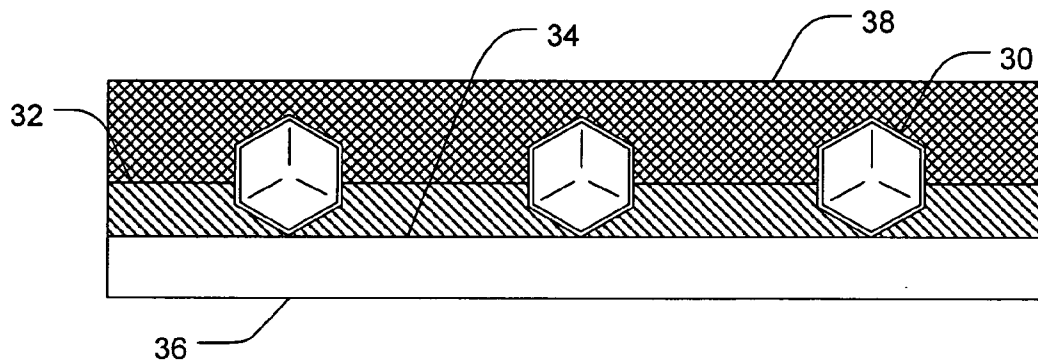




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Sung(10) **Pub. No.: US 2008/0096479 A1**(43) **Pub. Date: Apr. 24, 2008**(54) **LOW-MELTING POINT SUPERABRASIVE
TOOLS AND ASSOCIATED METHODS**(57) **ABSTRACT**(76) Inventor: **Chien-Min Sung**, Taipei County
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SANDY, UT 84091-1219(21) Appl. No.: **11/583,353**(22) Filed: **Oct. 18, 2006****Publication Classification**(51) **Int. Cl.**
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Superabrasive tools and their methods of manufacture are disclosed. In one aspect, a method for making a low-melting point superabrasive tool having a plurality of superabrasive particles is provided. Such a method may include coating each of the plurality of superabrasive particles with a reactive element that chemically bonds to each of the plurality of superabrasive particles and bonding together the plurality of superabrasive particles with a molten braze that wets the reactive element at a temperature of less than about 700° C. In some aspects, the method may further include arranging the plurality of superabrasive particles on a leveling surface and bonding the plurality of superabrasive particles together with the molten braze such that, upon formation of the superabrasive tool, the plurality of superabrasive particles have been leveled by the leveling surface to an RA value of less than about 40 µm.



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Samsung Electronics Co. Ltd. et al v. Chien-Min Sung

Samsung's Exhibit 1005

Ex. 1005, Page 1

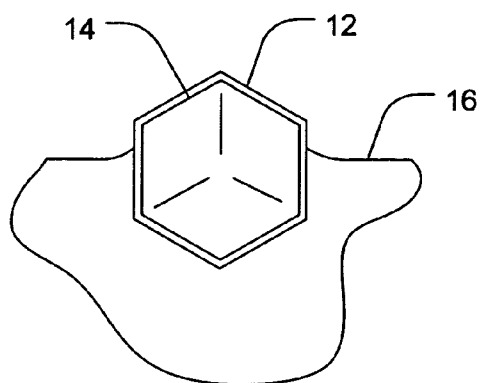


FIG. 1

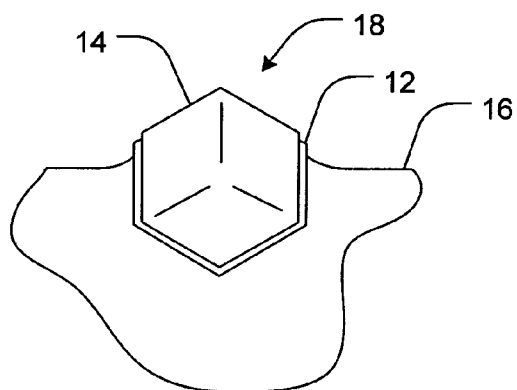


FIG. 2

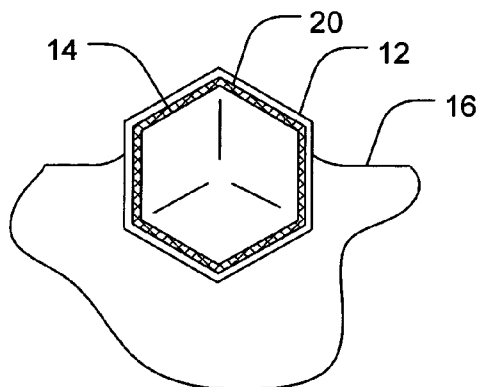


FIG. 3

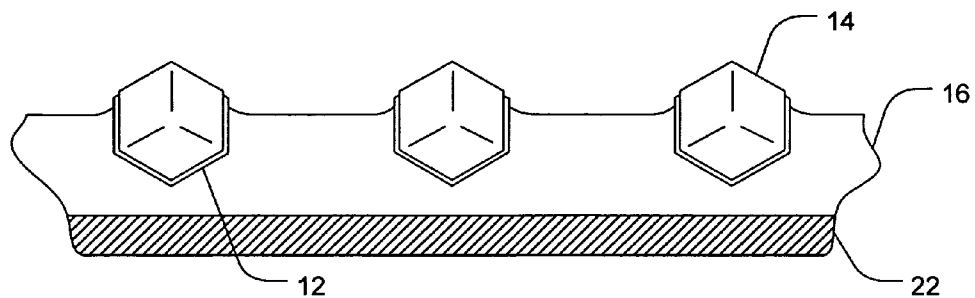


FIG. 4

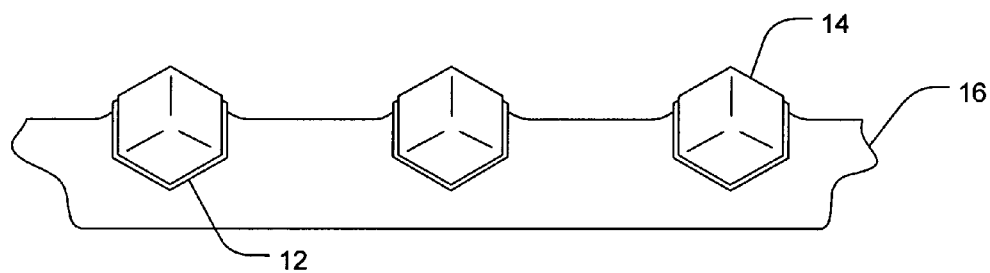


FIG. 5

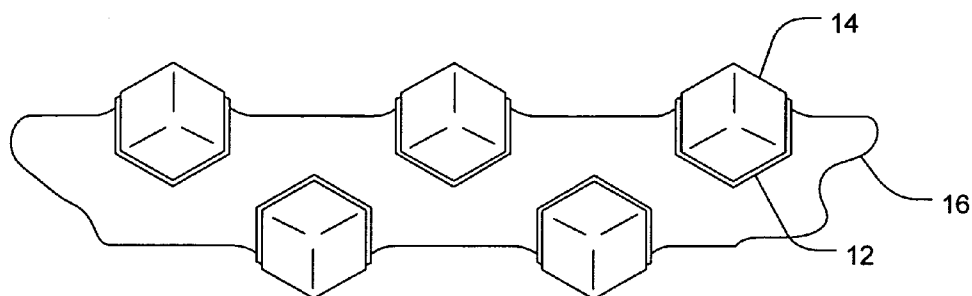


FIG. 6

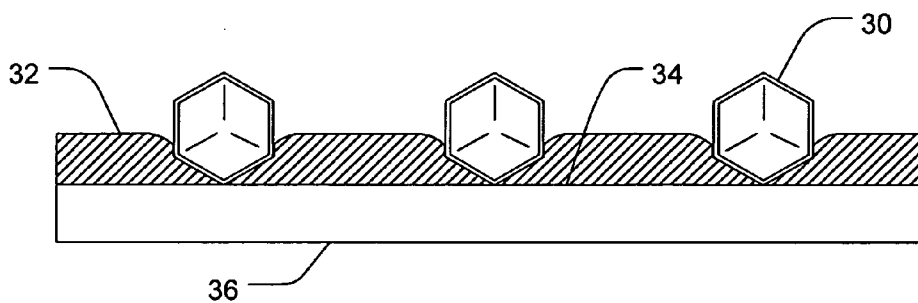


FIG. 7

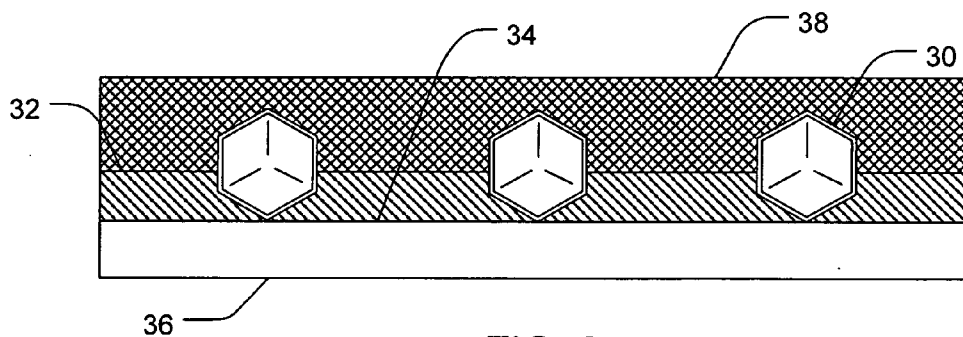


FIG. 8

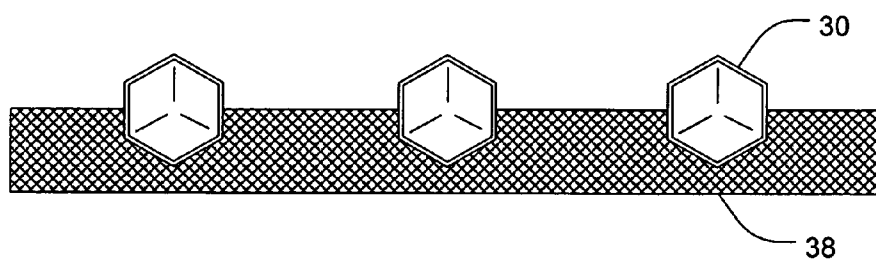


FIG. 9

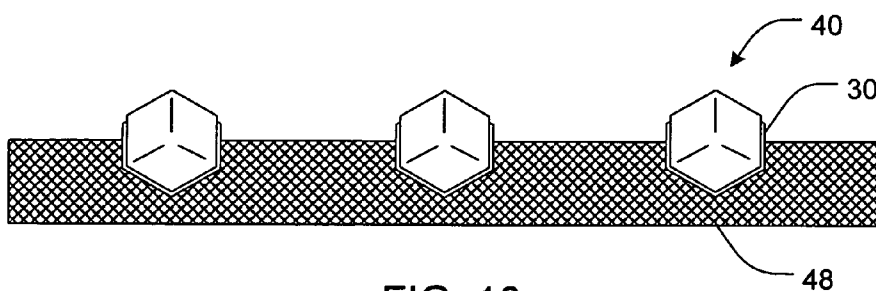


FIG. 10

LOW-MELTING POINT SUPERABRASIVE TOOLS AND ASSOCIATED METHODS

FIELD OF THE INVENTION

[0001] The present invention relates generally to tools having superabrasive particles embedded in a support matrix having a low-melting point and associated methods. Accordingly, the present invention involves the chemical and material science fields.

BACKGROUND OF THE INVENTION

[0002] 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.

[0003] 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.

[0004] 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.

[0005] 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.

[0006] 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 known 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 necessitates the precise leveling of particle tip height 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.

[0007] In addition to issues with properly holding very small superabrasive particles, traditional metal braze alloys have the tendency to warp and buckle during a heating process, causing additional issues in obtaining a CMP pad dresser having superabrasive particle tips leveled to within a narrow tolerance range.

[0008] As a result, a CMP pad dresser that is suitable for dressing a CMP pad that meets the demands placed upon the CMP industry by the continual reductions in semiconductor size is still being sought.

SUMMARY OF THE INVENTION

[0009] 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 for making a low-melting point superabrasive tool having a plurality of superabrasive particles is provided. Such a method may include coating each of the plurality of superabrasive particles with an intermediate layer that chemically bonds to each of the plurality of superabrasive particles and bonding together the plurality of superabrasive particles with a molten braze that wets the intermediate layer at a temperature of less than about 700° C. In some aspects, the method may further include arranging the plurality of superabrasive particles on a leveling surface and bonding the plurality of superabrasive particles together with the molten braze such that, upon formation of the superabrasive tool, the plurality of superabrasive particles have been leveled by the leveling surface to an RA value of less than about 40 μm .

[0010] Various methods of arranging the plurality of superabrasive particles are also contemplated. For example, in one aspect arranging the plurality of superabrasive particles may include disposing a spacer layer on the leveling surface and disposing the plurality of superabrasive particles at least partially within the spacer layer such that a portion of each of the plurality of superabrasive particles contact the leveling surface.

[0011] Numerous braze materials having low-melting temperatures are contemplated, all of which are considered to be within the scope of the present invention. Non-limiting examples may include Al, Ag, Sb, Zn, Pb, Cd, Cu, Ti, Bi, Sn, In, Ga, and combinations thereof. The braze materials may also include alloys having low-melting temperatures. Examples may include, without limitation, Al—Si, Babbitt,

Cu—Mg, Al—Cu, Al—Mg, Cu—Zn, Al—Ge, Cu—Sn, Al—Sn, Sn—Zn, Sn—Ti, Sn—Pb, Sn—Cu—Ag, and combinations thereof.

[0012] In one aspect of the present invention, a wetting layer may be applied to the intermediate layer to improve the wetting between the reactive element and the braze. Various wetting layer materials are contemplated, non-limiting examples of which may include Si, Cu, Ni, Cr, and combinations thereof.

[0013] The present invention also provides superabrasive tools comprised of low-melting braze materials. In one aspect, for example, a low-melting point superabrasive tool is provided. The superabrasive tool may include a plurality of superabrasive particles coated with an intermediate layer and bonded together with a braze having a melting point less than about 700° C., the plurality of coated superabrasive particles having tips leveled to an RA value of less than about 40 μm . In another aspect, the tips of the superabrasive particles may have an RA value of less than about 30 μm . In yet another aspect, the tips of the superabrasive particles may have an RA value of less than about 20 μm . In a further aspect, the tips of the superabrasive particles may have an RA value of less than about 10 μm .

[0014] 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

[0015] FIG. 1 is a cross-sectional view of a superabrasive particle disposed in a metal matrix in accordance with one embodiment of the present invention.

[0016] FIG. 2 is a cross-sectional view of a superabrasive particle disposed in a metal matrix in accordance with another embodiment of the present invention.

[0017] FIG. 3 is a cross-sectional view of a superabrasive particle disposed in a metal matrix in accordance with yet another embodiment of the present invention.

[0018] FIG. 4 is a cross-sectional view of a superabrasive tool in accordance with one embodiment of the present invention.

[0019] FIG. 5 is a cross-sectional view of a superabrasive tool in accordance with another embodiment of the present invention.

[0020] FIG. 6 is a cross-sectional view of a superabrasive tool in accordance with yet another embodiment of the present invention.

[0021] FIG. 7 is a cross-sectional view showing a step in the manufacture of a superabrasive tool in accordance with one embodiment of the present invention.

[0022] FIG. 8 is a cross-sectional view showing a step in the manufacture of a superabrasive tool in accordance with another embodiment of the present invention.

[0023] FIG. 9 is a cross-sectional view showing a step in the manufacture of a superabrasive tool in accordance with yet another embodiment of the present invention.

[0024] FIG. 10 is a cross-sectional view showing a step in the manufacture of a superabrasive tool in accordance with a further embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0025] Definitions

[0026] In describing and claiming the present invention, the following terminology will be used in accordance with the definitions set forth below.

[0027] 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 reactive material” includes reference to one or more of such materials.

[0028] 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/mm² 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.

[0029] 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.

[0030] 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, euhebral, 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.

[0031] As used herein “wetting” refers to the process of flowing a molten metal across at least a portion of the surface of a superabrasive particle. Wetting is often due, at least in part, to the surface tension of the molten metal, and may lead to the forming of chemical bonds between the superabrasive particle and the molten metal at the interface thereof, when a reactive element is present.

[0032] As used herein, “chemical bond” and “chemical bonding” may be used interchangeably, and refer to a molecular bond that exert an attractive force between atoms that is sufficiently strong to create a binary solid compound at an interface between the atoms. Chemical bonds involved in the present invention are typically carbides in the case of diamond superabrasive particles, or nitrides or borides in the case of cubic boron nitride.

[0033] As used herein, “coat,” “coating,” and “coated,” with respect to a superabrasive grit or particle, refers to an area along at least a portion of an outer surface of the particle that has been intimately contacted with a reactive metal, or reactive metal alloy, and that contains chemical bonds between the particle and the alloy, or that will contain such chemical bonds upon the liquification and solidification of the reactive metal, or reactive metal alloy. In some aspects, the coating may be a layer which substantially encases or

encloses the entire superabrasive particle. It is to be understood that such layers are limited in some instances to a certain minimum thickness. Further, it is to be understood that such a coating may be applied to particles on an individual basis, or as a group of particles, and that such a coating may be effected as a separate step made prior to incorporation of the superabrasive particles into a tool, for example, in order to form a tool precursor which can be combined with a support matrix to form certain tools. Moreover, it is possible that a number of coated particles be consolidated together, either with or without additional abrasive particles and used as a tool in and of themselves, without the need for incorporation into a support matrix.

[0034] 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.

[0035] 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.

[0036] 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.

[0037] As used herein, the term “profile” refers to a contour above a solidified braze layer surface to which the superabrasive particles are intended to protrude.

[0038] 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.

[0039] 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.

[0040] 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).

[0041] 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.

[0042] 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.

[0043] As used herein, “grid” means a pattern of lines forming multiple squares.

[0044] 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.

[0045] 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.

[0046] 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.

[0047] 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.

[0048] 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.

[0049] The Invention

[0050] The present invention provides low-melting point superabrasive tools 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 according to aspects 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. As has been discussed, superabrasive tools that are constructed with traditional molten braze materials are necessarily made at high temperatures that often warp the tool. Such warpage causes movements in the relative positions of the superabrasive particles as the tool cools. It is thus very difficult to obtain precise leveling of the tips of superabrasive particles in such tools for applications requiring very precise polishing. It has now been found that the variance between the tip heights of a plurality of superabrasive particles in a tool can be greatly reduced by utilizing a braze having a low-melting point to bond the superabrasive particles. Such low-melting point braze materials do not generate significant warpage due to the lower temperatures utilized to construct the tool. In addition, the inventor has also discovered that precisely leveling the tips of the plurality of superabrasive particles in the tool reduces the mechanical stress impinging on any individual superabrasive particle, thus counteracting the relatively lower retention strength of many low-melting point brazes as compared to traditional braze alloys. By reducing such impinging stress, superabrasive particles can be more readily retained in the solidified braze, particularly when used for delicate tasks.

[0051] Accordingly, in one aspect of the present invention a method for making a low-melting point superabrasive tool having a plurality of superabrasive particles is provided. Such a method may include coating each of the plurality of superabrasive particles with an intermediate layer that chemically bonds to each of the plurality of superabrasive particles, and bonding together the plurality of superabrasive particles with a molten braze having a melting temperature of less than about 700° C. In another aspect, the plurality of superabrasive particles may be bonded together with a molten braze having a melting temperature of less than about 500° C.

[0052] As is shown in FIG. 1, an intermediate layer 12 is coated onto a superabrasive particle 14 that is then disposed in a low-melting point braze 16. The intermediate layer 12 may be utilized for a variety of non-limiting purposes. In one aspect, for example, such a coating may improve the retention of the superabrasive particle 14 in the solidified braze

16. In one aspect the intermediate layer 12 may be chemically bonded to the superabrasive particle 12. For example, if the superabrasive particle is diamond and the intermediate layer is titanium (Ti), carbide bonds can be formed between the diamond and the Ti. The formation of carbide bonds can therefore occur at higher temperatures because the intermediate layer is applied to the superabrasive particles prior to incorporation into a superabrasive tool, thus minimizing warping during the manufacture of the tool. As has been suggested, the intermediate layer may also be mechanically bonded to the surface of the superabrasive particle to improve retention in the solidified braze material. Retention may be improved, for example, in those situations wherein the low-melting point braze adheres more strongly to the intermediate layer than to the surface of the superabrasive particle.

[0053] Following incorporation into a superabrasive tool, in one aspect the exposed portions 18 of the intermediate layer 12 protruding from the low-melting point braze 16 may be removed, as is shown in FIG. 2. Removal of the intermediate layer 12 from the superabrasive particle 14 may be accomplished by any method known to one of ordinary skill in the art, including, without limitation, mechanically abrading, sand blasting, chemical etching, etc. In another aspect, the intermediate layer may be left intact following incorporation of the superabrasive particle into a superabrasive tool.

[0054] As has been suggested herein, a plurality of superabrasive particles coated according to aspects of the present invention may be incorporated into superabrasive tools having a variety of configurations. For example, in one aspect, a support substrate 22 may be incorporated into a superabrasive tool as is shown in FIG. 4. Thus the plurality of superabrasive particles 14 coated with an intermediate layer 12 may be metallurgically bonded to the support substrate 22. In another aspect, a plurality of superabrasive particles 14 coated with an intermediate layer 12 may be metallurgically bonded together to form a superabrasive tool lacking a support substrate as shown in FIG. 5. Additionally, superabrasive particles 14 may be disposed along one surface of a superabrasive tool as shown in FIG. 5, or along multiple surfaces as shown in FIG. 6.

[0055] The superabrasive particles used in embodiments of the present invention may be selected from a variety of specific types of diamond and non-diamond materials. The selection of a particular superabrasive material may be somewhat dependent on the selection of the intermediate layer and low-melting braze materials to be used in the tool and vice versa. A given intermediate layer material may wet or bond better to a particular superabrasive material than to another, and such bonding affinity may influence the selection of materials. 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, Al₂O₃, ZrO₂, and WC.

[0056] Superabrasive particles according to various aspects of the present invention may take a number of different shapes and sizes as required to accommodate a specific purpose for the tool into which it is anticipated that they will be incorporated. Superabrasive particle shape may

affect retention as well as cutting characteristics of the superabrasive tool. As such, the selection of superabrasive particle shape for a given tool may depend to some extent on intended use, particularly for those applications requiring specific cutting characteristic or where retention may become problematic. Superabrasive particles may be of any shape known to one of ordinary skill in the art, including, without limitation, triangular, cubic, rectangular, trapezoidal, hexagonal, etc. In one aspect, substantially all of the superabrasive particles of a particular tool may be of a substantially uniform shape. In another aspect, the superabrasive particles incorporated into a superabrasive tool may have a more random shape distribution, with little or no intended uniformity of shape of the superabrasive particles across the surface of the tool. In yet another aspect, various shapes of superabrasive particle may be used in the same tool. For example, different shapes may be distributed in different regions of a superabrasive tool. In a spinning disk, for example, it may be beneficial to locate square or blocky particles near the center of the disk where the rotational velocity is lower, and more slender particles with defined cutting edges near the periphery where the rotational velocity is greater. In this way, the shape of the superabrasive particles may be selected to equalize the mechanical stress impinging on each particle as a function of physical location on the tool. Additionally, superabrasive particles having specific shapes can be located at particular locations on the tool in order to produce particular cutting patterns.

[0057] Similar to superabrasive particle shape, the size of particles incorporated into a tool may vary depending on intended use. In some cutting or polishing operations a high level of uniformity in the tool pattern may not be required or desired. For example, in one aspect the superabrasive particles may have no intended size distribution across the surface of the tool. In another aspect, substantially all of the superabrasive particles incorporated into the superabrasive tool may be of substantially the same size. In another aspect, various sizes of superabrasive particles may be located at specific locations across the surface of the superabrasive tool. Such partitioning of superabrasive particles according to size may equalize the mechanical stress impinging on each of the superabrasive particles across the surface of the tool, and thus may be used to increase overall retention of the particles. In a spinning disk, for example, larger superabrasive particles may be located more centrally and smaller superabrasive particles may be located more peripherally in order to counteract location-dependent variations in mechanical stress associated with rotational velocity. Such partitioning may also be utilized to produce a particular cutting pattern in a work piece. Although a variety of sizes are contemplated, in one aspect the plurality of superabrasive particle may be from about 5 microns to about 500 microns in size. In another aspect, the plurality of superabrasive particles may be from about 30 microns to about 200 microns. In yet another aspect the plurality of superabrasive particles may be from about 100 microns to about 200 microns in size. In a further aspect, the plurality of superabrasive particles may be from about 5 microns to about 50 microns.

[0058] The intermediate layers according to various aspects of the present invention may include any material known that may improve the bonding between the superabrasive particles and the low-melting braze material. In one aspect, the intermediate layer may include a reactive element

capable of forming chemical bonds with the superabrasive particle, regardless of whether or not chemical bonds are actually formed during the manufacture of the superabrasive tool. Various reactive elements are known that are capable of forming chemical bonds with various superabrasive materials. Particular reactive elements may bond more favorably with particular superabrasives. For example, in one aspect the intermediate layer may include a reactive element that is a carbide former. Carbide formers are capable of forming chemical bonds with carbon-containing superabrasive materials such as diamond. Examples of carbide formers may include, without limitation, aluminum (Al), boron (B), chromium (Cr), lithium (Li), magnesium (Mg), molybdenum (Mo), manganese (Mn), niobium (Nb), silicon (Si), tantalum (Ta), titanium (Ti), vanadium (V), tungsten (W), zirconium (Zr), and combinations thereof. In one specific aspect the carbide former may include Ti, and thus be capable of forming TiC bonds with a superabrasive material such as diamond. In another specific aspect, the carbide former may include Si, and thus be capable of forming SiC bonds with the superabrasive material. In one specific aspect, for example, the intermediate layer may be Si and the braze material may be Al—Si. Intermediate layers including carbide formers may typically be formed by conventional methods, such as the solid state and vapor deposition techniques discussed herein.

[0059] Intermediate layers may also include reactive elements that are nitride formers, and thus are capable of forming chemical bonds with nitride-containing superabrasive materials such as cBN. Examples of nitride formers may include, without limitation, Al, B, Cr, Li, Mg, Mo, Mn, Nb, Si, Ta, Ti, V, W, Zr and combinations thereof. In one specific aspect the nitride former may include Al, and thus be capable of forming AlN bonds with a superabrasive material such as cubic boron nitride. In another specific aspect, the nitride former may include Si, and thus be capable of forming SiN bonds with the superabrasive material. As with carbide formers, intermediate layers including nitride formers may typically be formed by conventional methods, such as the solid state and vapor deposition techniques discussed herein.

[0060] Many low-melting point alloys may not wet and thus not bond well to many intermediate layer elements. As is shown in FIG. 3, in these situations it may be beneficial to an additional layer, such as a wetting layer 20, to the intermediate layer 12 in order to facilitate increased interaction with the low-melting braze 16. The selection of wetting layer materials may thus depend on the compositions of the intermediate and the superabrasive materials. Suitable wetting layer materials may include, without limitation, Si, Cu, Ni, Cr, and combinations thereof. For example, intermediate layers containing Ti may not be wet effectively by various low-melting braze materials. In one aspect, wetting can be improved, however, by coating the intermediate layer with a wetting layer including Si, particularly when utilizing Si-containing braze materials such as Al—Si. The thickness of the wetting layer may vary widely depending on the particular manufacturing techniques used, and the intended use of the resulting superabrasive particles. In one aspect, however, the wetting layer may be about 1 micron thick. In another aspect, the wetting layer may be from about 0.1 micron to about 5 microns thick. In another aspect, the wetting layer may be less than about 1 micron thick.

[0061] The intermediate layer-coated superabrasive particles may be formed into a tool or bonded to a support matrix with a low-melting point braze. As has been described, the use of a low-melting point braze allows a superabrasive tool to be formed at lower temperatures, and thus the leveling of the tips of the incorporated superabrasive particles may be maintained in the finished tool. In one aspect low-melting is intended to describe any braze material that is capable of melting and forming a tool at temperatures below about 700° C. In another aspect, low-melting is intended to describe any braze material that capable of melting and forming a tool at temperatures below about 500° C.

[0062] With respect to specific materials, any low-melting point braze material known that is capable of retaining coated superabrasive particles may be used to construct the superabrasive tools according to aspects of the present invention. In one aspect, the low-melting point braze material may be substantially a single metal having a low-melting point. Non-limiting examples of such materials may include Al, Ag, Sb, Zn, Pb, Cd, Cu, Tl, Bi, Sn, In, Ga, and combinations thereof. A few single metal braze materials are shown in Table I, along with their approximate melting temperatures.

TABLE I

Braze Material	Melting Point (C.°)
Al	660.5°
Sb	630.8°
Zn	420.0°
Pb	327.5°
Cd	325.1°
Tl	304.0°
Bi	271.4°
Sn	232.0°
In	156.6°
Ga	29.8°

[0063] In another aspect of the present invention, low-melting point braze materials may include braze alloys. Alloying at least two metals or a metal with a non-metal generally decreases the melting point of the alloy, thus greatly expanding the number of available materials that can be utilized to construct a superabrasive tool. The components and exact ratios of the braze alloy may be selected to provide an alloy that has a melting point within a desired range for a particular superabrasive tool being constructed. In practice, at least two braze materials may be selected and combined in proper amounts to reduce the melting temperature of both materials and yield a braze alloy having a melting temperature of less than about 700° C. In yet another aspect, the melting temperature may be below about 500° C. Such alloys may be binary, ternary, or other multi-component alloys. Non-limiting examples of such braze alloys may include Al—Si, Babbitt, Cu—Mg, Al—Cu, Al—Mg, Cu—Zn, Al—Ge, Cu—Sn, Al—Sn, Sn—Zn, Sn—Tl, Sn—Pb, Sn—Cu—Ag, and combinations thereof. A few examples of such alloys are shown in Table II. The wt % is provided in Table II for the first named element in the metal alloy, unless otherwise indicated.

TABLE II

Metal Alloy	Wt %	Melting Point (C.°)
Al—Si	12.6	577°
Babbitt Alloy	—	480°
Cu—Mg	60	457°
Al—Cu	32	548.2°
Al—Mg	85–10	437–450°
Cu—Zn	99.3	425°
Al—Ge	51.6	420.0°
Sn—Pb	5	312°
Cu—Sn	99.3	227°
Al—Sn	99.4	220°
Sn—Cu—Ag	0.8 (Cu) 0.7 (Ag)	208°
Sn—Zn	91.2	198.5°
Sn—Tl	43	168°

[0064] As will be recognized by those of ordinary skill in the art, numerous combinations of specific braze materials may be alloyed in different ratios or amounts to achieve an alloy that bonds to the reactive element coating of the superabrasive particle, and that has a suitable melting point.

[0065] As has been discussed, the use of braze materials having a lower melting temperature reduces problems associated with warping, but tends to increase the likelihood of superabrasive particles pulling out of the tool during use. Retention of superabrasive particles in the braze matrix may be improved by arranging the superabrasive particles in the solidified braze such that mechanical stress impinging on any individual superabrasive particle is minimized. By minimizing such stresses, superabrasive particles can be more readily retained in the solidified braze, particularly for use in delicate tasks.

[0066] 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 all superabrasive particles. Such a uniform distribution of frictional force prevents any individual superabrasive particle from being overstressed and pulling out of the solidified braze layer.

[0067] Various configurations or arrangements are contemplated for minimizing the mechanical stress impinging on the superabrasive particles held in a tool. One potentially useful parameter may include the height that the superabrasive particles protrude above the solidified braze layer. A superabrasive particle that protrudes to a significantly greater height as compared to other superabrasive particles will experience a greater proportion of the impinging mechanical forces, and is thus more prone to pull out of the solidified braze layer. Thus an even height distribution of superabrasive particles may function to more effectively preserve the integrity of the superabrasive tool as compared to tools lacking such an even height distribution. Accordingly, the superabrasive particle tips may be leveled to spread the mechanical forces impinging on the tool across substantially all of the particles. In one aspect, for example, the plurality of superabrasive particles may be arranged on a leveling surface and bonded together with the molten braze such that, upon formation of the superabrasive tool, the plurality of superabrasive particles have been leveled by the leveling surface to an RA value of less than about 40 μm . In another aspect, the tips of the superabrasive particles may be leveled to an RA value of less than about 30 μm . In yet

another aspect, the tips of the superabrasive particles may be leveled to an RA value of less than about 20 μm . In a further aspect, the tips of the superabrasive particles may be leveled to an RA value of less than about 10 μm .

[0068] It should also be noted that mechanical forces impinging on leveled superabrasive particle tips may also be somewhat dependent on superabrasive particle spacing. In other words, the greater the distance separating superabrasive particles, the more the impinging forces will affect each superabrasive particle. As such, patterns with increased spacing between the superabrasive particles may benefit from even smaller variations from a predetermined height.

[0069] It may also be beneficial for the superabrasive particles to protrude from the solidified braze 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 superabrasive 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.

[0070] 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. For example, 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 peripheral locations. 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 braze 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.

[0071] 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. Superabrasive particles may be aligned along various designated profiles by any means known to one of ordinary skill in the art. In one aspect, however, the superabrasive particles may be arranged along a leveling surface that has a shape corresponding to a particular designated profile.

[0072] 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 is 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 is 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 arranged such that their tips vary from the designated profile to less than about 10% of the average size of the superabrasive particles.

[0073] 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 tool are larger in size than superabrasive particles in a peripheral location on the tool. In

another aspect, superabrasive particles in a central location of the tool may be smaller than superabrasive particles in a peripheral location on the 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 solidified braze 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 particles 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.

[0074] Variations in the attitude of superabrasive particles in the solidified braze layer may also function to more effectively distribute frictional forces across the tool. Orienting superabrasive particles in particular locations of the 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 braze 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 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 tool. For example, in one aspect superabrasive particles in a central location on the 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 tool may be configured with a face oriented towards the work piece. In another aspect, superabrasive particles in a central location on the tool may be configured with an apex portion oriented towards a work piece, superabrasive particles in a peripheral location on the tool may be configured with a face oriented towards the work piece, and superabrasive particles in a middle location on the tool may be configured with an edge oriented towards the work piece.

[0075] 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.

[0076] The distribution of frictional forces may also be varied through the arrangement or distribution of the superabrasive particles in the solidified braze 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 particles 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 spaced 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 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 particles depending on location to more effectively distribute frictional forces across the tool. In one aspect, for example, superabrasive particles in a peripheral location on the tool may be spaced farther apart than superabrasive particles in a central location on the 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 tool.

[0077] Various methods for making a superabrasive tool according to embodiments of the present invention are contemplated. In those aspects where strong chemical bonding is desired at the surface of the superabrasive particles, the intermediate layer can be applied to the superabrasive particles and chemical bonds can be formed therebetween prior to leveling the superabrasive particle tips. In other words, heat used to create chemical bonding is applied prior to incorporating the superabrasive particles into the tool so that warping can be minimized.

[0078] Various methods of disposing superabrasive particles on a substrate are contemplated, all of which would be considered to be within the scope of the present invention. For example, superabrasive particles may be disposed according to an arranged pattern 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.

[0079] 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 ori-

ented away from the plane of the braze 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 temporary spacer material. Accordingly, the tips of the superabrasive particles will have the same orientation or attitude.

[0080] In another aspect, it may be desired to orient apexes and edges away from the plane of the braze 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 $\frac{1}{2}$ 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 work piece during abrading or dressing.

[0081] Following manufacture of such a tool in a braze matrix, a portion of the braze can be removed along with the sieve to expose the superabrasive particles. Care should be taken, however, to carefully control the amount of braze 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 in the case of CMP pad dressers.

[0082] Various reverse casting methods may be utilized to manufacture the superabrasive tools, and particularly the CMP pad dressers according to aspects of the present invention. As shown in FIG. 7, a spacer layer 32 may be applied to a working surface 34 of a temporary substrate 36. Intermediate layer-coated superabrasive particles 30 may be disposed at least partially into the spacer layer 32, such that they protrude at least partially from the spacer layer 32 opposite the working surface 34 of the temporary substrate 36. 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. A fixative may be optionally applied to the working surface 34 to facilitate the attachment of the spacer layer 32 to the temporary substrate 36. A fixative may also be optionally applied to the spacer layer 32 to hold the superabrasive particles 30 essentially immobile along the spacer layer 32. 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 paraffin, a phenolic resin, a wax emulsion, an acrylic resin, or combinations thereof. In one aspect, the fixative is a sprayed acrylic glue.

[0083] A press may be utilized to apply force to the superabrasive particles in order to dispose the superabrasive particles into the spacer layer. The press may be constructed of any material known to one skilled in the art able to apply force to the superabrasive particles. 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 to the working surface. In one aspect of the present invention, the press is constructed of a porous rubber. A press constructed from a softer material such as a hard rubber, may conform slightly to the shape of the superabrasive particles, and thus more effectively push smaller as well as larger superabrasive particles through the spacer layer to the working surface.

[0084] 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 paraffin, a phenolic resin, a wax emulsions, an acrylic resin, and combinations thereof.

[0085] Referring now to FIG. 8, a low-melting point braze may be applied to the spacer layer 32 opposite the working surface 34 of the temporary substrate 36. A mold may be utilized to contain the low-melting point braze during manufacture. Upon solidifying the braze material, a low-melting point braze matrix 38 is formed, bonding at least a portion of each superabrasive particle 30. In some aspects, a permanent substrate may be coupled to the low-melting point braze matrix 38 to facilitate its use as a superabrasive tool.

[0086] As shown in FIG. 9, the spacer layer and the temporary spacer layer have been removed from the low-melting point braze matrix 38 to expose the superabrasive particles 30. This may be accomplished by peeling, grinding, sandblasting, scraping, rubbing, abrasion, etc. The distance of the protrusion of the superabrasive particles 30 from the low-melting point braze matrix 38 will be approximately equal to the thickness of the now removed spacer layer. The braze material may be etched, sandblasted or abraded to further expose the superabrasive particles. Additionally, a portion of the intermediate layer may be removed as described herein in order to expose a portion 40 of the surface area of the superabrasive particles 30, as is shown in FIG. 10.

[0087] 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 braze material during the manufacture of the tool, and thus the braze material may wick up the sides of the superabrasive particle. 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 braze matrix surrounding each superabrasive particle. This slight concave depression may decrease retention, resulting in premature superabrasive grit pullout from the braze matrix.

[0088] The temporary substrate may be made of any material capable of supporting the braze material and withstanding the temperatures experienced during manufacture. Example materials include glasses, metals, woods, ceramics, polymers, rubbers, plastics, etc. Additionally, the working surface of the temporary substrate may be of any shape beneficial to the construction of a superabrasive tool. Accordingly, the working surface may be level, sloped, flat, curved, or any other shape that would be useful in the manufacture of a CMP pad dresser or other superabrasive tool. Additionally, the working surface may be roughened to improve the orientation of the superabrasive particles as has been described herein. 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 braze matrix. 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 braze matrix.

[0089] Due to the soft nature of many low-melting point braze materials, it may also be beneficial to utilize a reinforcing material to improve the retention of the superabrasive particles. For example, in one aspect the superabrasive particles may be disposed or packed in a reinforcing material such as silica and then infiltrated with the molten braze material. It should be noted that any reinforcing material that improves the retention of the superabrasive particles in a braze material should be considered to be within the present scope.

[0090] 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.

1. A method for making a low-melting point superabrasive tool having a plurality of superabrasive particles, comprising:

coating each of the plurality of superabrasive particles with an intermediate layer that bonds to each of the plurality of superabrasive particles;

arranging the plurality of superabrasive particles on a leveling surface; and

bonding together the plurality of superabrasive particles with a molten braze that has a melting temperature of less than about 700° C.

2. The method of claim 1, wherein upon formation of the superabrasive tool, the plurality of superabrasive particles have been leveled by the leveling surface to an RA value of less than about 40 μ m.

3. The method of claim 2, wherein the leveling surface is removed from the superabrasive tool.

4. The method of claim 2, wherein arranging the plurality of superabrasive particles further comprises:

disposing a spacer layer on the leveling surface; and

disposing the plurality of superabrasive particles at least partially within the spacer layer such that a portion of each of the plurality of superabrasive particles contact the leveling surface.

5. The method of claim 1, wherein the plurality of superabrasive particles are mechanically bonded together with the molten braze.

6. The method of claim 1, wherein the plurality of superabrasive particles are chemically bonded together with the molten braze.

7. The method of claim 1, wherein the plurality of superabrasive particles are bonded together with a molten braze that has a temperature of less than about 500° C.

8. The method of claim 1, wherein the plurality of superabrasive particles includes diamond.

9. The method of claim 8, wherein the intermediate layer includes a carbide former.

10. The method of claim 9, wherein the carbide former includes a member selected from the group consisting of aluminum (Al), boron (B), chromium (Cr), lithium (Li), magnesium (Mg), molybdenum (Mo), manganese (Mn), niobium (Nb), silicon (Si), tantalum (Ta), titanium (Ti), vanadium (V), tungsten (W), zirconium (Zr), and combinations thereof.

11. The method of claim 9, wherein the carbide former includes Ti.

12. The method of claim 9, wherein the carbide former includes Si.

13. The method of claim 1, wherein the plurality of superabrasive particles includes cubic boron nitride.

14. The method of claim 13, wherein the intermediate layer includes a nitride former.

15. The method of claim 14, wherein the nitride former includes a member selected from the group consisting of aluminum (Al), boron (B), chromium (Cr), lithium (Li), magnesium (Mg), molybdenum (Mo), manganese (Mn), niobium (Nb), silicon (Si), tantalum (Ta), titanium (Ti), vanadium (V), tungsten (W), zirconium (Zr), and combinations thereof.

16. The method of claim 1, wherein the braze includes a member selected from the group consisting of Al, Ag, Sb, Zn, Pb, Cd, Cu, Tl, Bi, Sn, In, Ga, and combinations thereof.

17. The method of claim 1, wherein the braze is an alloy including a member selected from the group consisting of Al-Si, Babbitt, Cu-Mg, Al-Cu, Al-Mg, Cu-Zn, Al-Ge, Cu-Sn, Al-Sn, Sn-Zn, Sn-Ti, Sn-Pb, Sn-Cu-Ag, and combinations thereof.

18. The method of claim 17, wherein the braze alloy includes Al-Si.

19. The method of claim 17, wherein the braze alloy includes Sn-Cu-Ag.

20. The method of claim 1, further comprising applying a wetting layer to the intermediate layer to improve the wetting between the intermediate layer and the braze.

21. The method of claim 20, wherein the wetting layer includes a member selected from the group consisting of Si, Cu, Ni, Cr, and combinations thereof.

22. The method of claim 20, wherein the intermediate layer is Ti, the wetting layer is Si, and the braze is Al-Si.

23. The method of claim 1, wherein the intermediate layer is Si and the braze is Al-Si.

24. The method of claim 1, wherein the braze is substantially free of Cu.

25. The method of claim 2, wherein the tips of the superabrasive particles are leveled to an RA value of less than about 30 μm .

26. The method of claim 2, wherein the tips of the superabrasive particles are leveled to an RA value of less than about 20 μm .

27. The method of claim 2, wherein the tips of the superabrasive particles are leveled to an RA value of less than about 10 μm .

28. The method of claim 2, wherein the superabrasive particles are leveled to a predetermined height that is along a designated profile.

29. A low-melting point superabrasive tool, comprising: a plurality of superabrasive particles coated with an intermediate layer and bonded together with a braze

having a melting temperature of less than about 500° C. said plurality of coated superabrasive particles having tips leveled to an RA value of less than about 40 μm .

30. (canceled)

31. The superabrasive tool of claim 29, wherein the tips of the superabrasive particles have an RA value of less than about 30 μm .

32. The superabrasive tool of claim 29, wherein the tips of the superabrasive particles have an RA value of less than about 20 μm .

33. The superabrasive tool of claim 29, wherein the tips of the superabrasive particles have an RA value of less than about 10 μm .

34. The superabrasive tool of claim 29, wherein the plurality of superabrasive particles are of substantially the same size.

35. The superabrasive tool of claim 29, wherein the plurality of superabrasive particles are from about 30 microns to about 500 microns in size.

36. The superabrasive tool of claim 29, wherein the plurality of superabrasive particles are from about 100 microns to about 200 microns in size.

37. The superabrasive tool of claim 29, wherein the plurality of superabrasive particles are less than about 100 microns in size.

38. The superabrasive tool of claim 29, wherein the superabrasive tool is a polishing or grinding pad.

39. The superabrasive tool of claim 29, wherein the superabrasive tool is a CMP pad dresser.

40. The superabrasive tool of claim 29, wherein the superabrasive tool is for shaping dental materials.

41. The superabrasive tool of claim 29, wherein the superabrasive particles protrude to a predetermined height that is along a designated profile.

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