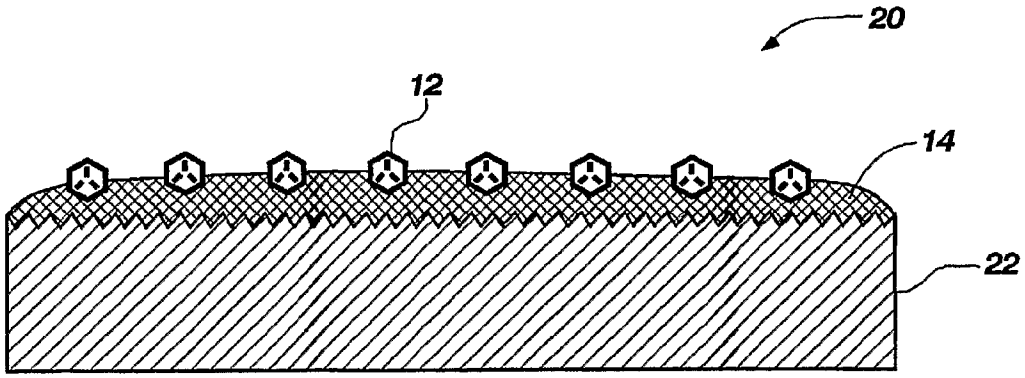


FIG. 1

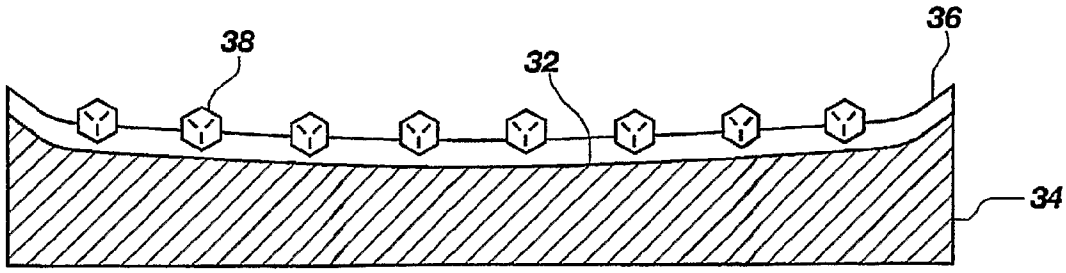


FIG. 2

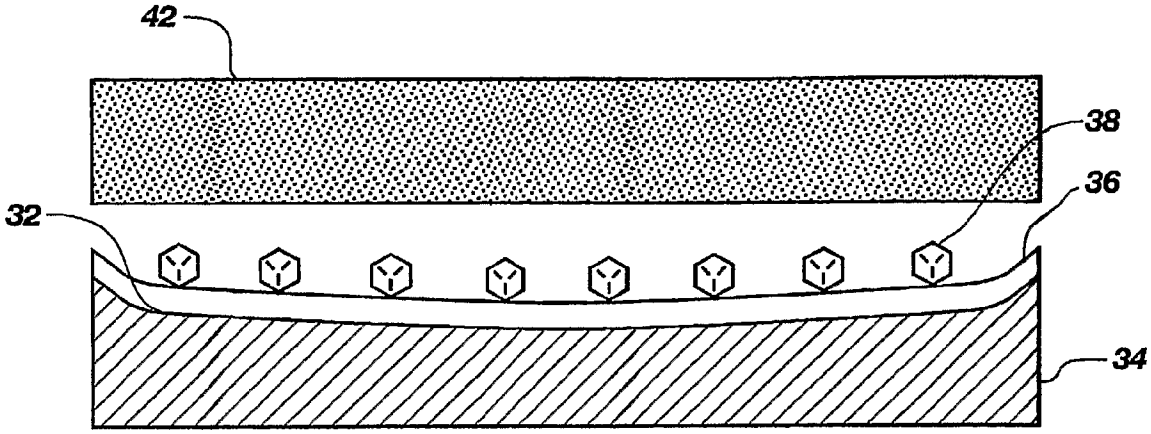


FIG. 3

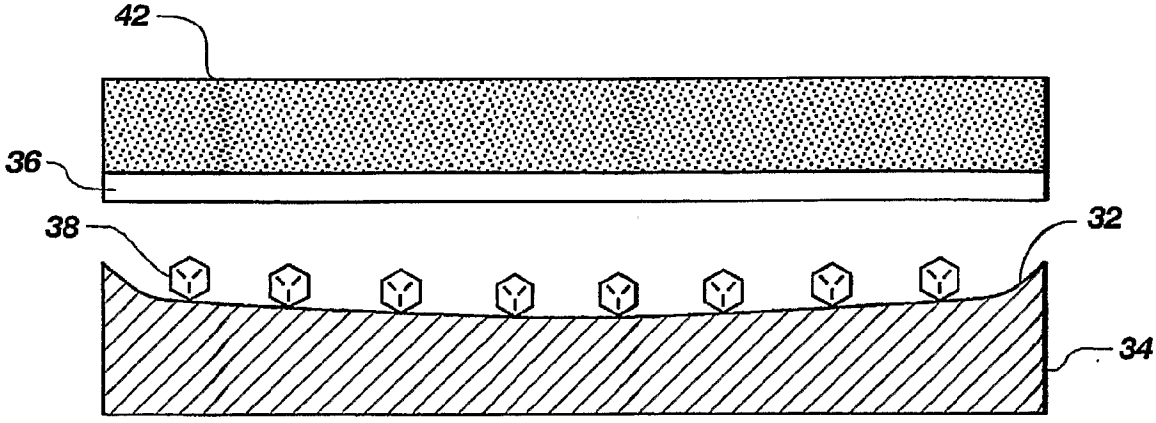


FIG. 4

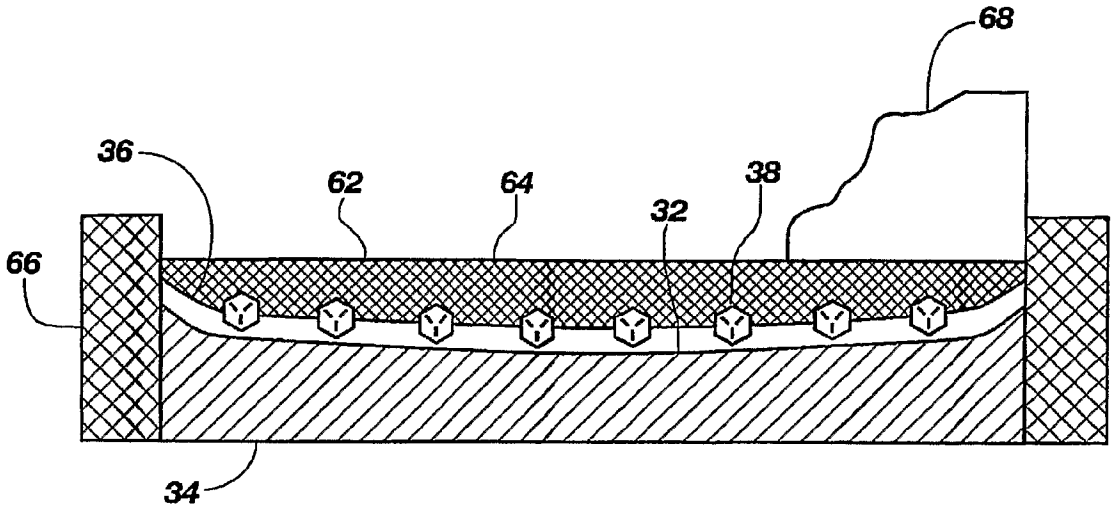


FIG. 5

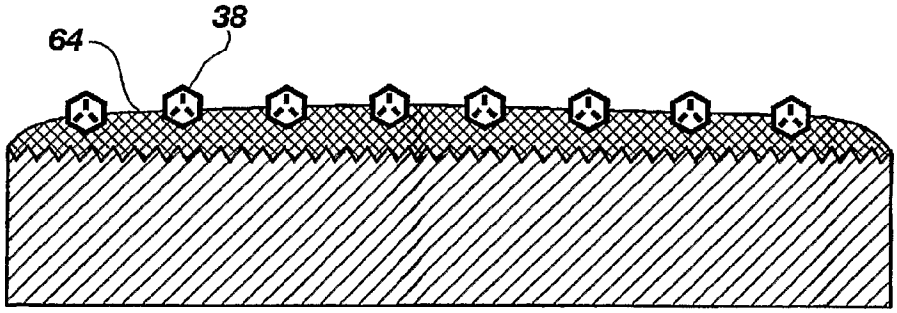


FIG. 6

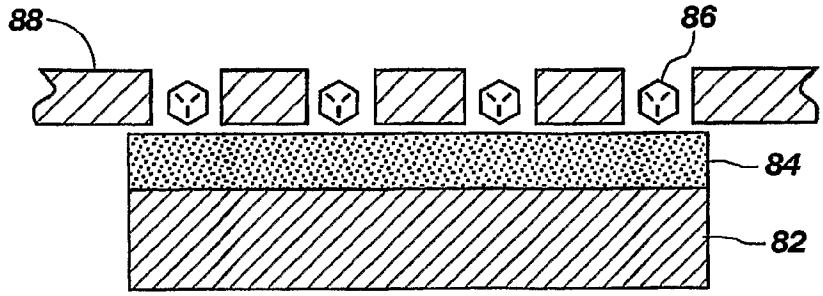


FIG. 7

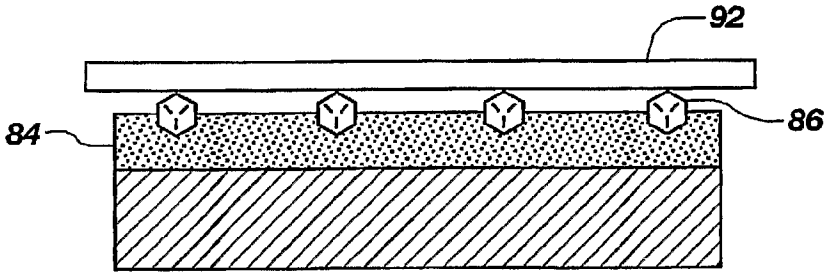


FIG. 8

WO2008063599

Publication Title:

SUPERHARD CUTTERS AND ASSOCIATED METHODS

Abstract:

Abstract of WO 2008063599

(A2) Translate this text A cutting device comprises a base having a solidified organic material layer disposed thereon. A plurality of individual polycrystalline cutting elements are secured in the solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements has a substantially matching geometric configuration.

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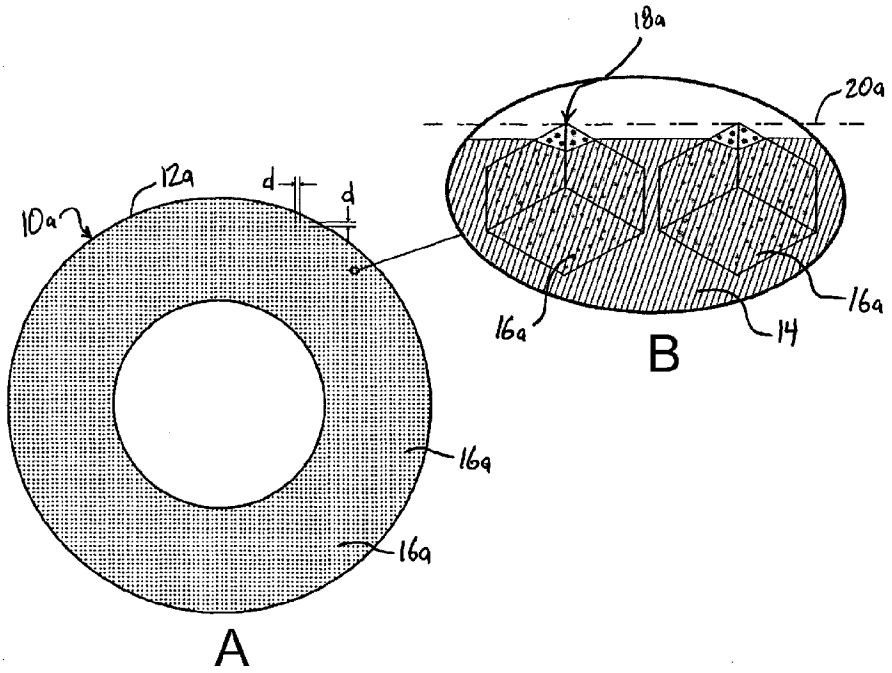
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(57) Abstract: A cutting device comprises a base having a solidified organic material layer disposed thereon. A plurality of individual polycrystalline cutting elements are secured in the solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements has a substantially matching geometric configuration.

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SUPERHARD CUTTERS AND ASSOCIATED METHODS

FIELD OF THE INVENTION

The present invention relates generally to cutting devices used to remove material from (e.g., plane, smooth, polish, dress, etc.) workpieces formed of various materials. Accordingly, the present invention involves the fields of chemistry, physics, and materials science.

BACKGROUND OF THE INVENTION

It is estimated that the semiconductor industry currently spends more than one billion U.S. Dollars each year manufacturing silicon wafers that exhibit very flat and smooth surfaces. Typically, chemical mechanical polishing ("CMP") is used in the manufacturing process of semiconductor devices to obtain smooth and even-surfaced wafers. In a conventional process, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movement of the platen and the carrier.

While this well-known process has been used successfully for many years, it suffers from a number of problems. For example, this conventional process is relatively expensive and is not always effective, as the silicon wafers may not be uniform in thickness, nor may they be sufficiently smooth, after completion of the process. In addition to becoming overly "wavy" when etched by a solvent, the surface of the silicon wafers may become chipped by individual abrasive grits used in the process. Moreover, if the removal rate is to be accelerated to achieve a higher productivity, the grit size used on the polishing pad must be increased, resulting in a corresponding increase in the risk of scratching or gouging expensive wafers. Furthermore, because surface chipping can be discontinuous, the process throughput can be very low. Consequently, the wafer surface preparation of current state-of-the-art processes is generally expensive and slow.

In addition to these considerations, the line width (e.g., nodes) of the circuitry on semiconductors is now approaching the virus domain (e.g., 10-100 nm). In addition, more layers of circuitry are now being laid down to meet the increasing demands of advanced logic designs. In order to deposit layers for making nanometer sized features,

each layer must be extremely flat and smooth during the semiconductor fabrication. While diamond grid pad conditioners have been effectively used in dressing CMP pads for polishing previous designs of integrated circuitry, they have not been found suitable for making cutting-edge devices with nodes smaller than 65 nm. This is because, with the decreasing size of the copper wires, non-uniform thickness due to rough- or over-polishing will change the electrical conductivity dramatically. Moreover, due to the use of coral-like dielectric layers, the fragile structure must be polished very gently to avoid disintegration. Hence, the pressure used in CMP processes must be reduced significantly.

In response, new CMP processes, such as those utilizing electrolysis (e.g. Applied Materials ECMP) of copper or those utilizing air film cushion support of wafer (e.g. Tokyo Semitsu), are being pursued to reduce the polishing pressure on the contact points between wafer and pad. However, as a consequence of gentler polishing action, the polishing rate of the wafer will decrease. To compensate for the loss of productivity, polishing must occur simultaneously over the entire surface of the wafer. In order to do so, the contact points between the wafer and the pad must be smaller in area, but more numerous in frequency. This is in contrast to current CMP practice in which the contacted areas are relatively large but relatively few in number.

Thus, in order to polish fragile wafers more and more gently, the CMP pad asperities must be reduced. However, to prevent the polishing rate from declining, more contact points must be created. Consequently, the pad asperities need to be finer in size but more in number. However, the more delicate the polishing process becomes, the higher the risk of scratching the surface of the wafer becomes. In order to avoid this risk, the highest tips of all asperities must be fully leveled. Otherwise, the protrusion of a few "killer asperities" can ruin the polished wafer.

SUMMARY OF THE INVENTION

The present invention provides a cutting device, including a base having a plurality of individual polycrystalline cutting elements secured in a solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements can have a matching geometric configuration.

In accordance with another aspect of the invention, a cutting device is provided, including a base having a solidified organic material layer attached thereto, and a plurality

of individual polycrystalline cutting elements secured in a solidified organic material layer, wherein each of the plurality of individual polycrystalline cutting elements can include at least one cutting tip. The cutting tips of the cutting elements can be aligned in a common plane.

In accordance with another aspect of the invention, a method of forming a cutting device is provided, including: obtaining a substrate; arranging on the substrate a plurality of individual polycrystalline cutting elements in an uncured organic material, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration, and curing the organic material to form a solidified organic material layer, such that each of the plurality of individual polycrystalline cutting elements are secured therein.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A is a schematic, top plan view of a cutting device in accordance with an embodiment of the invention;

FIG. 1B is an enlarged view of a portion of the cutting device of FIG. 1A;

FIG. 2A is a schematic, top plan view of a cutting device in accordance with another embodiment of the invention;

FIG. 2B is an enlarged view of a portion of the cutting device of FIG. 2A;

FIG. 3A is a schematic, top plan view of a polycrystalline blank, and a cutting device including individual polycrystalline cutting elements formed from the blank, in accordance with an embodiment of the invention;

FIG. 3B is an enlarged view of a portion of one cutting element of FIG. 3A, taken along section B-B of FIG. 3A;

FIG. 4 is a schematic, top plan view of a polycrystalline blank, and a cutting device including individual polycrystalline cutting elements formed from the blank, in accordance with another embodiment of the invention;

FIG. 5 is a schematic, top plan view of another polycrystalline blank in accordance with an embodiment of the invention, shown with the blank divided into a series of individual cutting elements;

FIG. 6 is a schematic, top plan view of a cutting device including individual polycrystalline cutting elements formed from the blank of FIG. 5 in accordance with another embodiment of the invention;

FIG. 7 is a schematic, top plan view of another cutting device, including the individual polycrystalline cutting elements formed from the blank of FIG. 5 in accordance with another embodiment of the invention;

FIG. 8 is a schematic, top plan view of another polycrystalline blank in accordance with an embodiment of the invention, shown with the blank divided into a series of individual cutting elements;

FIG. 9 is a schematic, top plan view of a cutting device, including the individual polycrystalline cutting elements formed from the blank of FIG. 8 in accordance with another embodiment of the invention;

FIG. 10 is a schematic, top plan view of another cutting device, including the individual polycrystalline cutting elements formed from the blank of FIG. 8 in accordance with another embodiment of the invention;

FIG. 11 is a schematic, top plan view of another polycrystalline blank in accordance with an embodiment of the invention, shown with the blank divided into a pair of individual cutting elements; and

FIG. 12 is a schematic, top plan view of a cutting device including the individual polycrystalline cutting elements formed from the blank of FIG. 11 in accordance with another embodiment of the invention.

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

the specific dimensions and aspects shown in the figures in order to produce the cutting devices of the present invention.

DETAILED DESCRIPTION

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

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

Definitions

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

All mesh sizes referred to herein are U.S. mesh unless otherwise indicated. Further, mesh sizes are generally understood to indicate an average mesh size of a given collection of particles since each particle within a particular "mesh size" may actually vary over a small distribution of sizes.

As used herein, a "common plane" refers to a profile, including planar or contoured profiles, above a base surface with which the peaks or tips of cutting elements are to be aligned. Examples of such profiles may include, without limitation, flat profiles, wavy profiles, convex profiles, concave profiles, multi-tiered profiles, and the like.

As used herein, cutting "edge" refers to a portion of a cutting element that includes some measurable width across a portion that contacts and removes material from a workpiece. As an exemplary illustration, a typical knife blade has a cutting edge that extends longitudinally along the knife blade, and the knife blade would have to be oriented transversely to a workpiece to scrape or plane material from the workpiece in order for the cutting "edge" of the knife blade to remove material from the workpiece.

As used herein, cutting "tip" refers to a portion of a cutting element that protrudes

the greatest distance from a bonding material, e.g., that is the first portion of the cutting element that contacts a workpiece when the article of the present invention is in use. It is to be understood that a cutting "tip" can include a planar surface, a pointed surface, or an edge; so long as the planar surface, pointed surface or edge of the cutting element is the first portion of the cutting element that contacts a workpiece from which material is to be removed with a cutting device to which the cutting element is attached.

As used herein, "sintering" refers to the joining of two or more individual particles to form a continuous solid mass. The process of sintering involves the consolidation of particles to at least partially eliminate voids between particles. Sintering may occur in either metal or carbonaceous particles, such as diamond. Sintering of metal particles occurs at various temperatures depending on the composition of the material. Sintering of diamond particles generally requires ultrahigh pressures and the presence of a carbon solvent as a diamond sintering aid, and is discussed in more detail below. Sintering aids are often present to aid in the sintering process and a portion of such may remain in the final product.

As used herein, "superhard" may be used to refer to any crystalline, or polycrystalline material, or mixture of such materials which has a Mohr's hardness of about 8 or greater. In some aspects, the Mohr's hardness may be about 9.5 or greater. Such materials include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), polycrystalline cubic boron nitride (PcBN) as well as other superhard materials known to those skilled in the art. Superhard materials may be incorporated into the present invention in a variety of forms including particles, grits, films, layers, etc. However, in most cases, the superhard materials of the present invention are in the form of polycrystalline superhard materials, such as PCD and PcBN materials. It is important to note that distinctions are made in the present disclosure between conventional superhard grits and polycrystalline superhard materials.

As used herein, "geometric configuration" refers to a shape that is capable of being described in readily understood and recognized mathematical terms. Examples of shapes qualifying as "geometric configurations" include, without limitation, cubic shapes, polyhedral (including regular polyhedral) shapes, triangular shapes (including equilateral triangles, isosceles triangles and three-dimensional triangular shapes), pyramidal shapes, spheres, rectangles, "pie" shapes, wedge shapes, octagonal shapes, circles, etc.

As used herein, "organic material" refers to a semisolid or solid complex amorphous mix of organic compounds. As such, "organic material layer" and "organic material matrix" may be used interchangeably, refer to a layer or mass of a semisolid or solid complex amorphous mix of organic compounds. Preferably the organic material will be a polymer or copolymer formed from the polymerization of one or more monomers.

As used herein, "metal" and "metallic" can be used interchangeably, and refer to a metal, or an alloy of two or more metals. A wide variety of metal or metallic materials is known to those skilled in the art, such as aluminum, copper, chromium, iron, steel, stainless steel, titanium, tungsten, zinc, zirconium, molybdenum, etc., including alloys and compounds thereof.

As used herein, "particle," when used in connection with a superabrasive material, refer to a particulate form of such material. Such particles may take a variety of shapes, including round, oblong, square, euhedral, etc., as well as a number of specific mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes.

As used herein, "particle" and "grit" may be used interchangeably.

As used herein, "cutting element" describes a variety of structures capable of removing (e.g., cutting) material from a workpiece. A cutting element can be a mass having several cutting points, ridges or mesas formed thereon or therein. It is notable that such cutting points, ridges or mesas may be from a multiplicity of protrusions or asperities included in the mass. Furthermore, a cutting element can also include an individual particle that may have only one cutting point, ridge or mesa formed thereon or therein.

As used herein, "grid" means a pattern of lines forming multiple squares.

As used herein, "mechanical force" and "mechanical forces" refer to any physical force that impinges on an object that causes mechanical stress within or surrounding the object. Example of mechanical forces would be frictional forces or drag forces. As such, the terms "frictional force" and "drag force" may be used interchangeably, and refer to mechanical forces impinging on an object as described.

As used herein, "mechanical stress" refers to a force per unit area that resists impinging mechanical forces that tend to compact, separate, or slide an object.

As used herein, the term "profile" refers to a contour above an organic material layer

surface to which the superabrasive particles are intended to protrude.

As used herein, "mechanical bond" and "mechanical bonding" may be used interchangeably, and refer to a bond interface between two objects or layers formed primarily by frictional forces. In some cases the frictional forces between the bonded objects may be increased by expanding the contacting surface areas between the objects, and by imposing other specific geometrical and physical configurations, such as substantially surrounding one object with another.

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. For example, a composition that is "substantially free of" particles would either completely lack particles, or so nearly completely lack particles that the effect would be the same as if it completely lacked particles. In other words, a composition that is "substantially free of" an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.

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

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

Concentrations, amounts, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used

merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc., as well as 1, 2, 3, 4, and 5, individually.

This same principle applies to ranges reciting only one numerical value as a minimum or a maximum. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides a cutting device and associated methods that can be utilized in cutting or otherwise affecting a workpiece to remove material from the workpiece and provide a finished, smooth and/or flat surface to the workpiece. Cutting devices of the present invention can be advantageously utilized, for example, as planing devices that plane material from a workpiece, as dressing devices that dress various workpieces, and as polishing devices that polish various workpieces.

In the embodiment of the invention illustrated in FIGs. 1A and 1B, a cutting device (e.g., disk) 10a is provided that optionally includes a base 12a that can have a solidified organic material layer (14 in FIGs. 1B and 2B) disposed thereon, attached thereto, or otherwise associated therewith. A plurality of individual polycrystalline cutting elements 16a can be secured in the solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements can have or exhibit a substantially matching geometric configuration, e.g., the geometric configuration of the cutting elements can substantially match that of other of the cutting elements. In the example illustrated in FIG. 1B, each of the plurality of individual polycrystalline cutting elements 16a has geometric configuration that is substantially cubic in nature. In the embodiment illustrated in FIG. 2B, the individual polycrystalline cutting elements 16b have a geometric configuration that can be characterized as a three-dimensional triangular configuration.

As illustrated in both FIGs. 1B and 2B, in one aspect of the invention, the plurality of individual polycrystalline cutting elements 16a, 16b can include at least one cutting tip (18a and 18b, respectively), with the cutting tips of the cutting elements being aligned in a common plane (20a, 20b, respectively). In this example, the common plane is a flat plane of predetermined height above the solidified organic matrix. Thus, the plurality of individual polycrystalline cutting elements can be held within the solidified organic material layer in a very precise manner such that each of the cutting elements contacts a workpiece (not shown) from which material is to be removed at substantially the same depth. In this way, each of the individual polycrystalline cutting elements can be subject to substantially the same level of drag force as the cutting device is moved relative to a workpiece. This feature of the invention can advantageously limit the premature removal of individual cutting elements that might otherwise shorten the life of the tool, and/or damage the workpiece being treated.

The individual cutting elements 16a, 16b can be formed from a variety of materials including, in one embodiment, a polycrystalline material or a superhard polycrystalline material. While not so limited, the superhard polycrystalline material can be a polycrystalline diamond compact ("PCD") or a polycrystalline cubic boron nitride compact ("PcBN"). The PCD or PcBN compact can be formed in a variety of manners, as discussed in more detail below. By forming the individual cutting elements from a polycrystalline material, and attaching the cutting elements individually to the cutting device, the beneficial properties of polycrystalline cutting elements can be achieved without requiring that portions of the cutting device not used for cutting also be formed from the polycrystalline material. Thus, considerable cost savings can be achieved.

The cutting devices of the present invention can be utilized in a number of applications, and in one embodiment are particularly well adapted for use in planing substantially brittle materials, such as silicon wafers, glass sheets, metals, used silicon wafers to be reclaimed by planarization, LCD glass, LED substrates, SiC wafers, quartz wafers, silicon nitride, zirconia, etc. In conventional silicon wafer processing techniques, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movements of the platen and the carrier. Thus,

the silicon wafer is essentially ground or polished, by very fine abrasives, to a relatively smooth surface.

While grinding of silicon wafers has been used with some success, the process of grinding materials such as silicon wafers often results in pieces of the material being torn or gouged from the body of the material, resulting in a less than desirable finish. This is due, at least in part, to the fact that grinding or abrasive processes utilize very sharp points of abrasive materials (which are often not level relative to one another) to localize pressure to allow the abrasives to remove material from a workpiece.

The PCD or PcBN cutting elements of the present invention are generally superhard, resulting in little yielding by the cutting elements when pressed against a wafer. As hardness is generally a measure of energy concentration, e.g., energy per unit volume, the PCD or PcBN compacts of the present invention are capable of concentrating energy to a very small volume without breaking. These materials can also be maintained with a very sharp cutting edge due to their ability to maintain an edge within a few atoms.

While not so required, in one embodiment of the invention shown in FIG. 1A, the individual polycrystalline cutting elements 16a can be arranged in or across the organic material layer or base in a grid pattern, e.g., in a pattern of squares. The cutting elements can be evenly spaced from one another at a distance "d" of from about 100 microns to about 800 microns. In one aspect of the invention, the individual polycrystalline cutting elements can be evenly spaced from one another at a distance "d" of about 500 microns.

In the embodiment of the invention illustrated in FIG. 2A, the individual polycrystalline cutting elements 16b can be arranged in or across the organic material layer or base as a series of concentric circles. As in the embodiment discussed above, the individual cutting elements can be evenly spaced from one another at a distance "d" of from about 100 microns to about 800 microns. In one aspect, the individual polycrystalline cutting elements can be evenly spaced from one another at a distance "d" of about 500 microns. By evenly spacing the individual cutting elements one from another, the drag force applied to the cutting elements during the cutting process can be evenly distributed among each of the cutting elements, eliminating or reducing the risk of premature pullout of one or more individual cutting elements. Premature pullout of one or more individual cutting elements can result in serious damage being done the workpiece being worked upon.

The retention of an individual polycrystalline cutting element in an organic material layer can be greatly improved by arranging the cutting elements the organic material layer such that mechanical stress impinging on any individual cutting element is minimized. By reducing the stress impinging on each individual cutting element they can be more readily retained in a solidified organic material layer, particularly for delicate tasks.

Various configurations or arrangements are contemplated for minimizing the mechanical stress impinging on the cutting elements held in the abrading tool. In addition to the spacing considerations discussed above, one potentially useful parameter may include the relative heights that the elements protrude above the organic material layer. A cutting element that protrudes to a significantly greater height than other cutting elements will experience a greater proportion of the impinging mechanical forces and thus is more prone to pull out of the solidified organic material layer. Thus, an even height distribution of the cutting elements may function to more effectively preserve the integrity of the abrading tool as compared to abrading tools lacking such an even height distribution.

As such, in one aspect, substantially all of the plurality of individual cutting elements may protrude to a predetermined height above the solidified organic material layer. Though any predetermined height that would be useful in an abrading or cutting tool would be considered to be within the presently claimed scope, in one specific aspect the predetermined height may produce a cutting depth of less than about 20 microns when used to abrade a workpiece. In another specific aspect, the predetermined height may produce a cutting depth of from about 1 micron to about 20 microns when used to abrade a workpiece. In yet another specific aspect, the predetermined height may produce a cutting depth of from about 10 micron to about 20 microns when used to abrade a workpiece. In yet another aspect, the predetermined height may produce a depth of up to or more than 50 or 100 microns.

It should also be noted that the leveling of the individual cutting elements to a predetermined height may be dependent on cutting element spacing. In other words, the farther the cutting elements are separated, the more the impinging forces will affect each cutting element. As such, patterns with increased spacing between the cutting elements may benefit from a smaller variation from predetermined height.

It may also be beneficial for the cutting elements to protrude from the solidified

organic material layer to a predetermined height or series of heights that is/are along a designated profile. Numerous configurations for designated profiles are possible, depending on the particular use of the abrading tool. In one aspect, the designated profile may be a plane. In planar profiles, the highest protruding points of the cutting elements are intended to be substantially level. It is important to point out that, though it is preferred that these points align with the designated profile, there may be some height deviation between cutting elements that occur due to limitations inherent in the manufacturing process.

In addition to planar profiles, in another aspect of the present invention the designated profile has a slope. Tools having sloping surfaces may function to more evenly spread the frictional forces impinging thereon across the cutting elements, particularly for rotating tools such as disk sanders and CMP pad dressers. The greater downward force applied by higher central portions of the tool may offset the higher rotational velocity at the periphery, thus reducing the mechanical stress experienced by cutting elements in that location. As such, the slope may be continuous from a central point of the tool to a peripheral point, or the slope may be discontinuous, and thus be present on only a portion of the tool. Similarly, a given tool may have a single slope or multiple slopes. In certain aspects, the tool may slope in a direction from a central point to a peripheral point, or it may slope from a peripheral point to a central point.

Various slopes are contemplated that may provide a benefit to solidified organic material layer tools. It is not intended that the claims of the present invention be limited as to specific slopes, as a variety of slopes in numerous different tools are possible. In one aspect, however, a CMP pad dresser may benefit from an average slope of 1/1000 from the center to the periphery.

As a variation on tools having a slope, in certain aspects the designated profile may have a curved shape. One specific example of a curved shape is a dome shape tool. Such curved profiles function in a similar manner to the sloped surfaces. Tools may include such curved profiles in order to more effectively distribute the frictional forces between all of the cutting elements, thus reducing failures of individual particles and prolonging the life of the tool.

As has been mentioned herein, while it is intended that the tips of the cutting elements align along the designated profile, some level of deviation may occur. These

deviations may be a result of the design or manufacturing process of the tool. Given the wide variety of sizes and shapes of cutting elements that may potentially be utilized in a given tool, such deviations may be highly dependent on a particular application. Also, when referring to the designated profile, it should be noted that the term "tip" is intended to include the highest protruding point of a cutting element, whether that point be an apex, an edge, or a face. Orientational positioning, tip leveling, and other techniques of manipulating superabrasive particles are further described in U.S. Patent Application No. 11/223,786, filed on September 9, 2005, and U.S. Patent Application No. 11/733,325, filed April 10, 2007, both of which are incorporated herein by reference.

As such, in one aspect a majority of the plurality of cutting elements is arranged such that the tips vary from the designated profile by from about 1 micron to about 150 microns. In another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 5 microns to about 100 microns. In yet another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 10 microns to about 75 microns. In a further aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 10 microns to about 50 microns. In another aspect, they are arranged such that their tips vary from the designated profile by from about 50 microns to about 150 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by from about 20 microns to about 100 microns. In a further aspect, they are arranged such that their tips vary from the designated profile by from about 20 microns to about 50 microns.

In another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 20 microns to about 40 microns. Additionally, in one aspect, they are arranged such that their tips vary from the designated profile by less than about 20 microns. In another aspect, they are arranged such that their tips vary from the designated profile by less than about 10 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by less than about 5 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by less than about 1 micron. In a further aspect, a majority of the plurality of the cutting elements are arranged such that their tips vary from the designated profile to less than about 10% of the average size of the cutting elements.

The determination of the distance that the tips of the cutting elements extend from the organic binder can also be affected by considering how much of the cutting elements extend above the binder compared to how much of the cutting elements remain submerged beneath the binder surface. In the embodiment illustrated in FIGs. 1A and 1B, a ratio of an amount the cutting elements 16a protrude above the binder to an amount submerged beneath the binder is about 4 to 1. In the embodiment illustrated in FIGs. 2A and 2B, about 2/3 of the cutting elements 16b are submerged, with about 1/3 being exposed above the binder. Other ratios are also possible, from a 20 to 1 ratio to about 0.2 to 1, inclusive of ranges therebetween.

By forming the individual cutting elements in the shapes described herein, a relatively large portion of the cutting elements 16a, 16b can be submerged beneath the organic binder. In this manner, the area that affords the greatest cross section for engagement with the binder material is "buried" beneath the greatest amount of binder. This feature of the invention, namely that the widest (i.e. largest cross section of the cutting element) is closer to one end of the particle than the other, and thus the wider end can be placed below the surface of the organic matrix, provides great retention advantages over conventional diamond, or synthetic diamond, grits wherein a largest cross section of the grit is concentrated near a midpoint of the grit, and thus is placed at or near the surface of a matrix in which the grit is held. The widest portion may be at or near the end that is most distal from the working (e.g., cutting) end of the cutting element.

In addition to the shapes of cutting elements illustrated in the figures, in one embodiment of the invention, the cutting elements are formed in pyramidal shapes. The present inventor has found that such a configuration provides a number of advantages. For example, pyramidal-shaped cutting elements concentrate most of the volume/mass of the cutting element toward a lowermost portion of the cutting element, ensuring that the cutting element is more securely held to whichever type of base (e.g., cutting tool) the elements are bonded to, integrated with, or other associated with. In addition, by forming pyramids with a triangular base, the support base of the pyramids is even more massive relative to the tip, and the tip can be made sharper (e.g., 60 degrees) without breaking or fracturing during the dressing of CMP pads.

In general, sharper tips will cut pads faster, leading to a corresponding reduction in total dressing time. Moreover, the asperities formed on the pad are also sharper and more

dense. Such asperities can polish wafers, and/or dress CMP pads faster without causing undesirable non-uniformity on the wafer. Alternatively, square pyramids can be used when a lower cut rate is desired, as the tip angle likely has a larger magnitude (e.g. 90 degrees). Thus creating a wider cut path with greater drag and resulting in a lower cut rate. However, the square PCD cutter can be formed more sharply than conventional, single crystal diamond grits that have variable tip angles ranging from 90 degrees to over 125 degrees. Thus, pyramids formed of polycrystalline materials are generally much more effective cutters, with triangular pyramids (i.e. 3 sided) being particularly effective.

In addition, as the cutting elements of the present invention can be made with very closely controlled geometry, the present polycrystalline cutting elements can cut pads with less tearing. Also, with the addition of the secondary cutting elements formed on the major cutting elements, the present cutting elements can perform even better. In other words, serrations in the cutting surface may improve the cutting action of the cutting elements. In contrast, single crystal grits are generally very smooth, so they can cause a lot of plastic deformation on the pad and tearing of cut "shreds." It should be noted that the irregular surface of the polycrystalline cutting elements additionally improves retention in the organic material layer. Such irregular surfaces allow the organic material to "grip" a cutting element to a greater extent than would be possible with the smooth surfaces of a single crystal cutting element.

In addition, oftentimes pad conditioners dress pads under conditions in which work load is unevenly distributed across the cutting elements. Specifically, the outer rim of cutting elements often must do the most cutting work, with the interior elements not being subject to a as high a degree of stress. One manner in which the present invention addresses this problem is by configuring the "outer" cutting elements, some times as PCD grits, (e.g., those located closer to the outer perimeter of the cutting or dressing tool) more robust, and/or the inner elements slightly higher (e.g. about 10 microns higher) than the outer elements. The outer cutting elements can also be disposed on the cutting tool at a greater density, e.g., they can be spaced closer together, and/or be positioned at a slightly lower elevation. In this design, the distribution of cutting elements may not be in grid form, but can include a series of concentric rings that can be radially symmetric.

In one embodiment of the invention, the outer elements can be formed with larger support bases relative to the cutting tips (in one aspect they can have triangular bases),

and they may also have an edge formed on the cutting tip rather than just a point. Also, the outermost cutting elements may have a small (e.g. 50 microns) mesa formed at their cutting tips that can cut the pad with edge of the mesa rather than with a straight edge or a point.

In one embodiment of the invention, the cutting elements can be pyramids that are asymmetrical in shape. For example, since the cutting force is generally applied from "outside to inside," the pyramid design may have a relatively steeply sloped wall facing the outer perimeter of the cutting device, but with a relatively gentler slope (e.g. 10 degrees from the horizontal plane) in the trailing side. That is, the table portion on the tip of the pyramid may not be horizontal, but may exhibit a slight "tilt" toward inward to allow debris to escape more easily. This aspect of the invention differs from diamond grit cutting pads, as such conventional cutting pads include a negative angle such that the tearing or cutting force is superimposed with a compressive force. This embodiment of the invention can allow cutting without a great deal of compression so the removal of pad "shread" is much easier.

In other words, the present invention allows a majority of the energy consumed to be used in cutting, rather than plastic deformation. This advantage can be further improved upon by forming the vertical wall of the pyramids such that they slope slightly less than 90 degrees (e.g., about 80 degrees). In this case the table of the pyramids can be sharper on the top of the mesa, similar to an inverted pyramid. This can improve the efficiency of pad cutting because the cutting is performed with a positive angle, similar to a razor blade used in shaving. Such a design has not been possible with single crystal diamond designs, as the cutting edge contact with such designs is always negative in angle. The present pyramidal cutting elements can provide positive cutting edges that are not subject to premature failure due, at least in part, to its ability to support such a cutting edge with a more gently sloping wall on the trailing side of the cutting interface (e.g., with the asymmetrical shape of the pyramids). In one aspect, such an asymmetry can be formed by wire-EDM cutting, and it can be formed with pyramids with tips of point, edge, and mesa tops. Also, when the cutting elements are individual particles or grits, such particle or grit can receive the intended configuration, including an assymetrical configuration as described above by using a mold with a proper shape for processing of the PCT particle.

In one embodiment of the invention, the spacing of the pyramids can be adjusted to adjust the contact pressure of each cutting point, edge or mesa. In general, the farther the pyramids are spaced from one another, the higher the contact pressure between the pyramid and the pad. Thus, the fewer tips present to support the applied force, the deeper the penetration of each of the tips and the larger the formed asperities. Generally, the polishing rate of the wafer is dependent on the number and size of the asperities. Denser, smaller asperities can polish as fast as fewer, larger asperites. But the former is more uniform with no excessive force that may cause non-uniformity, scratching, erosion or dishing of the delicate wafer, etc. This can be particularly true with copper smaller than 90 nm and with low-k dielectric having greater than 20% pores.

The individual polycrystalline cutting elements can be formed in a variety of manners and from a variety of materials, as would occur to one having ordinary skill in the relevant art. In one aspect of the invention, the cutting elements are sintered polycrystalline diamond cubes with silicon/SiC as the matrix. Each of the cubes can contain about 90 V% of diamond (about 10 microns in grain size) and the remaining phase can be either silicon or SiC. A very small amount of titanium can be used facilitate the sintering process. The cubes can be pressed in a graphite mold and formed in a size of about 1 mm on each side. While the cubic examples provided above have proven particularly efficacious, it is to be understood that a variety of sizes and configurations of polycrystalline materials can be utilized in the present invention.

By forming the cutting elements from individual units of superhard polycrystalline material, in defined geometric shapes, arrangement of the cutting elements in a very precise manner becomes much easier. As the defined geometric shapes can be replicated fairly precisely from one cutting element to another, the positioning of, and accordingly, the stress impinged upon, each cutting element can be accomplished fairly consistently across the face off the cutting device in question. With prior art abrasive grits, for example, the overall shape and size of each a plurality of grits might change considerably from one grit to another, making precise placement of the grits difficult to accomplish.

The material utilized in the organic material layer 14 can vary widely. Numerous organic materials are known to those skilled in the art which would be useful when utilized in embodiments of the present invention, and are considered to be included herein. The organic material layer can be any curable resin material, resin, or other

polymer with sufficient strength to retain the individual polycrystalline cutting elements of the present invention. It may be beneficial to use an organic material layer that is relatively hard, and maintains a flat surface with little or no warping. This allows the abrading tool to incorporate very small individual polycrystalline cutting elements at least partially therein, and to maintain these small cutting elements at relatively level and consistent heights.

Additionally, various organic materials may act to absorb mechanical forces impinging on the cutting elements disposed therein, and thus spread and equalize such forces across the abrading tool.

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

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

Organic materials that may be useful in embodiments of the present invention include, but are not limited to: amino resins including alkylated urea-formaldehyde resins, melamine-formaldehyde resins, and alkylated benzoguanamine-formaldehyde resins; acrylate resins including vinyl acrylates, acrylated epoxies, acrylated urethanes, acrylated polyesters, acrylated acrylics, acrylated polyethers, vinyl ethers, acrylated oils, acrylated silicons, and associated methacrylates; alkyd resins such as urethane alkyd resins; polyester resins; polyamide resins; polyimide resins; reactive urethane resins; polyurethane resins; phenolic resins such as resole and novolac resins; phenolic/latex resins; epoxy resins such as bisphenol epoxy resins; isocyanate resins; isocyanurate resins; polysiloxane resins including alkylalkoxysilane resins; reactive vinyl resins; resins

marketed under the Bakelite trade name, including polyethylene resins, polypropylene resins, epoxy resins, phenolic resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, ethylene copolymer resins, acrylonitrile-butadiene-styrene (ABS) resins, acrylic resins, and vinyl resins; acrylic resins; polycarbonate resins; and mixtures and combinations thereof. In one aspect of the present invention, the organic material may be an epoxy resin. In another aspect, the organic material may be a polyimide resin. In yet another aspect, the organic material may be a polyurethane resin. In yet another aspect, the organic material may be a polyurethane resin.

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

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of each superabrasive particle to facilitate the retention of the superabrasive particles in the organic material matrix via chemical bonding. A wide variety of organic and organometallic compounds are known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive particles and the organic material matrix, thus increasing the retention of the particles therein. In this way, the organometallic coupling agent acts as a bridge to form bonds between the organic material matrix and the surface of the superabrasive particles. In one aspect of the present invention, the organometallic coupling agent can be a titanate, zirconate, silane, or mixture thereof.

Specific non-limiting examples of silanes suitable for use in the present invention include: 3- glycidoxypropyltrimethoxy silane (available from Dow Corning as Z-6040); γ-methacryloxy propyltrimethoxy silane (available from Union Carbide Chemicals Company as A-174); β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, γ-

aminopropyltriethoxy silane, N-(β-aminoethyl)-γ-aminopropylmethyldimethoxy silane (available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.); and additional examples of suitable silane coupling agents can be found in U.S. Pat. Nos. 4,795,678, 4,390,647, and 5,038,555, which are each incorporated herein by reference.

Specific non-limiting examples of titanate coupling agents include: isopropyltriisostearoyl titanate, di(cumylphenylate)oxyacetate titanate, 4-aminobenzenesulfonyldodecylbenzenesulfonyl titanate, tetraoctylbis (ditridecylphosphite) titanate, isopropyltri(N-ethylamino-ethylamino) titanate (available from Kenrich Petrochemicals. Inc.), neoalkyoxy titanates such as LICA-01, LICA-09, LICA-28, LICA-44 and LICA-97 (also available from Kenrich), and the like.

Specific non-limiting examples of aluminum coupling agents include acetoalkoxy aluminum diisopropylate (available from Ajinomoto K.K.), and the like.

Specific non-limiting examples of zirconate coupling agents include: neoalkoxy zirconates, LZ-01, LZ-09, LZ- 12, LZ-38, LZ-44, LZ-97 (all available from Kenrich Petrochemicals, Inc.), and the like. Other known organometallic coupling agents, e.g., thiolate based compounds, can be used in the present invention and are considered within the scope of the present invention.

The amount of organometallic coupling agent used depends on the coupling agent and on the surface area of the individual polycrystalline cutting elements. Typically, 0.05% to 10% by weight of the organic material layer is sufficient.

Turning now to FIG. 3A, in one aspect of the invention, the individual polycrystalline cutting elements can be obtained and/or formed from a polycrystalline blank of material. One such blank of material is shown at 30 in FIG. 3A, with the polycrystalline blank being formed in a disk having a diameter of roughly 30 mm and a thickness that can vary from around 0.2 mm to upwards of 2 mm.

The disk 30 can be divided into a series of individual cutting elements in a variety of manners known to those having ordinary skill in the art, including, without limitation, electro-chemical machining, by laser ablation, by plasma etching, by oxidation (to form carbon dioxide or monoxide gas), hydrogenation (to form methane gas), etc. Laser beams with relatively longer wavelengths (e.g. ND:YAG) have been shown to form cutting grooves on PCD effectively (laser beams with relatively short wavelengths (e.g. excimers) may be used to carve out the secondary cutting elements on top of the primary cutting

elements, as shown and discussed in connection with FIG. 3B. While the latter may be slower in cutting speed, it is generally more precise due to the shorter wavelength used. Moreover, the surface damage can be less with more concentrated energy in higher frequencies. This has been found suitable for shaving or planing a silicon wafer in accordance with the present invention.

In one aspect of the invention, the material is removed from the PCD or PcBN compact by electrical discharge machining ("EDM"). In this aspect, the EDM process can utilize one or more electrodes that include diamond. For example, the cathode used in the EDM process can be a boron doped diamond material and the anode used in the EDM process can be the PCD (in this case, the PCD would generally need to be at least partially electrically conductive). As current is applied through the boron doped diamond material, the material of the PCD can be carefully and controllably removed to form various cutting elements from the PCD.

As will be appreciated, the disk 30 is divided into 8 similarly shaped and sized wedges 32. In one embodiment of the invention, the wedges 32 can be attached to a base 12b by way of the solidified organic material layer discussed above. In the embodiment of the invention illustrated in FIG. 3A, the wedges 32 are radially distributed about the face of the cutting device and/or base or substrate. In this manner, the wedges 32 can be arranged so as to each be subject to substantially the same force (and each be substantially as likely to be retained within the organic matrix) when used to abrade or treat a workpiece (not shown). While not so required, in one embodiment of the invention, the PCD blank 30 can be on the order of about 30 mm in diameter, while the base 12b can be on the order of about 100 mm in diameter. Thus, a cutting device with a diameter of around 100 cm can be formed from superhard material taken from a PCD of only about 30 mm.

As shown in FIG. 4, in one aspect of the invention, a longitudinal axis of each of the individual polycrystalline cutting elements (e.g., wedges 32) is aligned along a radius R of the cutting device. In the embodiment shown, the individual polycrystalline cutting elements are distributed on the cutting device in alternating orientations. The manner of arranging the cutting elements across the face of the base or substrate 12b can be varied for particular applications. Due to the consistent shape and size of the individual polycrystalline cutting elements, however, arrangement and attachment of the cutting

elements to the base is made considerably easier. Accordingly, varying the arrangement for particular applications can be more easily and accurately accomplished.

By utilizing a relatively small amount of polycrystalline material (e.g., disk 30), relative to the size of the base 12b which is to be used to treat the workpiece (not shown), the amount polycrystalline material used can be greatly reduced, leading to considerable cost savings. The present inventor has found, however, that cutting devices of the present invention perform equally well, or nearly equally as well, as conventional cutting devices that utilize "full-face" polycrystalline cutting or grinding tools.

As will be appreciated, the blank 30 of FIG. 3A has been divided into 8 equal portions. However, as shown in FIGs. 5 through 12, the disks 30b, 30c and 30d can be divided into twelve equal portions (represented by wedges 32b), sixteen equal portions (represented by wedges 32c), two equal portions (represented by wedges 32d), and so forth. In this manner, the present invention provides additional flexibility for creation and arrangement of the individual polycrystalline cutting elements across the tool. It is contemplated that a variety of other configurations is also possible, including, without limitation, differently sized and shaped individual polycrystalline cutting elements.

Returning to FIG. 3B, in one aspect of the invention, the individual polycrystalline cutting elements 32 can include a series of secondary cutting elements 40 formed on a face of each of the individual polycrystalline cutting elements. The secondary cutting elements can be configured to maintain a sharpness of each of the cutting elements during use of the cutting device. The secondary cutting elements can vary in shape, and can include rectangular-shaped cutting elements, pyramidal-shaped cutting elements, triangular-shaped cutting elements, etc. The secondary cutting elements can also be formed in a truncated pyramidal shape (not shown). By utilizing secondary cutting elements on the primary cutting elements, the total cutting edge length of the cutting element can be extended by as much as 10,000 times.

In accordance with another aspect, the present invention provides a method of forming a cutting device, comprising: obtaining a substrate; arranging on the substrate a plurality of individual polycrystalline cutting elements, each of the plurality of individual polycrystalline cutting elements having a matching geometric configuration; and securing each of the plurality of individual polycrystalline cutting elements to the substrate with a solidified organic material layer.

The method can further comprise aligning at least one cutting tip of each of the plurality of individual polycrystalline cutting elements in a common plane.

Examples

The following examples present various methods for making the cutting tools of the present invention. Such examples are illustrative only, and no limitation on present invention is meant thereby.

Example 1:

Individual sintered polycrystalline diamond cubes with silicon/SiC as the matrix were used as the cutting elements for forming a CMP pad conditioner. Each of the cubes contains about 90 V% of diamond (about 10 microns in grain size) and the remaining phase is either silicon or SiC. A very small amount of titanium is also present to facilitate the sintering process. The cubes were pressed in a graphite mold and were formed in a size of about 1 mm on each side.

An epoxy mold was provided with cavities configured to receive one apex of the PCD cubes. A parting layer was spread on top of the mold. Subsequently, another epoxy is cast on the top in vacuum. After curing, the mold is removed, exposing the apex of each cube. The apexes become the cutting tip of a pad conditioner.

Example 2

A disk of sintered polycrystalline diamond with silicon/SiC as the matrix is divided into a series of wedges of substantially the same volume. The wedges are used as the cutting elements for forming a CMP pad conditioner. Each of the wedges contains about 90 V% of diamond (about 10 microns in grain size) and the remaining phase is either silicon or SiC. A very small amount of titanium is also present to facilitate the sintering process.

An epoxy mold was provided with cavities configured to receive each of the PCD wedges. A parting layer was spread on top of the mold. Subsequently, another epoxy is cast on the top in vacuum. After curing, the mold is removed, exposing the face of each wedge. The faces (and edges of the faces) of the wedges become the cutting elements of a pad conditioner.

Example 3

PCD blanks pressed from a cubic press were trimmed from both sides to remove refractary metal container (e.g. Ta). The outside diameter of the blanks were ground off. The PCD blanks were bonded to a cemented WC base and the PCD layer was EDM shaped to form pyramids distributed in a predetermined pattern. The PCD blanks were subsequently divided into a series of wedge-shaped cutting pieces and the cutting pieces were placed on a flat mold with the cutting pieces leveled with the mold.

The mold was placed in a vacuum chamber and epoxy is poured over the top. Finally, a stainless steel plate was placed on the top of the flowing epoxy and pressed toward the PCD until only a thin layer of epoxy remained between the backing of the PCD and the steel substrate. After curing of the epoxy, the PCD cutting tool was cleaned and mounting structure (e.g., holes) was formed on the back of the steel substrate.

The PCT cutting pieces can be arranged on the stainless steel plate in an annular ring pattern, circular plates, squares, etc. These patterns can be optimized to suit a particular CMP application.

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

CLAIMS

What is claimed is:

1. A cutting device, comprising:

a base having a solidified organic material layer disposed thereon; and

a plurality of individual polycrystalline cutting elements secured in the solidified organic material layer, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration.

2. The cutting device of claim 1, wherein each of the plurality of individual polycrystalline cutting elements includes at least one cutting tip, the tips of the cutting elements being aligned in a common plane.

3. The cutting device of claim 1, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

4. The cutting device of claim 3, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

5. The cutting device of claim 4, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

6. The cutting device of claim 4, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

7. The cutting device of claim 4, wherein the individual polycrystalline cutting elements are radially distributed about the face of the cutting device.

8. The cutting device of claim 7, wherein a longitudinal axis of each of the individual polycrystalline cutting elements is aligned along a radius of the cutting device.

9. The cutting device of claim 8, wherein the individual polycrystalline cutting elements are distributed on the cutting device in alternating orientations.

10. The cutting device of claim 1, further comprising a series of secondary cutting elements formed on a face of each of the individual polycrystalline cutting elements, the secondary cutting elements being configured to maintain a sharpness of each of the cutting elements during use of the cutting device.

11. A cutting device, comprising:

a plurality of individual polycrystalline cutting elements secured in a solidified organic material layer, each of the plurality of individual polycrystalline cutting elements including at least one cutting tip, the tips of the cutting elements being aligned in a common plane.

12. The cutting device of claim 11, wherein arrangement of the individual polycrystalline cutting elements uniformly distributes drag forces across substantially each individual polycrystalline cutting element.

13. The cutting device of claim 11, wherein a majority of each of the individual polycrystalline cutting elements protrudes to a predetermined height above the solidified organic material layer.

14. The cutting device of claim 13, wherein the predetermined height produces a cutting depth of less than about 20 microns when used to abrade a workpiece.

15. The cutting device of claim 11, wherein each of the plurality of individual polycrystalline cutting elements has a substantially matching geometric configuration.

16. The cutting device of claim 11, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

17. The cutting device of claim 16, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

18. The cutting device of claim 17, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

19. The cutting device of claim 17, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

20. The cutting device of claim 17, wherein the individual polycrystalline cutting elements are radially distributed in the organic material layer.

21. The cutting device of claim 11, wherein the individual polycrystalline cutting elements are of substantially the same size and substantially the same shape.

22. The cutting device of claim 11, wherein the individual polycrystalline cutting elements are arranged as a grid.

23. The cutting device of claim 22, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of from about 100 microns to about 800 microns.

24. The cutting device of claim 23, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of about 500 microns.

25. The cutting device of either of claim 1 or claim 11, wherein the solidified organic material layer comprises a member selected from the group consisting of amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone

resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof.

26. The cutting device of claim 25, wherein the solidified organic material layer is an epoxy resin.

27. The cutting device of claim 25, wherein the solidified organic material layer is a polyurethane resin.

28. The cutting device of claim 25, wherein the solidified organic material layer is a polyimide resin.

29. The cutting device of claim 25, further comprising a reinforcing material disposed within at least a portion of the solidified organic material layer.

30. The cutting device of claim 29, wherein the reinforcing material is a material selected from the group consisting of ceramics, metals, or combinations thereof.

31. A method of forming a cutting device, comprising:

obtaining a substrate;

arranging on the substrate a plurality of individual polycrystalline cutting elements, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration; and

securing each of the plurality of individual polycrystalline cutting elements to the substrate with a solidified organic material layer.

32. The method of claim 31, further comprising aligning at least one cutting tip of each of the plurality of individual polycrystalline cutting elements in a common plane.

33. The method of claim 31, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

34. The method of claim 33, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

35. The method of claim 34, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

36. The method of claim 34, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

37. The method of claim 34, wherein the individual polycrystalline cutting elements are radially distributed about the substrate.

38. The method of claim 31, wherein the individual polycrystalline cutting elements are of substantially the same size and substantially the same shape.

39. The method of claim 31, wherein the individual polycrystalline cutting elements are arranged as a grid.

40. The method of claim 39, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of from about 100 microns to about 800 microns.

41. The cutting device of either of claim 1 or claim 11, wherein the polycrystalline cutting elements comprise superhard polycrystalline cutting elements.

42. The cutting device of claim 41, wherein the superhard polycrystalline cutting elements comprise superhard polycrystalline particles.

43. The method of claim 31, where the polycrystalline cutting elements comprise superhard polycrystalline cutting elements.

44. The method of claim 43, wherein the superhard polycrystalline cutting elements comprise superhard polycrystalline particles.

45. The method of claim 43, wherein the superhard polycrystalline cutting elements are selected from the group consisting of: polycrystalline diamond and polycrystalline cubic boron nitride.

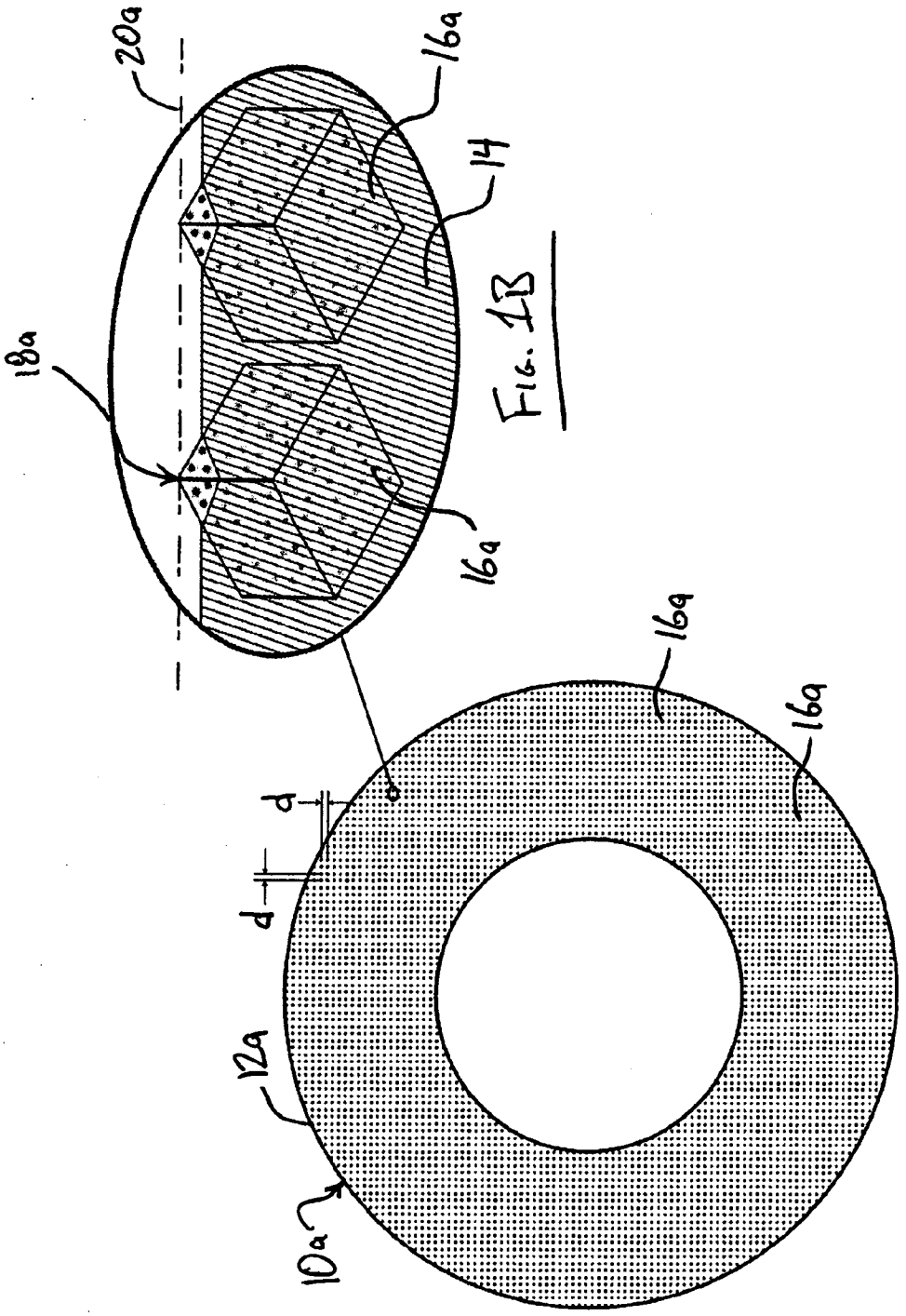


FIG. 1B

FIG. 1A

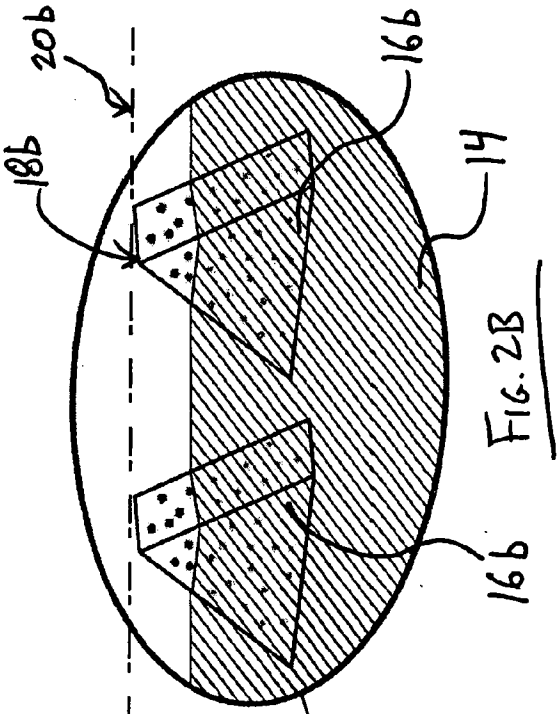


FIG. 2B

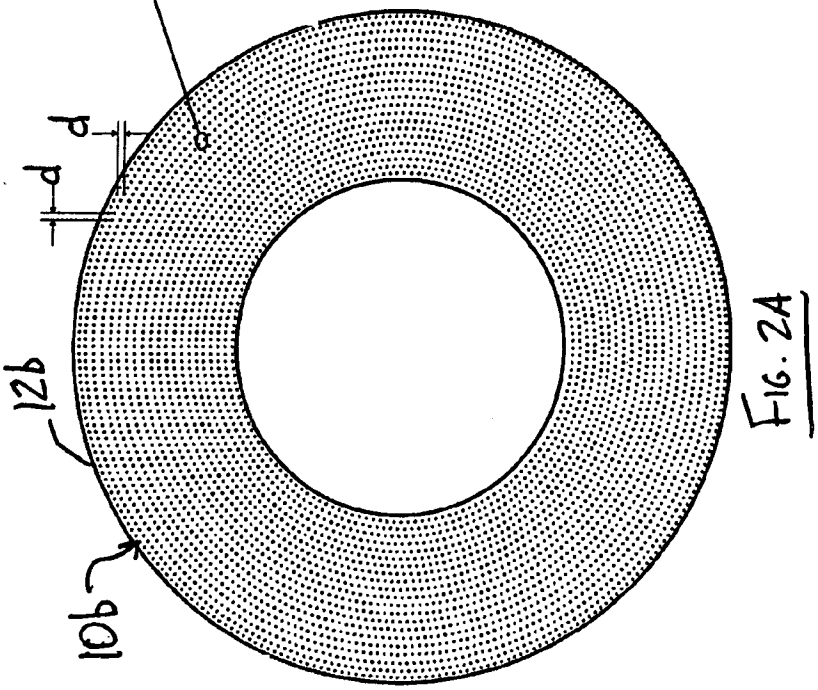


FIG. 2A

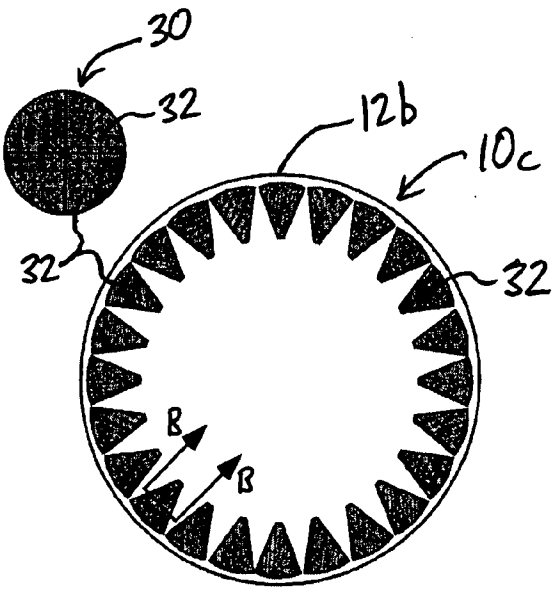


FIG. 3A

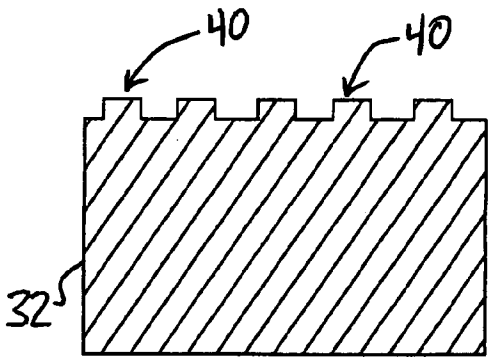


FIG. 3B

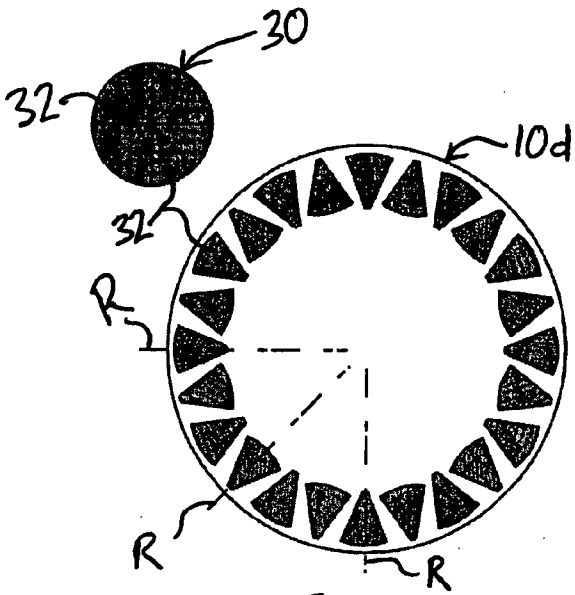


FIG. 4

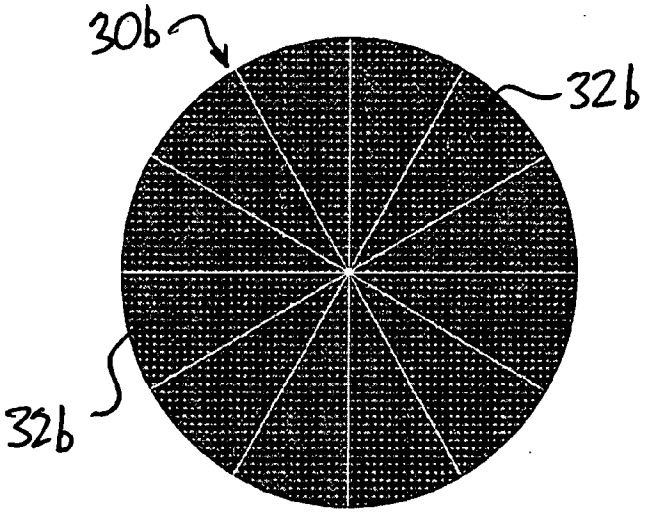


FIG. 5

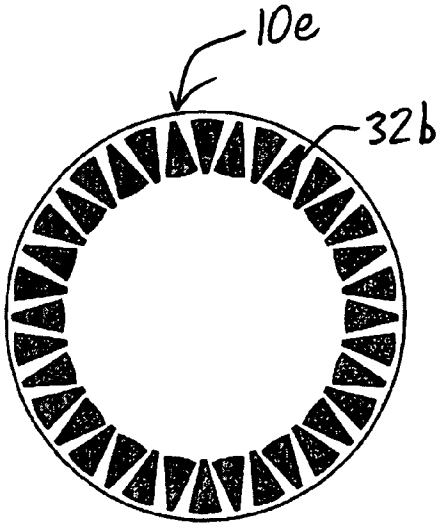


FIG. 6

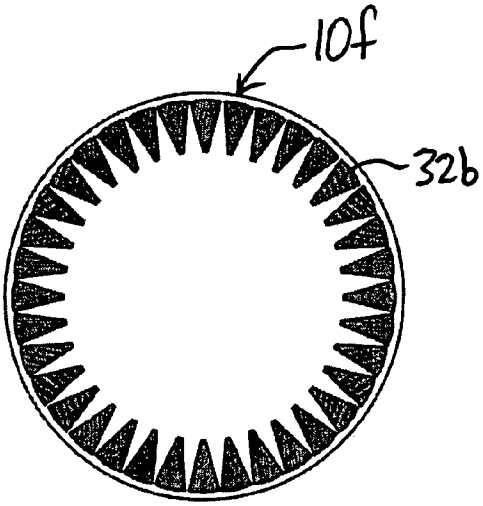


FIG. 7

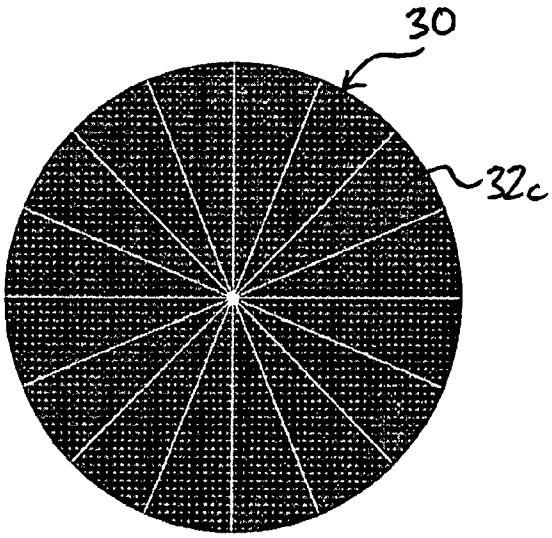


FIG. 8

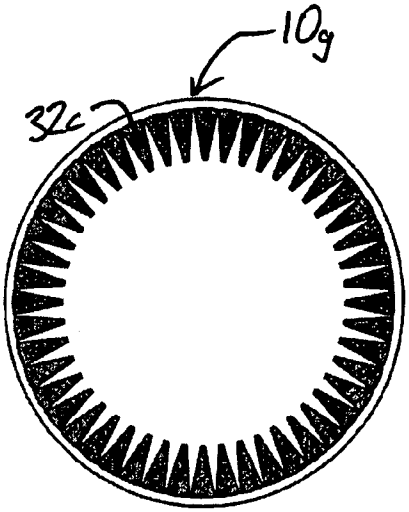


FIG. 9

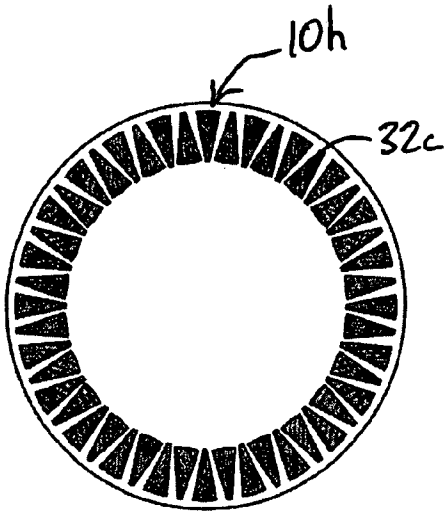


FIG. 10

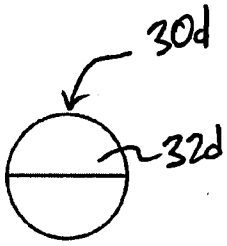


FIG. 11

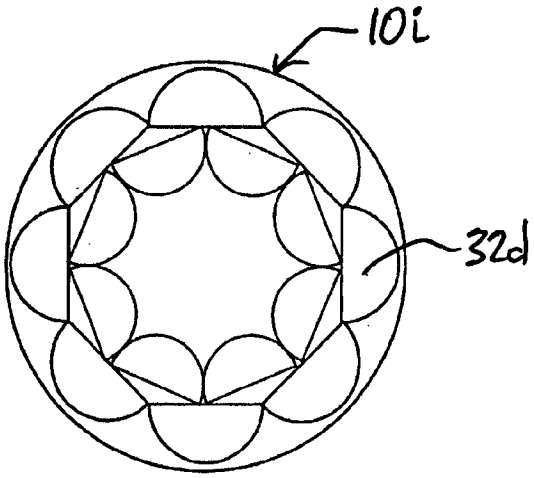


FIG. 12

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Publication Title:

CMP PAD CONDITIONERS WITH MOSAIC ABRASIVE SEGMENTS AND ASSOCIATED METHODS

Abstract:

Abstract of WO 2009043058

(A2) A CMP pad conditioner comprises a plurality of abrasive segments. Each abrasive segment includes a segment blank and an abrasive layer attached to the segment blank, the abrasive layer including a superhard abrasive material, A pad conditioner substrate is also provided. Each of the plurality of abrasive segments is permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

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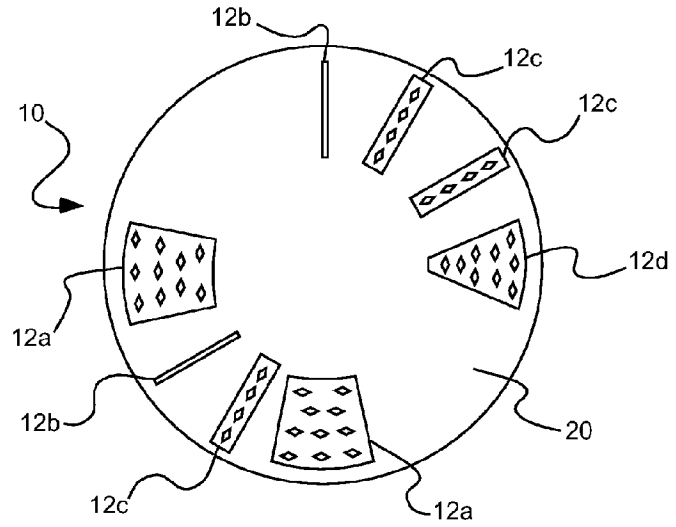


FIG. 1

(57) Abstract: A CMP pad conditioner comprises a plurality of abrasive segments. Each abrasive segment includes a segment blank and an abrasive layer attached to the segment blank, the abrasive layer including a superhard abrasive material, A pad conditioner substrate is also provided. Each of the plurality of abrasive segments is permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

WO 2009/043058 A2

CMP PAD CONDITIONERS WITH MOSAIC ABRASIVE SEGMENTS AND ASSOCIATED METHODS

PRIORITY CLAIM:

This application claims the benefit of U.S. Provisional Patent Application Serial No. 60/976,198, filed September 28, 2007 and U.S. Non-Provisional Patent Application Serial No. 12/168,110, filed July 5, 2008, each of which are hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to CMP pad conditioners used to remove material from (e.g., smooth, polish, dress, etc.) CMP pads. Accordingly, the present invention involves the fields of chemistry, physics, and materials science.

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

In accordance with one embodiment, the present invention provides a CMP pad conditioner, including a plurality of abrasive segments. Each abrasive segment can include a segment blank and an abrasive layer attached to the segment blank. The abrasive layer can include a superhard abrasive material. A pad conditioner substrate is also provided and each of the plurality of abrasive segments can be permanently affixed to the pad conditioner substrate in an orientation that enables removal of

material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

In accordance with another aspect of the invention, a CMP pad conditioner is provided, including a plurality of abrasive segments. Each abrasive segment can include a segment blank, an organic adhesive layer, and an abrasive layer attached to the segment blank by the organic adhesive layer. The abrasive layer can include a superhard abrasive material. A pad conditioner substrate is also provided, with each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

In accordance with another aspect of the invention, a CMP pad conditioner is provided, including a plurality of abrasive segments. Each abrasive segment can include a segment blank and an abrasive layer attached to the segment blank by a brazing alloy. The abrasive layer can include a superhard abrasive material. A pad conditioner substrate is also provided, with each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

In accordance with another aspect of the invention, a CMP pad conditioner is provided, including a plurality of abrasive segments. Each abrasive segment can include a segment blank and an abrasive layer attached to the segment blank. The abrasive layer can include a superhard abrasive blade. A pad conditioner substrate is also provided, with each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

In accordance with another aspect of the invention, a CMP pad conditioner is provided, including a plurality of abrasive segments. Each abrasive segment can include a segment blank and an abrasive layer attached to the segment blank. The abrasive layer can include a cutting face angled at 90 degrees or less relative to a

finished surface to be applied to the CMP pad. A pad conditioner substrate is also provided, with each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

In accordance with another aspect of the invention, a method of forming a CMP pad conditioner is provided, including: obtaining at least one abrasive segment, the abrasive segment including: a segment blank; and an abrasive layer attached to the segment blank, the abrasive layer including a superhard abrasive material. The method can include positioning the at least one abrasive segment on a face of a pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another; and permanently affixing the at least one abrasive segment to the pad conditioner substrate.

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 any accompanying or following claims, or may be learned by the practice of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic, top plan view of an exemplary pad conditioner in accordance with an embodiment of the invention;

FIG. 1A is an enlarged, perspective schematic view of an exemplary abrasive segment that can be used in the pad conditioner of FIG. 1;

FIG. 1B is an end, schematic view of the abrasive segment of FIG. 1A, shown with one exemplary abrasive profile;

FIG. 1C is an end, schematic view of the abrasive segment of FIG. 1A, shown with another exemplary abrasive profile;

FIG. 2 is a schematic, top plan view of another pad conditioner in accordance with an embodiment of the invention;

FIG. 2A is an enlarged, perspective schematic view of an abrasive segment of the pad conditioner of FIG. 2;

FIG. 3A is a side, schematic view of an abrasive segment having a cutting face shown removing material from a section of a CMP pad;

FIG. 3B is a side, schematic view of an abrasive segment having a differently configured cutting face shown removing material from a section of a CMP pad;

FIG. 3C is a side, schematic view of an abrasive segment having a differently configured cutting face shown removing material from a section of a CMP pad;

FIG. 4A is a schematic, perspective view of an abrasive segment formed in a blade configuration in accordance with an embodiment of the invention;

FIG. 4B is a schematic, perspective view of another abrasive segment formed in a blade configuration in accordance with an embodiment of the invention; and

FIG. 5 is a schematic, side view of a portion of a CMP pad dresser having a series of abrasive segments arranged at varying elevations relative to one another.

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. For example, an abrasive layer is illustrated in some of the figures as including a plurality of abrasive particles: however, many of the specific embodiments disclosed herein do not necessarily include abrasive particles. Therefore, it will be appreciated that departure can and likely will be made from the specific dimensions and aspects shown in the figures in order to produce the pad conditioners 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 any appended or following claims, the singular forms "a," "an" and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "an abrasive segment" can include one or more of such segments.

Definitions

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

All mesh sizes that may be referred to herein are U.S. mesh sizes 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 term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. As an arbitrary example, when two or more objects are referred to as being spaced a "substantially" constant distance from one another, it is understood that the two or more objects are spaced a completely unchanging distance from one another, or so nearly an unchanging distance from one another that a typical person would be unable to appreciate the difference. The exact allowable degree of deviation from absolute completeness may in some cases depend upon 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. As an arbitrary example, a cavity that is "substantially free of" foreign matter would either completely lack any foreign matter, or so nearly completely lack foreign matter that the effect would be the same as if it completely lacked foreign matter. In other words, a cavity that is "substantially free of" foreign matter may still actually contain minute portions of

foreign matter so long as there is no measurable effect upon the cavity as a result thereof.

As used herein, a pad conditioner "substrate" means a portion of a pad conditioner that supports abrasive materials, and to which abrasive materials and/or segment blanks that carry abrasive materials may be affixed. Substrates useful in the present invention may of a variety of shapes, thicknesses, or materials that are capable of supporting abrasive materials in a manner that is sufficient to provide a pad conditioner useful for its intended purpose. Substrates may be of a solid material, a powdered material that becomes solid when processed, or a flexible material. Examples of typical substrate materials include without limitation, metals, metal alloys, ceramics, relatively hard polymers or other organic materials, glasses, and mixtures thereof. Further, the substrate may include a material that aids in attaching abrasive materials to the substrate, including, without limitation, brazing alloy material, sintering aids and the like.

As used herein, "segment blank" refers to a structure similar in many respects to the pad conditioner substrates defined above. Segment blanks are utilized in the present invention to carry abrasive layers: attachment of the abrasive layers to the pad conditioner substrates is typically achieved by way of attaching the segment blanks to the pad conditioner substrates. It is important to note that a variety of manners of attaching the segment blanks to the substrates, and a variety of manners of attaching the abrasive layers to the segment blanks, are discussed herein. It is to be understood that all of these various attachment mechanisms can be used interchangeably herein: that is, if a method of attaching a segment blank to a substrate is discussed herein, the method of attachment discussed can also be used to attach an abrasive layer to a segment blank. For any particular CMP pad dresser being discussed, however, it is understood that attachment methods of the abrasive layers to the segment blanks can differ from, or can be the same as, the method used to attach the segment blanks to the pad conditioner substrate.

As used herein, "geometric configuration" refers to a shape that is capable of being described in readily understood and recognized mathematical terms. Examples of shapes qualifying as "geometric configurations" include, without limitation, cubic

shapes, polyhedral (including regular polyhedral) shapes, triangular shapes (including equilateral triangles, isosceles triangles and three-dimensional triangular shapes), pyramidal shapes, spheres, rectangles, "pie" shapes, wedge shapes, octagonal shapes, circles, etc.

As used herein, "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, "abrasive profile" is to be understood to refer to a shape, configuration, or a space defined by abrasive materials that can be used to remove material from a CMP pad. Examples of abrasive profiles include, without limitation, rectangular shapes, tapering rectangular shapes, truncated wedge shapes, wedge shapes, a "saw tooth" profile and the like. In some embodiments, the abrasive profile exhibited by abrasive segments of the present invention will apparent when viewed through a plane in which the CMP pad will be oriented during removal of material from the CMP pad.

As used herein, an "abrading surface or point" may be used to refer to a surface, edge, face, point or peak of an abrasive segment that contacts and removes material from a CMP pad. Generally speaking, the abrading surface or point is the portion of the abrasive segment that first contacts the CMP pad as the abrasive segment and the CMP pad are brought into contact with one another.

As used herein, "superhard" may be used to refer to any crystalline, or polycrystalline material, or mixture of such materials which has a Mohr's hardness of about 8 or greater. In some aspects, the Mohr's hardness may be about 9.5 or greater. Such materials include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), polycrystalline cubic boron nitride (PcBN), corundum and sapphire, as well as other superhard materials known to those skilled in

the art. Superhard materials may be incorporated into the present invention in a variety of forms including particles, grits, films, layers, pieces, segments, etc. In some cases, the superhard materials of the present invention are in the form of polycrystalline superhard materials, such as PCD and PcBN materials.

As used herein, "organic material" refers to a semisolid or solid complex or 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, including resins, polymers, gums, etc. Preferably the organic material will be a polymer or copolymer formed from the polymerization of one or more monomers. In some cases, such organic material may be adhesive.

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

As used herein, "particle" and "grit" may be used interchangeably.

As used herein, an "abrasive layer" describes a variety of structures capable of removing (e.g., cutting, polishing, scraping) material from a CMP pad. An abrasive layer can include a mass having several cutting points, ridges or mesas formed thereon or therein. It is notable that such cutting points, ridges or mesas may be from a multiplicity of protrusions or asperities included in the mass. Furthermore, an abrasive layer can include a plurality of individual abrasive particles that may have only one cutting point, ridge or mesa formed thereon or therein. An abrasive layer can also include composite masses, such as PCD pieces, segment or blanks, either individually comprising the abrasive layer or collectively comprising the abrasive layer.

As used herein, "metallic" includes 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, 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 generally provides pad conditioners and associated methods that can be utilized in conditioning (e.g., smoothing, polishing, dressing) or otherwise affecting a CMP pad to remove material from the CMP pad in order to provide a finished, smooth and/or flat surface to the pad. Pad conditioners of the

present invention can be advantageously utilized, for example, in dressing CMP pads that are used in polishing, finishing or otherwise affecting silicon wafers.

In the embodiment of the invention illustrated in FIG. 1, a CMP pad conditioner 10 is provided. The pad conditioner can include at least one abrasive segment 12a, 12b, 12c and 12d (sometimes the varied and numerous abrasive segments discussed herein are collectively referred to as "12x"). As best appreciated from the example shown in FIG. 1A, each abrasive segment 12 can include a segment blank 14 and an abrasive layer 16 attached to the segment blank. The abrasive layer 16 can include a superhard abrasive material: in the exemplary embodiment of FIG. 1A, the superhard abrasive material includes a plurality of superhard particles 18. A pad conditioner substrate 20 (FIG. 1) can also be provided. The pad conditioner substrate can vary according to the applications for which the pad conditioner is designed, but generally includes a face on which the abrasive segments can be affixed to allow the pad conditioner to be used to grind, plane, cut or otherwise remove material from a CMP pad (not shown).

The at least one abrasive segment 12x can be permanently fixed to the pad conditioner 20 in an orientation that enables removal of material from the CMP pad by the abrasive layer as the pad conditioner and the pad are moved relative to one another. For example, in the embodiment shown in FIG. 1, the abrasive segments 12x are arranged radially along an edge of a substantially circular pad conditioner substrate. Such an arrangement has been found well suited to remove material from a CMP pad (while "dressing" the pad) by rotating the pad conditioner substrate relative to the pad.

The present invention provides a number of advantages over conventional devices. One such advantage lies in the ability to customize methods of attachment of the abrasive layer 16 to the segment blank 14 independently of methods of attachment of the segment blank or blanks to the pad conditioner substrate. For example, as various attachment methods may involve very high temperatures and/or pressures, very demanding environmental conditions, or simply are very labor intensive when attempted with pad conditioners of large or complex surface areas, performing the attachment method on distinct, easily handled segment blanks can improve costs,

efficiencies and integrities of the attachment process. Also, leveling of the components of the abrasive layer on each segment blank can be performed more easily when done in discrete, relatively small lots. The resulting plurality of abrasive segments can likewise be more easily positioned, leveled, spaced, oriented, etc., across the face of the pad conditioner substrate 20 after the abrasive layer is individually attached to each of the abrasive segments.

In addition, by obtaining a plurality of abrasive segments 12x, each with an abrasive layer 16 already attached thereto, an abrasive pattern across the face of the pad conditioner substrate 20 can be designed to optimize various conditioning procedures. For example, the spacing between adjacent abrasive segments can be carefully selected to aid in, or better control, the flow of various fluids (e.g., slurry) around and through the abrasive segments to increase the efficacy and efficiency of the material removing process. Also, as shown in FIG. 1, segment blanks having differing abrasive profiles (e.g., different sizes, shapes, abrasive aggressiveness, etc.) can be used on a single substrate, to enable customization of an abrading profile of the pad conditioner as a whole.

As will be discussed in further detail below, not only can the abrasive profile of each abrasive segment be customized, the type of, or composition of, the abrasive segment can vary from one segment 12x to another. For example, segment 12c may include a plurality of individual abrasive grits 18 attached to the segment blank 14 via an organic adhesive material layer 16. Segment 12a can include a substantially continuous piece of PCD compact attached to a segment blank via a differing attachment mechanism. Also, relative height or elevation of abrasive segments can be varied on any particular pad dresser. For example, the abrasive segment 12a of FIG. 1 can be elevated slightly higher than or lower than abrasive segment 12c of FIG. 1.

The various segment blanks 14 shown and discussed herein can be formed from a variety of materials, including, without limitation, metallic materials such as aluminum, copper, steel, metal alloys, etc., ceramic materials, glasses, polymers, composite materials, etc. Generally speaking, virtually any material to which an abrasive segment 12x can be attached will suffice.

In some embodiments, the material of the segment blank can be chosen to provide superior results during the process of attaching the abrasive layer thereto. As discussed above, the abrasive layer can be attached to the segment blank in a variety of manners, including epoxy bonding methods (e.g., organic bonding methods), metal brazing, sintering, electrodeposition, etc. The material of the segment blank can be chosen based upon the attachment process anticipated. For example, a segment blank formed partially or fully from nickel, or stainless steel, can be utilized in some processes involving brazing and/or sintering. Also, ceramic or metallic materials might be utilized in organic attachment methods.

Various embodiments of the invention employ various methods of attachment of the abrasive layer 16 to the segment blank 14. In one embodiment, an organic material layer can be deposited on the segment blank, and one or more abrasive particles, chips, segments, etc., can be fixed to the segment blank by way of the organic material layer. Examples of suitable organic 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.

So-called "reverse casting" methods can be used to accurately and controllably orient and attach the abrasive material on the segment blank (and to orient and attach the segment blanks to the pad conditioner substrate). Such methods can include initially securing a superabrasive material, e.g., a plurality of superabrasive grits, to a substrate using a "mask" material. The portions of the particles protruding from the mask material can then be attached to a pad conditioner substrate using the methods discussed herein, after which (or during which), the masking material can be removed. It has been found that these reverse casting techniques can increase the amount of abrasive particles (or other abrasive contact points) to as much as 10% and more of the total amount of abrasive particles or contact points.

Suitable reverse casting methods can be found in various patents and patent

applications to the present inventor, including U.S. Patent Application Serial No. 60/992,966, filed December 6, 2007; U.S. Patent Application Serial No. 11/804,221, filed May 16, 2007; and U.S. Patent Application Serial No. 11/805,549,filed May 22, 2007, each of which is hereby incorporated herein by reference. These techniques can be used when attaching the abrasive segments of the present invention to pad conditioner substrate: and when attaching the abrasive layers of the present invention to the segment blanks. Such techniques allow very precise control of lateral placement of the abrasive segments or abrasive layers, as well as very precise control of relative elevation of the abrasive segments or abrasive layers.

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

In one aspect of the present invention, the organic material 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 can be essentially irreversible, if desired.

Organic materials that may be useful in embodiments of the present invention include, but are not limited to: amino resins including alkylated urea-formaldehyde resins, melamine-formaldehyde resins, and alkylated benzoguanamine-formaldehyde resins; acrylate resins including vinyl acrylates, acrylated epoxies, acrylated urethanes, acrylated polyesters, acrylated acrylics, acrylated polyethers, vinyl ethers, acrylated oils, acrylated silicons, and associated methacrylates; alkyd resins such as urethane alkyd resins; polyester resins; polyamide resins; polyimide resins; reactive urethane resins; polyurethane resins; phenolic resins such as resole and novolac resins;

phenolic/latex resins; epoxy resins such as bisphenol epoxy resins; isocyanate resins; isocyanurate resins; polysiloxane resins including alkylalkoxysilane resins; reactive vinyl resins; resins marketed under the Bakelite™ trade name, including polyethylene resins, polypropylene resins, epoxy resins, phenolic resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, ethylene copolymer resins, acrylonitrile-butadiene-styrene (ABS) resins, acrylic resins, and vinyl resins; acrylic resins; polycarbonate resins; and mixtures and combinations thereof. In one aspect of the present invention, the organic material may be an epoxy resin. In another aspect, the organic material may be a polyimide resin. In yet another aspect, the organic material may be a polyurethane resin. In yet another aspect, the organic material may be a polyurethane resin.

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

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of each superabrasive material to facilitate the retention of the superabrasive material in the organic material via chemical bonding. A wide variety of organic and organometallic compounds is known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive materials and the organic material matrix, thus increasing the retention of the superabrasive materials therein. In this way, the organometallic coupling agent can serve as a bridge to form bonds between the organic material matrix and the surface of the superabrasive material. In one aspect of the present invention, the organometallic coupling agent can be a titanate, zirconate,

silane, or mixture thereof.

Specific non-limiting examples of silanes suitable for use in the present invention include: 3- glycidoxypropyltrimethoxy silane (available from Dow Corning as Z-6040); γ-methacryloxy propyltrimethoxy silane (available from Union Carbide Chemicals Company as A-174); β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, γ-aminopropyltriethoxy silane, N-(β-aminoethyl)-γ-aminopropylmethyldimethoxy silane (available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.).

Specific non-limiting examples of titanate coupling agents include: isopropyltriisostearoyl titanate, di(cumylphenylate)oxyacetate titanate, 4-aminobenzenesulfonyldodecylbenzenesulfonyl titanate, tetraoctylbis (ditridecylphosphite) titanate, isopropyltri(N-ethylamino-ethylamino) titanate (available from Kenrich Petrochemicals. Inc.), neoalkyoxy titanates such as LICA-01, LICA-09, LICA-28, LICA-44 and LICA-97 (also available from Kenrich), and the like.

Specific non-limiting examples of aluminum coupling agents include acetoalkoxy aluminum diisopropylate (available from Ajinomoto K.K.), and the like.

Specific non-limiting examples of zirconate coupling agents include: neoalkoxy zirconates, LZ-01, LZ-09, LZ- 12, LZ-38, LZ-44, LZ-97 (all available from Kenrich Petrochemicals, Inc.), and the like. Other known organometallic coupling agents, e.g., thiolate based compounds, can be used in the present invention and are considered within the scope of the present invention.

The amount of organometallic coupling agent used can depend upon the coupling agent and on the surface area of the superabrasive material. Oftentimes, 0.05% to 10% by weight of the organic material layer can be sufficient.

Metal brazing can also be utilized to attach the abrasive layer 16 to the segment blank 14. Metal brazing techniques are known in the art. For example, in fabricating a diamond saw blade, the process can include mixing diamond particles (e.g., 40/50 U.S. mesh saw grit) with a suitable metal support matrix (bond) powder (e.g., cobalt powder of 1.5 micrometer in size). The mixture is then compressed in a mold to form the right shape (e.g., a saw segment). This "green" form of the tool can then be consolidated by sintering at a temperature between 700-1200 degrees C to

form a single body with a plurality of abrasive particles disposed therein. Finally, the consolidated body can be attached (e.g., by brazing) to a tool body; such as the round blade of a saw, to form the final product. Many other exemplary uses of this technology are known to those having ordinary skill in the art.

Various sintering methods can also be utilized to attach the abrasive layer 16 to the segment blank 14. Suitable sintering methods will be easily appreciated by one of ordinary skill in the art having possession of this disclosure.

The abrasive layer 16 can also be attached to the segment blank 14 by way of known electroplating and/or electrodeposition processes. As an example (not shown in the figures) of a suitable method for positioning and retaining abrasive materials prior to and during the electrodeposition process, a mold can be used that includes an insulating material that can effectively prevent the accumulation of electrodeposited material on the molding surface. Abrasive particles can be held on the molding surface of the mold during electrodeposition. As such, the accumulation of electrodeposited material can be prevented from occurring on the particle tips and the working surface of the pad conditioner substrate. Such techniques are described in U.S. Patent Application Serial No. 11/292,938, filed December 2, 2005, which is hereby incorporated herein by reference.

One or more apertures can extend through the insulating material to allow for circulation of an electrolytic fluid from an area outside the mold through the mold and to the surface of the pad conditioner substrate in order to effect electrodeposition of the material used to secure the abrasive particles to the pad conditioner substrate. Such circulation can be advantageous as it is generally necessary to keep a sufficient concentration of the ions (not shown) in an electrolytic fluid at the location of electrodeposition. Other well known techniques can also be utilized, it being understood that the above-provided example is only one of many suitable techniques.

The segment blank can similarly be attached to the pad conditioner substrate in a variety of manners. Depending upon the material from which the segment blank is formed, various manners of fixing the segment blank to the pad conditioner substrate may be utilizing. Suitable attachment methods include, without limitation, organic binding, brazing, welding, etc.

The geometric configuration of the abrasive segment 12 can vary. In the embodiment illustrated in FIG. 1A and 1B, the abrasive segment includes a generally rectangular segment blank 14 with a layer 16 of abrasive material (that can include abrasive particles 18) attached to an upper portion thereof. The size of the segment blank can vary. In one aspect of the invention, segment size can be adjusted to achieve uniform distribution of diamond grits about an annular ring array. Each segment can contain up to about a thousand diamond grits with pitch set from 3X to 10X of the diamond size. Smaller segments can be better distributed to share the loading during dressings.

As will be appreciated, in the embodiment of FIG. 1B, the layer 16 of abrasive material extends partially onto (or "down") side edges of the segment blank 14. In the embodiment of FIG. 1C, the abrasive layer extends onto (or down) the side edges to a much lesser degree. The modular nature of the present systems allows a great deal of flexibility in attaching the abrasive layer 16 to the segment blanks 14. As the segment blanks can be prepared separately from the pad conditioner substrate, a variety of manufacturing advantages can be realized when applying the abrasive layer to the segment blank, without regard to the size, shape, mass, material, etc., of the pad conditioner substrate to which the segment blanks will eventually be attached.

While not so required, in one aspect of the invention, the plurality of abrasive segments can each include a substantially matching geometric configuration. In the embodiment illustrated in FIG. 2, each of the plurality of abrasive segments 12e presents a substantially wedge-shaped superabrasive profile (that can be truncated, if so desired). The abrasive layer 16e can be attached to segment blank 14e in a variety of manners, much the same as discussed above.

The plurality of abrasive segments 12x can be radially distributed about a face of the pad conditioner substrate 20, and can include a substantially uniform spacing between each segment. Also, a longitudinal axis of each of the plurality of abrasive segments can be aligned along a radius of the pad conditioner substrate. The abrasive segments 12e of the embodiment shown in FIGs. 2 and 2A can be arranged across the face of the pad conditioner substrate 20 in alternating or varying alignments: as

shown, the tapering portion of the segments can be aligned toward or away from a center of the pad conditioner substrate in alternating stages.

The abrasive segments arranged about the face of the conditioner substrate can each be substantially the same in size, shape, abrasive composition, height relative to one another, etc. In other embodiments, the size, shape, abrasive composition, height relative to one another, etc., can be purposefully varied, to achieve optimal design flexibility for any particular application. Also, each of the afore-mentioned qualities can be varied from segment to another: e.g., alternating segments can include PCD abrasive pieces, chips or slats, with adjacent segments including abrasive particles.

The retention of abrasive segments 12x on the pad conditioner substrate 20 can be improved by arranging the abrasive segments such that mechanical stress impinging on any individual abrasive segment is minimized. By reducing the stress impinging on each abrasive segment they can be more readily retained in place on the substrate, particularly for delicate tasks. Minimizing of stress variations between segments can be accomplished by spacing the segments evenly (or consistently) from one another, leveling to a uniform height (relative to the face of the pad conditioner substrate) an uppermost portion of each segment, radially aligning the segments about the face of the pad conditioner substrate, etc. Various other height and spacing techniques can be utilized to obtain a desired affect.

In one embodiment of the invention, the spacing of the abrasive segments can be adjusted to alter the contact pressure of the contact portion (e.g., the portion of the segment that engages and removes material from the CMP pad) of each segment. In general, the farther the segments are spaced from one another, the higher the contact pressure between the segment and the CMP pad. Thus, a higher density of abrasive segments across the face of the pad conditioner substrate can, in some cases, provide a more desirable abrasive interface between the pad conditioner substrate and the CMP pad. In other applications, a lower density of abrasive segments may be beneficial. In either case, the present invention provides a great deal of design flexibility to obtain the optimal abrading profile.

By forming the abrasive segments in individual units having defined geometric shapes, arrangement of the abrasive segments in a very precise manner becomes much

easier. As the defined geometric shapes can be replicated fairly precisely from one abrasive segment to another, the positioning of, and accordingly, the stress impinged upon, each abrasive segment can be accomplished fairly consistently across the face of the pad conditioner substrate in question. With prior art abrasive grits, for example, the overall shape and size of each a plurality of grits might change considerably from one grit to another, making precise placement of the grits difficult to accomplish. This problem is adequately addressed by the advantageous features of the present invention.

It has been found that diamond pad conditioners used commercially normally contain about ten thousand diamond grits. Due to the distortion of the substrate, particularly when the disk is manufactured by a high temperature process (e.g. by brazing), and also the distribution of grit sizes and diamond orientations, the cutting tips are located at different heights. When they are pressed against a polishing pad, only about 1% of the protruded diamond can be in engagement with a pad. This can increase the stress on the diamond cutting most deeply into the pad, and the diamond may break and cause catastrophic scratching of the expensive wafers.

By utilizing the present invention, the height difference of between particles can be greatly reduced. In one aspect of the invention, the segments are set on a flat metal (e.g. stainless steel) mold with designed spacing in a retainer ring. Epoxy with hardener fully mixed can be poured into the retainer ring to fill up and cover all segments. The diamond grits on the mold can be shielded by the penetration of the epoxy flow. After curing (with or without heating), the retainer ring and the mold can be removed. The diamond segments are thereby firmly embedded in the epoxy matrix. Due to the leveling of diamond by the flat mold, the tip height variations of the tallest diamond grits are minimized.

The mosaic disk thusly formed can be pressed against the polishing pad with the same fixed load. Resulting tests show that the engagement ratio can be over 50%. In other words, the number of working crystals can be increased many times so that the disk life can be greatly extended. In addition, due to the avoidance of deep cutting, the polishing pad can be used with a much longer life. Also, the dressed grooves can be made much more shallow and less dense. The slurry retention and

abrasive utility are both improved. The CMP's cost of consumable (CoC) and cost of ownership (CoO) are both reduced. The wafer polished is more uniform without scratching so the die yield can be higher.

Turning now to FIGs. 3A-5, a variety of differing embodiments of the invention are illustrated. In FIGs. 3A-3C, an embodiment is shown which aids in addressing issues relating to plastic deformation of a CMP pad (shown by example and in sectioned view at 24). This embodiment reduces the downward force required between the pad conditioner and the CMP pad. As a result, the CMP pad is left with a conditioned surface that is much more smooth and level than that obtained using conventional methods.

The conditioner shown in FIGs. 3A-3C can include abrasive layer 12f (only a section of which is shown). The abrasive layer can include a cutting face 26 angled at 90 degrees or less relative to a finished surface to be applied to the CMP pad (e.g., relative to movement of the cutting face away from the finished surface – sometimes referred to as a positive cutting angle). The face 26 of the abrasive layer 12f can be oriented such that relative movement of the pad conditioner (in the direction indicated at 23 in FIG. 3A) and the CMP pad 24 results in clean removal of material from the CMP pad with the cutting face to thereby condition the CMP pad.

By angling the cutting face 26 at 90 degrees or less, relative to a finished surface to be applied to the pad 24, the dressing process can cleanly shave a layer of pad material from the pad. The resultant surface applied to the pad can be safely used in the CMP process without damaging expensive silicon wafers. The present pad conditioners can be used to shave even a very shallow, thin layer of material from the pad and leave behind a clean, smooth and even finished surface on the pad. This technique can be used to remove thin layers of glaze that can be formed on the surface of the CMP pad.

The cutting face 26 is shown in FIGs. 3A and 3B oriented at an angle $\square_1$ of about 90 degrees relative to the finished surface to be applied to the CMP pad. Cutting face 26a of FIG. 3C is oriented at angle $\square_2$ that is less than 90 degrees relative to the finished surface to be applied to the CMP pad, on the order of about 60 degrees. The cutting faces can be oriented at a variety of angles, and in one embodiment vary from about 45 degrees to about 90 degrees relative to the finished surface of the CMP

pad. It has been found that reducing the angle creates an even sharper cutting interface between the cutting element and the pad.

The abrasive layers 12f, 12f' and 12f'' of FIGs. 3A-3C can be formed (along with their corresponding segment blank, not shown in these figures) as elongate cutting blades. These blades can include a significantly longer length than a width, similar to blade of a conventional kitchen knife. In this aspect of the invention, the blade can be used to cut, scrape or carve a relatively wide swath of material from the PCD pad (24 in FIGs. 3A-3C). As shown by example in FIGs. 4A and 4B, the abrasive layer, shown by example at 12f and 12f', can include either a substantially continuous cutting edge (as shown in FIG. 4A), or a series of cutting teeth can be formed in the blade (as shown in FIG. 4B). Examples of ways in which such cutting teeth can be formed are detailed in U.S. Provisional Patent Application Serial No. 60/987,687, filed November 13, 2007, which is hereby incorporated herein by reference.

Those embodiment illustrated in the figures that include angled cutting faces each include a cutting face that is formed having the corresponding angle. In some embodiments, however, it is to be understood that a relatively normal (e.g., 90 degree) cutting face can be utilized, except that the abrasive segment on which the cutting face is formed can be "tilted" when attached to the substrate. In other words, the cutting face is not angled relative to the abrasive segment, rather angling of the abrasive segment results in angling of the cutting face. In this manner, an angled cutting face is provided without requiring that the referenced angle be formed on (or in) the abrasive segment.

Additional and varying abrasive segments for use in the present invention are also contemplated. For example, use is contemplated of the various cutting elements/abrasive segments detailed in U.S. Patent Application No. 11/357,713, filed February 17, 2006, which is hereby incorporated herein by reference.

In addition, formation of the abrasive layer on the segment blanks can be accomplished by way of a variety of techniques, including but not limited to vapor deposition techniques similar to those outlined in U.S. Patent Application Serial No. 11/512,755, filed August 29, 2006, which is hereby incorporated herein by reference.

In addition, the abrasive segments can be formed utilizing ceramic components (as either or both the segment blank and/or the abrasive layer); electroplating techniques, etc.

In the embodiment illustrated in FIG. 5, a series of abrasive layers 14g, 14g' and 14g" is provided, each of which includes a cutting tip oriented at a different elevation. In this aspect of the invention, the leading abrasive segment (of which abrasive layer 14g forms a part) is generally at a relatively higher elevation than are trailing abrasive layers 14g' and 14g", as the trailing layers would not otherwise contact pad material remaining after the leading blade has passed. The abrasive segments having abrasive layers 14g, 14g' and 14g" can be formed in a variety of manners and in a variety of shapes, sizes and configurations, as detailed, for example, in U.S. Provisional Patent Application Serial 60/988,643, filed November 16, 2007, which is hereby incorporated herein by reference in its entirety. This embodiment can utilize intentionally cascaded cutting elements to achieve a desired abrading affect.

The following examples present various methods for making the pad conditioners of the present invention. Such examples are illustrative only, and no limitation on the present invention is to be thereby realized.

Examples:

Example 1:

A pad conditioner was formed by first arranging diamond grit (e.g. 50/60 mesh) on a stainless steel flat mold (also, a slightly convex or contoured mold can be utilized) having a layer of adhesive (e.g. acrylic). A hard rubber material was used to press individual diamond grits into the adhesive while tips of the grits were leveled by the flat mold. A mixture of epoxy and hardener was then poured onto the grit protruding outside the adhesive (a containment ring oriented outside the mold can retain the epoxy). After curing, the mold was then removed and the adhesive was peeled away. The remaining ODD contains diamond grit protruding outside a solidified epoxy substrate. The back of the epoxy can be machined and the disk adhered to a stainless steel (e.g. 316) plate with fastening holes for mounting on a CMP machine.

Example 2:

A pad conditioner was formed by radially arranging serrated PCD blades. As in the previous example, the teeth of the PCD blade were leveled with a mold that can be positioned either on the bottom or on the top of the pad conditioner. Epoxy was then cast as in the previous example. In the case that the mold is on the top, the blades are pressed slightly into the slot of a substrate and the slot is sealed by epoxy or silicone.

Example 3:

A composite design married the embodiments of Example 1 and Example 2 discussed above. This design leverages the many cutting tips of Example 1 with the cutting efficiency of Example 2. In this Example 3, smaller organic abrasive segments were formed by using a fiber reinforced polymer that is generally harder than epoxy. The organic segments were then radially arranged about a pad conditioner substrate with the blades of Example 2 interspersed therebetween. The cutting tips of the blades were leveled so as to be about 20 microns higher than were the tips of the organic abrasive segments. In this manner, the penetration depth of blade cutting teeth is controlled, while the organic cutting teeth play a secondary role in dressing the pad with the effect of removing glaze and also grooving the pad.

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. A CMP pad conditioner, comprising:

a plurality of abrasive segments, each abrasive segment including:

a segment blank; and

an abrasive layer attached to the segment blank, the abrasive layer including a superhard abrasive material; and

a pad conditioner substrate;

each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

2. The pad conditioner of claim 1, wherein at least some of the plurality of abrasive segments are radially distributed about a face of the pad conditioner substrate.

3. The pad conditioner of claim 1, wherein at least two of the plurality of abrasive segments differ in at least one of: a geometric configuration; an abrasive layer material; and an abrasive profile.

4. The pad conditioner of claim 1, wherein arrangement of the abrasive segments on the face of the pad conditioner substrate uniformly distributes drag forces across substantially each abrasive segment.

5. The pad conditioner of claim 1, wherein a longitudinal axis of each of the plurality of abrasive segments is aligned along a radius of the pad conditioner substrate.

6. The pad conditioner of claim 1, wherein each of the abrasive layers includes an abrading surface or point, and wherein the abrading surfaces or points are

leveled relative to one another such that no abrading surface or point protrudes above another abrading surface or point by more than about 30 microns.

7. The pad conditioner of claim 1, wherein each of the abrasive layers includes an abrading surface or point, and wherein at least one abrading surface or point is oriented at a greater elevation than is an abrading surface or point of an immediately adjacent abrasive layer.

8. The pad conditioner of claim 1, wherein the plurality of abrasive layers are attached to the segment blanks with an organic material layer including one or more 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.

9. The pad conditioner of claim 1, wherein the abrasive layers are attached to the segments blanks by a brazing alloy.

10. The pad conditioner of claim 1, wherein the abrasive layers comprise PCD blades.

11. The pad conditioner of claim 1, wherein the abrasive layers include individual abrasive grits.

12. The pad conditioner of claim 1, wherein each of the abrasive layers includes a cutting face, and wherein each cutting face is angled at 90 degrees or less relative to a finished surface of the CMP pad.

13. A CMP pad conditioner, comprising:

a plurality of abrasive segments, each abrasive segment including:

a segment blank;

an organic adhesive layer; and

an abrasive layer attached to the segment blank by the organic adhesive layer, the abrasive layer including a superhard abrasive material; and

a pad conditioner substrate;

each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

14. The pad conditioner of claim 13, wherein at least some of the plurality of abrasive segments are radially distributed about a face of the pad conditioner substrate.

15. The pad conditioner of claim 13, wherein at least two of the plurality of abrasive segments differ in at least one of: a geometric configuration; an abrasive layer material; and an abrasive profile.

16. The pad conditioner of claim 13, wherein arrangement of the abrasive segments on the face of the pad conditioner substrate uniformly distributes drag forces across substantially each abrasive segment.

17. The pad conditioner of claim 13, wherein a longitudinal axis of each of the plurality of abrasive segments is aligned along a radius of the pad conditioner substrate.

18. The pad conditioner of claim 13, wherein each of the abrasive layers includes an abrading surface or point, and wherein the abrading surfaces or points are

leveled relative to one another such that no abrading surface or point protrudes above another abrading surface or point by more than about 30 microns.

19. The pad conditioner of claim 13, wherein each of the abrasive layers includes an abrading surface or point, and wherein at least one abrading surface or point is oriented at a greater elevation than is an abrading surface or point of an immediately adjacent abrasive layer.

20. A CMP pad conditioner, comprising:

a plurality of abrasive segments, each abrasive segment including:

a segment blank; and

an abrasive layer attached to the segment blank by a brazing alloy, the abrasive layer including a superhard abrasive material; and

a pad conditioner substrate;

each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

21. The pad conditioner of claim 20, wherein at least some of the plurality of abrasive segments are radially distributed about a face of the pad conditioner substrate.

22. The pad conditioner of claim 20, wherein at least two of the plurality of abrasive segments differ in at least one of: a geometric configuration; an abrasive layer material; and an abrasive profile.

23. The pad conditioner of claim 20, wherein arrangement of the abrasive segments on the face of the pad conditioner substrate uniformly distributes drag forces across substantially each abrasive segment.

24. The pad conditioner of claim 20, wherein a longitudinal axis of each of the plurality of abrasive segments is aligned along a radius of the pad conditioner substrate.

25. The pad conditioner of claim 20, wherein each of the abrasive layers includes an abrading surface or point, and wherein the abrading surfaces or points are leveled relative to one another such that no abrading surface or point protrudes above another abrading surface or point by more than about 30 microns.

26. The pad conditioner of claim 20, wherein each of the abrasive layers includes an abrading surface or point, and wherein at least one abrading surface or point is oriented at a greater elevation than is an abrading surface or point of an immediately adjacent abrasive layer.

27. A CMP pad conditioner, comprising:

a plurality of abrasive segments, each abrasive segment including:

a segment blank; and

an abrasive layer attached to the segment blank, the abrasive layer including a superhard abrasive blade; and

a pad conditioner substrate;

each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

28. The pad conditioner of claim 27, wherein at least some of the plurality of abrasive segments are radially distributed about a face of the pad conditioner substrate.

29. The pad conditioner of claim 27, wherein at least two of the plurality of abrasive segments differ in at least one of: a geometric configuration; an abrasive layer material; and an abrasive profile.

30. The pad conditioner of claim 27, wherein arrangement of the abrasive segments on the face of the pad conditioner substrate uniformly distributes drag forces across substantially each abrasive segment.

31. The pad conditioner of claim 27, wherein a longitudinal axis of each of the plurality of abrasive segments is aligned along a radius of the pad conditioner substrate.

32. The pad conditioner of claim 27, wherein each of the abrasive layers includes an abrading surface or point, and wherein the abrading surfaces or points are leveled relative to one another such that no abrading surface or point protrudes above another abrading surface or point by more than about 30 microns.

33. The pad conditioner of claim 27, wherein each of the abrasive layers includes an abrading surface or point, and wherein at least one abrading surface or point is oriented at a greater elevation than is an abrading surface or point of an immediately adjacent abrasive layer.

34. A CMP pad conditioner, comprising:

a plurality of abrasive segments, each abrasive segment including:

a segment blank; and

an abrasive layer attached to the segment blank, the abrasive layer including a cutting face angled at 90 degrees or less relative to a finished surface to be applied to the CMP pad; and

a pad conditioner substrate;

each of the plurality of abrasive segments being permanently affixed to the pad conditioner substrate in an orientation that enables removal of material from a CMP

pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another.

35. The pad conditioner of claim 34, wherein at least some of the plurality of abrasive segments are radially distributed about a face of the pad conditioner substrate.

36. The pad conditioner of claim 34, wherein at least two of the plurality of abrasive segments differ in at least one of: a geometric configuration; an abrasive layer material; and an abrasive profile.

37. The pad conditioner of claim 34, wherein arrangement of the abrasive segments on the face of the pad conditioner substrate uniformly distributes drag forces across substantially each abrasive segment.

38. The pad conditioner of claim 34, wherein a longitudinal axis of each of the plurality of abrasive segments is aligned along a radius of the pad conditioner substrate.

39. The pad conditioner of claim 34, wherein each of the abrasive layers includes an abrading surface or point, and wherein the abrading surfaces or points are leveled relative to one another such that no abrading surface or point protrudes above another abrading surface or point by more than about 30 microns.

40. The pad conditioner of claim 34, wherein each of the abrasive layers includes an abrading surface or point, and wherein at least one abrading surface or point is oriented at a greater elevation than is an abrading surface or point of an immediately adjacent abrasive layer.

41. A method of forming a CMP pad conditioner, comprising:
obtaining at least one abrasive segment, the abrasive segment including:

a segment blank; and

an abrasive layer attached to the segment blank, the abrasive layer including a superhard abrasive material;

positioning the at least one abrasive segment on a face of a pad conditioner substrate in an orientation that enables removal of material from a CMP pad by the abrasive layer as the pad conditioner and the CMP pad are moved relative to one another; and

permanently affixing the at least one abrasive segment to the pad conditioner substrate.

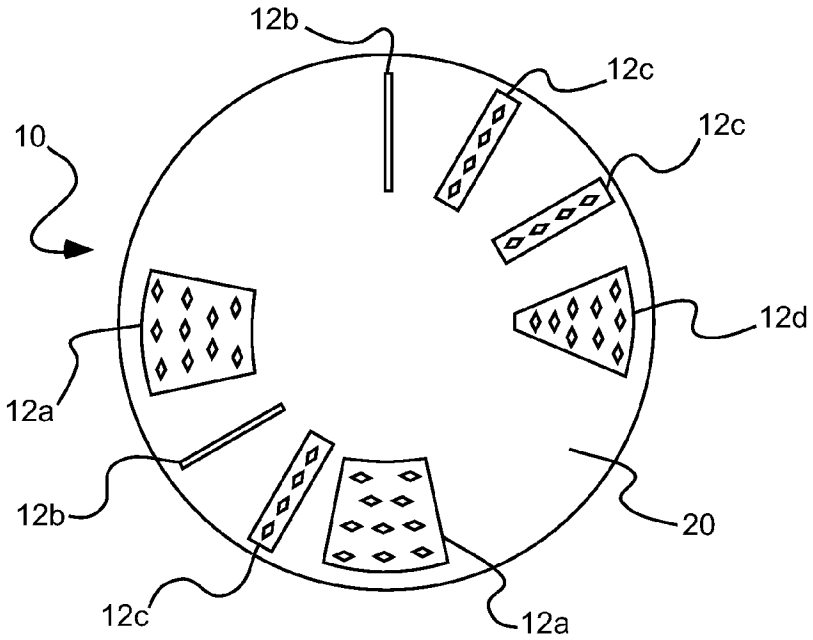


FIG. 1

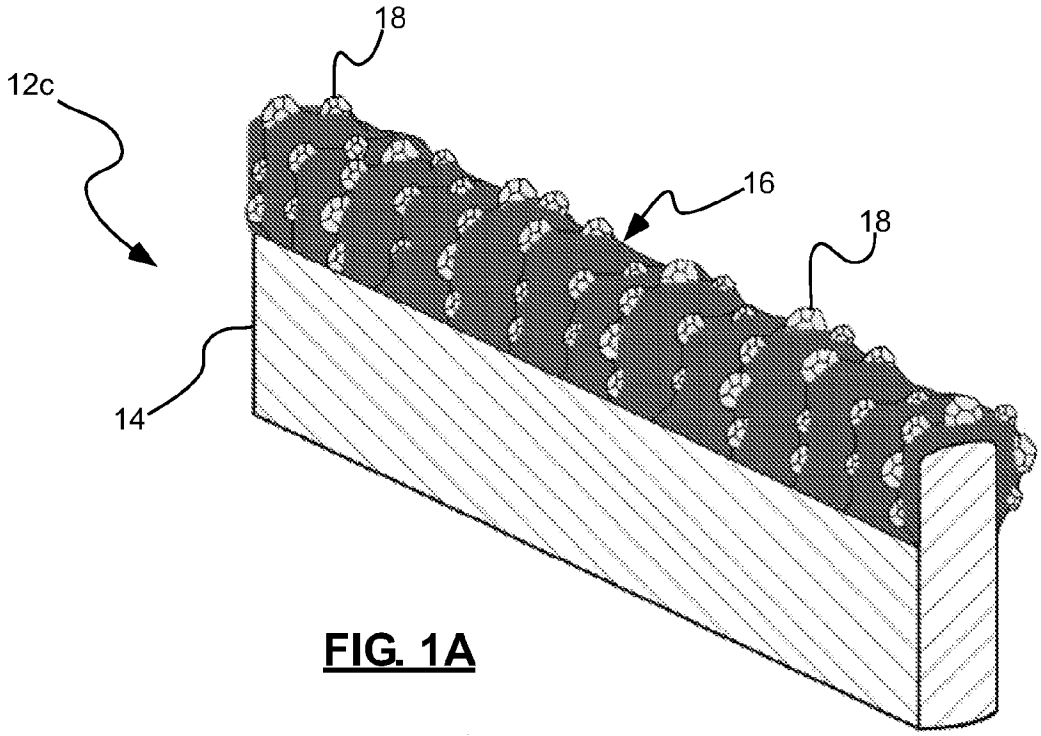


FIG. 1A

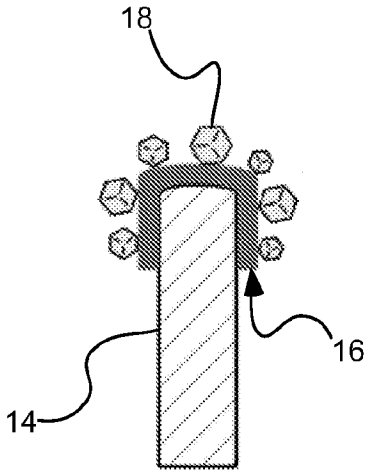


FIG. 1B

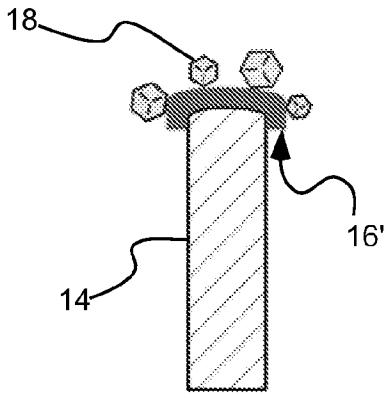


FIG. 1C

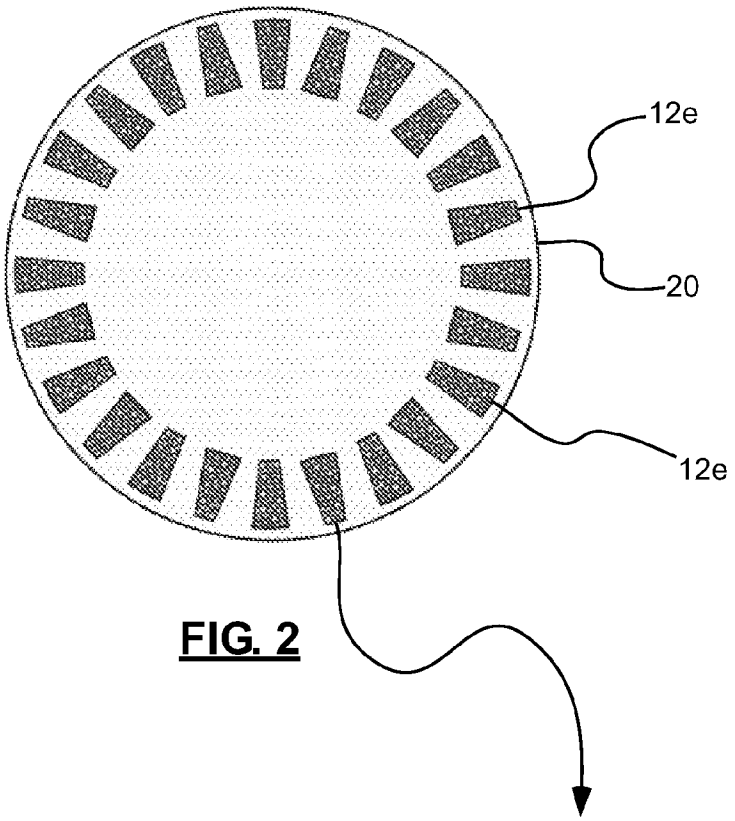


FIG. 2

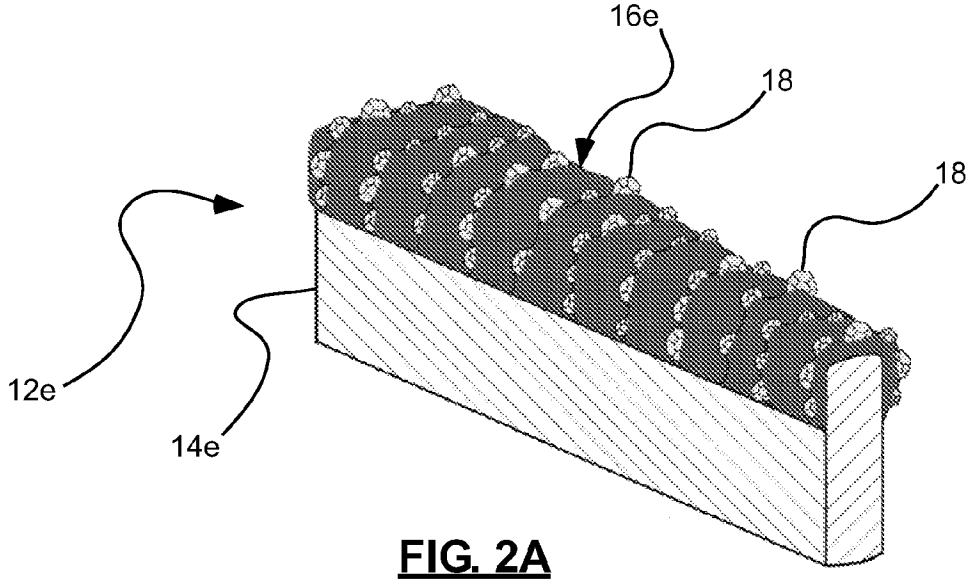


FIG. 2A

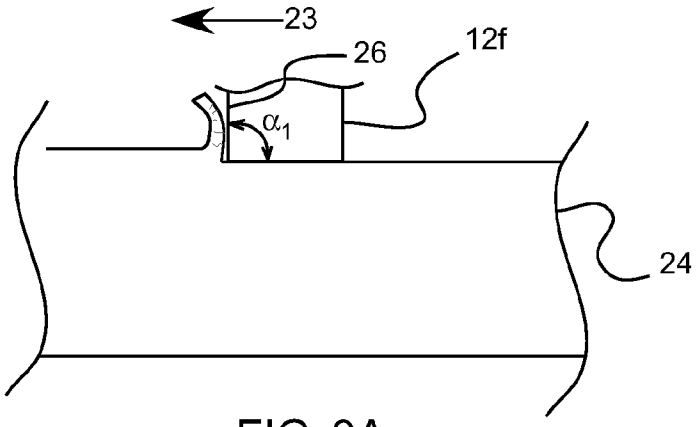


FIG. 3A

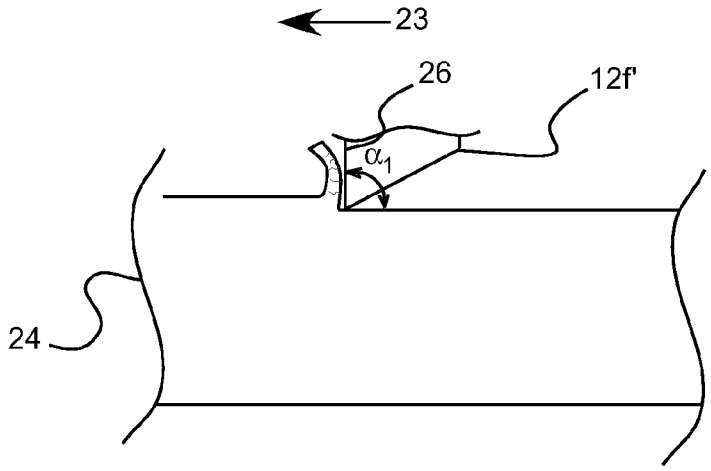


FIG. 3B

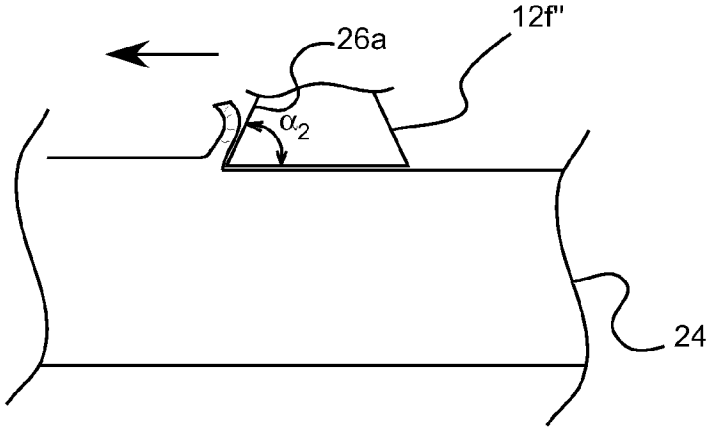


FIG. 3C

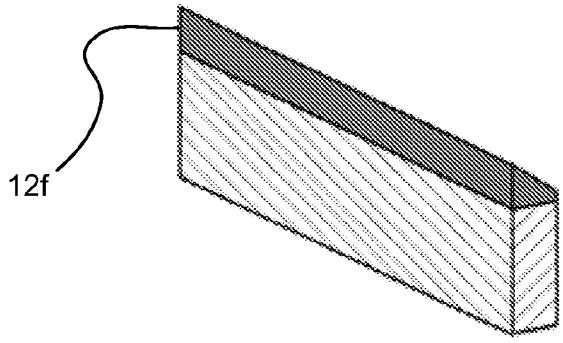


FIG. 4A

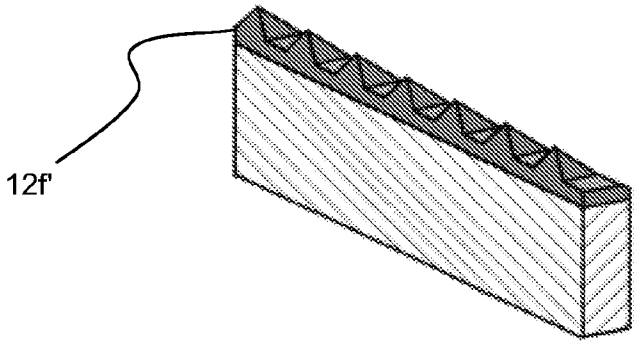


FIG. 4B

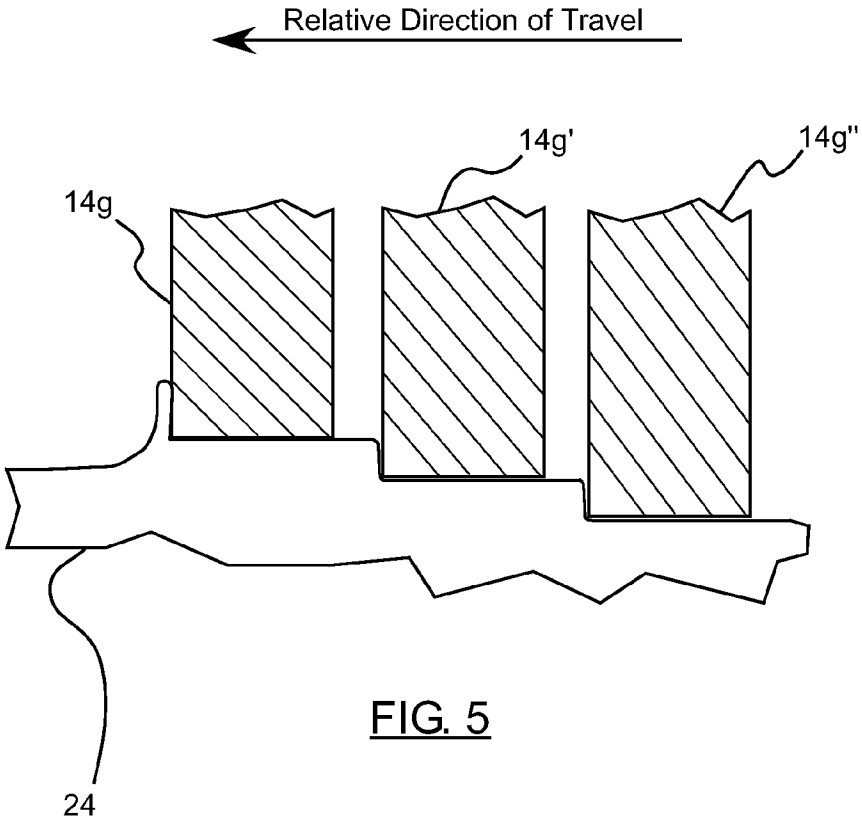


FIG. 5

WO2009064677

Publication Title:

CMP PAD DRESSERS

Abstract:

Abstract of WO 2009064677

(A2) Translate this text An abrasive tool (112) includes an assembly of tool precursors (116). At least one of the tool precursors has a continuous polycrystalline diamond, polycrystalline cubic boron nitride, or ceramic material cutting element (18) formed into a blade shape. The abrasive tool can additionally include a setting material (68), which is configured to attach the tool precursors and form a single mass. The selection, arrangement, and setting of the tool precursors can result in an abrasive tool having a predetermined cutting configuration. Methods for forming such an abrasive tool are also disclosed.

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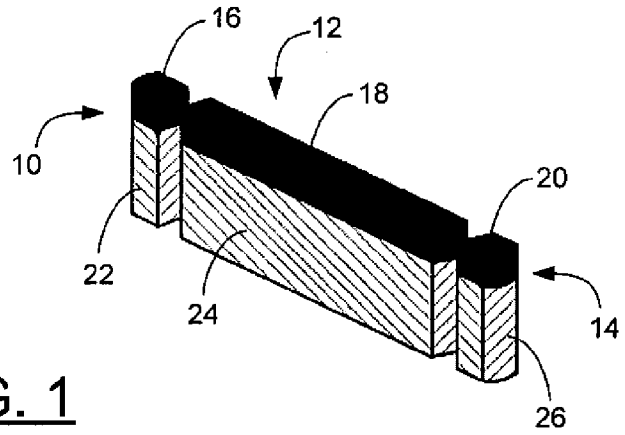


FIG. 1

(57) Abstract: An abrasive tool (112) includes an assembly of tool precursors (116). At least one of the tool precursors has a continuous polycrystalline diamond, polycrystalline cubic boron nitride, or ceramic material cutting element (18) formed into a blade shape. The abrasive tool can additionally include a setting material (68), which is configured to attach the tool precursors and form a single mass. The selection, arrangement, and setting of the tool precursors can result in an abrasive tool having a predetermined cutting configuration. Methods for forming such an abrasive tool are also disclosed.

WO 2009/064677 A2

CMP PAD DRESSERS

PRIORITY CLAIM

This application claims the benefit of: U.S. Provisional Patent Application Serial No. 60/987,687, filed November 13, 2007; and U.S. Provisional Patent Application Serial No. 60/988,643, filed November 16, 2007, each of which is hereby incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to devices and methods for use in connection with dressing or conditioning a chemical mechanical polishing (CMP) pad. Accordingly, the present invention involves the fields of chemical engineering, chemistry, metallurgy, and materials science.

BACKGROUND OF THE INVENTION

Chemical mechanical process (CMP) has become a widely used technique for polishing certain work pieces. Particularly, the computer manufacturing industry has begun to rely heavily on CMP processes for polishing wafers of ceramics, silicon, glass, quartz, metals, and mixtures thereof for use in semiconductor fabrication. Such polishing processes generally entail applying the wafer against a rotating pad made from a durable organic substance such as polyurethane. To the pad is added a chemical slurry containing a chemical solution capable of breaking down the wafer substance and an amount of abrasive particles which act to physically erode the wafer surface. The slurry is continually added to the spinning CMP pad, and the dual chemical and mechanical forces exerted on the wafer cause it to be polished in a desired manner.

To effectively work over a period of time, a CMP pad needs to be kept in good condition so that distribution of abrasive particles is optimized for each polishing. One method of reducing "glazing" or accumulation of debris on the CMP pad is dressing or conditioning the pad. Dressing refers to attempts made to revive the top of the pad by "combing" or "cutting" it with various devices. Many types of devices and processes have been used for this purpose. Some CMP pad dressers cause the CMP pads to prematurely wear out.

SUMMARY OF THE INVENTION

In accordance with one aspect of the invention, an abrasive tool can be provided and can include an assembly of tool precursors. At least one of the tool precursors can include a continuous polycrystalline diamond or polycrystalline cubic boron nitride, or other ceramic material cutting element formed into a blade shape. The abrasive tool can additionally include a setting material, which is configured to attach the tool precursors and form a single mass. The selection, arrangement, and setting of the tool precursors can result in an abrasive tool having a predetermined cutting configuration.

In accordance with another aspect of the invention, an abrasive tool can be provided and can include an assembly of tool precursors. The tool precursors can include at least one elongated substrate with a continuous polycrystalline diamond, cubic boron nitride (cBN), or other ceramic material cutting element on a surface thereof. The precursor assembly can provide a tool having a surface with a predetermined cutting configuration. The abrasive tool can further include a setting material configured to attach the tool precursors into a single mass that forms the predetermined cutting configuration.

In accordance with another aspect of the invention, a method of forming an abrasive tool can be provided, including providing a plurality of tool precursors. At least one of the tool precursors can have a continuous diamond or cubic boron nitride, or other ceramic cutting element formed in a blade shape. The method can further include securing the tool precursors together to form a tool having a working surface that includes the polycrystalline diamond, cubic boron nitride, or other ceramic material cutting element formed into a blade shape.

In accordance with another aspect of the invention, a CMP pad conditioner can be provided, including a base and a plurality of cutting elements extending from the base. The plurality of cutting elements can each have a cutting tip operable to engage material of the CMP pad. At least some of the cutting elements can have a cutting tip oriented at a different elevation relative to cutting tips of other cutting elements.

In accordance with another aspect of the invention, at least one of the cutting elements can include a cutting tip oriented at a greater elevation, relative to a base of

the pad conditioner, than does a cutting tip of an immediately adjacent cutting element.

In accordance with another aspect of the invention, the at least one cutting element abuts the immediately adjacent cutting element.

In accordance with another aspect of the invention, the cutting elements can include a cutting face oriented at 90 degrees or less relative to a surface of the CMP pad conditioned by the cutting elements.

In accordance with another aspect of the invention, the cutting elements can include a trailing edge angled to provide a relief area between the cutting elements and a surface of the CMP pad conditioned by the cutting elements.

In accordance with another aspect of the invention, the cutting elements and the base can be formed from an integral piece of material. In one embodiment, the cutting elements and the base are formed from an integral piece of a polycrystalline diamond compact.

In accordance with another aspect of the invention, the cutting elements can be coupled to the base.

In accordance with another aspect of the invention, at least two of the cutting elements are arranged such that movement of the pad conditioner and the CMP pad relative to one another results in a first, lower elevation cutting element removing material from the CMP pad, followed by a second, higher elevation cutting element removing further material from the CMP pad.

In accordance with another aspect of the invention, a method of conditioning a CMP pad is provided, including: engaging material of the CMP pad with a cutting tip of at least one cutting element; moving the cutting element and the CMP pad relative to one another to thereby remove material from the CMP pad with the cutting tip of the cutting element to create an exposed layer of CMP pad material; engaging the exposed layer of CMP pad material with the cutting tip of the cutting element, or with a cutting tip of a second cutting element; and moving the cutting element engaged with the exposed layer of CMP pad material and the CMP pad relative to one another to thereby remove the exposed layer of CMP pad material.

In accordance with another aspect of the invention, engaging the exposed layer of CMP pad material comprises engaging the exposed layer with the cutting tip of the cutting element used to create the exposed layer.

In one embodiment, engaging the exposed layer of CMP pad material comprises engaging the exposed layer with the cutting tip of the second cutting element.

In accordance with another aspect of the invention, the cutting element and the second cutting element extend from a common base.

In accordance with another aspect of the invention, a method of conditioning a CMP pad is provided, including: removing, with a cutting element, a thin layer of material from the CMP pad; and removing, with the same or a different cutting element, a second layer of material from the CMP, the second layer of material being revealed by removal of the thin layer of material.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a side perspective view of a plurality of tool precursors, in accordance with an embodiment of the present invention;

FIG. 2 is a side perspective view of a tool precursor having a PCD or cBN, or ceramic layer in a blade formation, in accordance with an embodiment of the present invention;

FIG. 3 is a side perspective view of a tool precursor having a PCD or cBN, or ceramic layer formed in a plurality of asperities, in accordance with an embodiment of the present invention;

FIG. 4 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 5 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 6 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 7 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 8 is a side view of a tool precursors leveled and set in an epoxy, thus forming an abrasive tool, in accordance with an embodiment of the present invention;

FIG. 9 is a top view of an abrasive tool having tool precursors arranged in a spoke formation, in accordance with an embodiment of the present invention;

FIG. 10 is a perspective view of a mass from which tool precursors can optionally be formed, in accordance with an embodiment of the present invention;

FIG. 11 is a perspective view of a mass from which tool precursors can optionally be formed, in accordance with an embodiment of the present invention;

FIG. 12 is a side view of a mass, similar to FIG. 11, from which tool precursors can optionally be formed, in accordance with an embodiment of the present invention;

FIG. 13 is a side perspective view of a tool precursor having a PCD or CBN or ceramic layer in a blade formation, in accordance with an embodiment of the present invention;

FIG. 14 is a side perspective view of an assembly of tool precursors, in accordance with an embodiment of the present invention;

FIG. 15 is a side cross-sectional view of an abrasive tool, in accordance with an embodiment of the present invention;

FIG. 16 is a side view of a pad conditioner engaging a CMP pad in accordance with an embodiment of the invention;

FIG. 17 is a side view of another pad conditioner engaging a CMP pad in accordance with an embodiment of the invention;

FIG. 18 is a side view of another pad conditioner engaging a CMP pad in accordance with an embodiment of the invention;

FIG. 19 is a partial view of a pad being conditioned in accordance with another embodiment of the invention;

FIG. 20 is a top view of an exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 21 is a top view of another exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 22 is a top view of another exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 23 is a top view of another exemplary pad conditioner illustrating one possible arrangement of cutting elements across the face of the pad conditioner;

FIG. 24 illustrates the performance of various cutting teeth (varied in both shape and spacing) of the present invention; and

FIG. 25 illustrates a comparison of a pad dresser in accordance with the present invention as compared to conventional technology.

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

DETAILED DESCRIPTION

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

It must be noted that, as used in this specification and the appended claims, the singular forms "a," "an" and, "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "a CMP pad dresser" includes one or more of such dressers, reference to "an operating parameter" includes reference to one or

more of such operating parameters, and reference to "the asperity" includes reference to one or more of such asperities.

Definitions

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

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" translucent would mean that the object is either completely translucent or nearly completely translucent. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. In other words, a composition that is "substantially free of" an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.

The terms "dressing" and "conditioning" are interchangeable and refer to the process of rejuvenating a CMP pad by removing debris from the pad, as well as optionally lifting matted fibers and creating new grooves. Likewise, the terms "dresser" and "conditioner" are used interchangeably and indicate the apparatus used for dressing or conditioning.

As used herein, "substrate" means a material which supports or can support a PCD or cBN, or ceramic layer, and to which a PCD or cBN, or ceramic layer may be affixed. Substrates useful in the present invention may be any shape, thickness, or material, that is capable of supporting abrasive particles in a manner that is sufficient provide a tool useful for its intended purpose. Substrates may be of a solid material, a powdered material that becomes solid when processed, or a flexible material. Examples of typical substrate materials include without limitation, metals, metal alloys, ceramics, solidified resins and polymeric materials and mixtures thereof.

As used herein, the terms "base" or "substrate" can be used to refer to a

portion of a pad conditioner that supports abrasive materials, and to which abrasive materials may be affixed, or may extend from. Substrates useful in the present invention may be any shape, thickness, or material, that is capable of supporting abrasive materials in a manner that is sufficient provide a pad conditioner useful for its intended purpose. Substrates may be of a solid material, a powdered material that becomes solid when processed, or a flexible material. Examples of typical substrate materials include without limitation, metals, metal alloys, ceramics, relatively hard polymers or other organic materials, glasses, and mixtures thereof. Further the substrate may include material that aids in attaching abrasive materials to the substrate, including, without limitation, brazing alloy material, sintering aids and the like. The substrate and the abrasive cutting elements can, in some embodiments, be formed from the same material and can be formed from an integral, single piece of material.

As used herein, "leading edge" means the edge of a CMP pad dresser that is a frontal edge based on the direction that the CMP pad is moving, or the direction that the pad is moving, or both. Notably, in some aspects, the leading edge may be considered to encompass not only the area specifically at the edge of a dresser, but may also include portions of the dresser which extend slightly inward from the actual edge. In one aspect, the leading edge may be located along an outer edge of the CMP pad dresser. In another aspect, the CMP pad dresser may be configured with a pattern of abrasive particles that provides at least one effective leading edge on a central or inner portion of the CMP pad dresser working surface. In other words, a central or inner portion of the dresser may be configured to provide a functional effect similar to that of a leading edge on the outer edge of the dresser.

As used herein, the process of "brazing" is intended to refer to the creation of chemical bonds between the atoms of the non-metallic, such as diamond, CBN, or ceramic materials and the braze material. Further, "chemical bond" means a covalent bond, such as a carbide, nitride, or boride bond, rather than mechanical or weaker inter-atom attractive forces. Thus, when "brazing" is used in connection with superabrasive particles a true chemical bond is being formed. However, when "brazing" is used in connection with metal to metal bonding the term is used in the

more traditional sense of a metallurgical bond. Therefore, brazing of a superabrasive segment to a tool body does not require the presence of a carbide, nitride, or boride former.

As used herein, "ceramic" refers to a hard, often crystalline, substantially heat and corrosion resistant material which may be made by firing a non-metallic material, sometimes with a metallic material. A number of oxide, nitride, and carbide materials considered to be ceramic are well known in the art, including without limitation, aluminum oxides, silicon oxides, boron nitrides, silicon nitrides, and silicon carbides, tungsten carbides, etc.

As used herein, "metallic" means any type of metal, metal alloy, or mixture thereof, and specifically includes but is not limited to steel, iron, and stainless steel.

As used herein, "abrasive profile" is to be understood to refer to a shape or a space defined by abrasive materials that can be used to remove material from a CMP pad. Examples of abrasive profiles include, without limitation, rectangular shapes, tapering rectangular shapes, truncated wedge shapes, wedge shapes, and the like. In some embodiments, the abrasive profile exhibited by abrasive segments of the present invention will apparent when viewed through a plane in which the CMP pad will be oriented during removal of material from the CMP pad.

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

As used herein, "organic material" refers to a semisolid or solid complex amorphous mix of organic compounds. As such, "organic material layer" and "organic material matrix" may be used interchangeably, refer to a layer or mass of a

semisolid or solid complex amorphous mix of organic compounds. Preferably the organic material will be a polymer or copolymer formed from the polymerization of one or more monomers.

As used herein, "particle" and "grit" may be used interchangeably.

As used herein, the term "abrasive" can be used to describe a variety of structures capable of removing (e.g., cutting, polishing, scraping) material from a CMP pad. An abrasive can include a mass having several cutting points, ridges or mesas formed thereon or therein. It is notable that such cutting points, ridges or mesas may be from a multiplicity of protrusions or asperities included in the mass. Furthermore, an abrasive can include a plurality of individual abrasive particles that may have only one cutting point, ridge or mesa formed thereon or therein. An abrasive can also include composite masses, such as PCD pieces, segment or blanks, either individually comprising the abrasive layer or collectively comprising the abrasive layer.

As used herein, the term "cutting tip" is generally used to refer to a portion of a cutting element that engages and removes material from a workpiece (generally a CMP pad). "Cutting tips" can include points, edges, surfaces, etc., that are capable of cutting material from a CMP pad. The terms "cutting tip," "edge," "blade," etc., can be, but are not always, used interchangeably.

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

Concentrations, amounts, particle sizes, volumes, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-

ranges encompassed within that range as if each numerical value and sub-range is explicitly recited.

As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc. This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

It has been found that the overall CMP process can be improved through dressing or conditioning with a CMP pad dresser that effectively dresses the CMP pad, so as to optimally allow for extended CMP pad life, while reducing glazing and other negative effects on the CMP pad. Such improvements can occur as a result of precisely-machined CMP pad dressers. By utilizing dressers as disclosed herein, CMP pads can be refreshed, without losing CMP pad life as with the use of typical CMP pad dressers. Furthermore, the methods disclosed herein for creating such dressers provide a relative fast and economical way to create such precise tools. Additionally, the method provides for the creation of a CMP pad dresser that has a predetermined working surface.

In accordance with embodiments presented herein, various details are provided which are applicable to each of the CMP pad dressers and method for creating or forming the CMP pad dressers. Thus, discussion of one specific embodiment is related to and provides support for this discussion in the context of the other related embodiments.

An abrasive tool can include an assembly of tool precursors. Tool precursors can be of a variety of shapes and sizes. FIGs 1-3 illustrate a plurality of tool precursors. FIG. 1 illustrates three tool precursors 10, 12, 14. Each of the illustrated precursors includes a polycrystalline diamond (PCD), cubic boron nitride (PcBN), or ceramic layer 16, 18, 20, on one surface of a substrate 22, 24, 26, of the tool precursor. In each embodiment, the layer could alternatively comprise or consist essentially of

either PCD or PcBN. Additionally, the layer may comprise or consist of diamond in other forms, including CVD deposited diamond and also various ceramic materials. In one embodiment (not shown), the layer may be a ceramic or PcBN layer which is overlayed with an outer layer of CVD diamond. The layers illustrated are substantially uniform in thickness across the full area of the surface of the substrate. Tool precursor 12 illustrates an elongated tool precursor having a continuous polycrystalline diamond or polycrystalline cubic boron nitride cutting element formed thereon. In one embodiment, the tool precursor 12 of FIG. 1 can be further machined to form a blade shape as illustrated in FIG. 2. As shown, the tool precursor 30 includes an elongated substrate 32 and a continuous polycrystalline diamond or cubic boron nitride cutting element 34 on a surface of the substrate. The cutting element is formed into of a blade shape, having a single tip 36 of the cutting element substantially along the length the elongated tool precursor.

It should be understood that while much discussion is directed to PCD, diamond, PcBN, and/or cubic boron nitride cutting elements, other materials can be used as the cutting element, either alone or in combination with other materials, and are to be included in the scope of the disclosure herein. For example, the cutting element can comprise or consist essentially of ceramics, or other diamond or cBN films, including those deposited via chemical vapor deposition (CVD). Non-limiting examples of ceramics that can be used as a cutting element include alumina, aluminum carbide, silica, silicon carbide, silicon nitride, zirconia, zirconium carbide, and mixtures thereof. Cutting elements can be, in one embodiment, sintered masses, partially sintered masses, and/or layers of material attached to the substrate of the tool precursor according to any method known in the art. The cutting element can, in one aspect, include a mixture, homogeneous or otherwise, of a plurality of materials, optionally including abrasive particles. In another aspect, the cutting element can include a plurality of layers of material. As a non-limiting example, the cutting element can include a ceramic overcoated with CVD diamond.

In one aspect, the tool precursor of FIG. 2 can be further machined to form a plurality of asperities as illustrated in FIG. 3. As shown, the tool precursor 40 has an elongated substrate 42 with a continuous polycrystalline diamond or cubic boron

nitride cutting element 44 on one surface of the substrate. The diamond or cubic boron nitride cutting element is formed into a plurality of asperities 46 having a single tip or point. As shown, the asperities are of a pyramidal shape. Although pyramidal shape is illustrated as the asperity shape, any shape having a tip that can form an asperity is to be explicitly included herein. Regarding pyramidal shapes, the pyramidal shaped asperities can include irregular and regularly shaped pyramids. Such asperities can include any three-dimensional shape having triangular non-base surfaces that converge on one point. The base shape is typically quadrilateral or trilateral, but can be any polygon shape. In the case of FIG. 3, pyramid shaped asperities having a triangular base are shown and such pyramids have a substantially flat vertical side as will be explained in more detail. Alternatively, pyramids with a cubic base could be used. One of the faces of the pyramidal asperities of FIG. 3 is substantially perpendicular to the plane of the substrate surface. In such case, it is possible to pair two similar tool precursors in a back-to-front manner so as to form a pyramid shape having a larger base, i.e. each tool precursor would provide approximately one half of the asperity. In the case of arranging the tool precursors of FIG. 3 in a back-to-front manner, the pyramids formed by aligning two of the tool precursors together to form a single line of pyramidal asperities have a quadrilateral base shape, with half of each base being provided by a single tool precursor. In one embodiment, tool precursors of the present invention can be prepared by forming a PCD or PcBN blank with a PCD or PcBN layer attached to a substrate as shown in FIG. 10, and an elongated segment can be removed as shown. Next, an electro discharge machining (EDM) wire can be used to form the tool precursors by shaping the PCD or PcBN layer of each segment. The precursors can then be assembled into a finished tool.

In one aspect, a substrate having a continuous PCD or PcBN layer can be formed into a blade shape, either through EDM wire or other grinding or material removal method. Such blade shape is illustrated in FIG. 2. With the blade shape formed, asperities can be formed through use of EDM wire, or other precise material removal method. In forming asperities from a blade shape, the asperities can be formed immediately adjacent to each other, or can be spaced. The angles of each