The present invention provides for an assembly for positioning and holding abrasive particles to be electroplated with a metal. The assembly can include a substrate with a surface that is configured for receiving abrasive particles. The assembly can further include an intermediate layer configured to hold the particles and mask at least a portion of each abrasive particle. Additionally, a method for making an abrasive tool using such an assembly is provided, as well as abrasive tools made thereby. In one aspect of this invention, abrasive tools can have abrasive particle tips that are arranged in accordance with a predetermined vertical pattern and a predetermined horizontal pattern as well as a predetermined particle attitude.

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**Electroplating**  
Ni

**Stripping**

**Casting**

**Removing**
EDD Manufacturing Example 2

Roughening

Neting

Gluing

Shielding

Planting

Pressing with Rubber Pad
EDD Pad Conditioner with Leveled and Oriented Diamond Crystals
EDD Manufacturing Example 1

Knerling

Stamper/Roller (e.g. steel)
Polymer (e.g. PET)

Gluing

Adhesive

Transfering

Low Sticking Tape

Diamond (Patterned)
Electroplating

Stripping

Casting

Finishing

EDD (Sharp Tip Grid)
ELECTROPLATED ABRASIVE TOOLS, METHODS, AND MOLDS

FIELD OF THE INVENTION

[0001] The present invention relates generally to electroplated abrasive tools and methods for making electroplated abrasive tools. Accordingly, the present invention involves the fields of electrochemistry, materials science, and physics.

BACKGROUND OF THE INVENTION

[0002] Abrasive tools have long been used in numerous applications, including the cutting, drilling, sawing, grinding, lapping, and polishing of materials. One common form of an abrasive tool is one that uses abrasive particles on a tool substrate to perform the cutting, grinding, polishing, etc.

[0003] Superabrasive particles, such as diamond, polycrystalline diamond (PCD), cubic boron nitride (CBN), and polycrystalline cubic boron nitride (PCBN) have been widely used for many materials removal applications due to their extreme hardness, atomic density, and high thermal conductivity. For example, dressing disks, grinding disks, saw blades, wire saws, and drill bits have all included superabrasive particles attached to a substrate.

[0004] Despite their apparent advantages, a number of issues continue to hamper the performance and usable life of many known superabrasive tools. For example, superabrasive particle placement and retention remain problematic. One additional issue is the height to which a superabrasive particle extends above the tool substrate. For many applications, it is advantageous to have all particles extend to a substantially uniform height above the tool substrate. In many instances, uniform particle height can help evenly distribute work load on the particles and thereby help improve particle retention. In other cases, it may be advantageous to have the particles extend to varying heights above the tool substrate according to a predetermined vertical pattern.

[0005] Many methods have been employed for the fabrication of superabrasive tools, such as brazing, hot pressing, infiltration, and electroplating among others. However, most of such methods are unable to produce a tool with the above-recited superabrasive particle placement characteristics. Further, tools made by most known methods require post fabrication processing in order to obtain a working surface with suitable characteristics, such as proper particle exposure.

[0006] As a result, abrasive tools and methods for making abrasive tools which allow accurate horizontal and vertical placement of abrasive particles, and that can achieve a suitable working surface with little or no post fabrication processing continue to be sought.

SUMMARY OF THE INVENTION

[0007] Accordingly, the present invention provides abrasive tools having particles arranged according to both vertical and horizontal patterns and particle attitude, and which can require little or no post electro deposition processing, as well as methods for the manufacture and use thereof. The present invention additionally provides devices for use as a part of such manufacturing processes.

[0008] In one aspect, the present invention provides an assembly for positioning and holding abrasive particles to be electroplated with a metal. The assembly can include a substrate with a surface configured for receiving abrasive particles and an intermediate layer configured to hold the particles on the substrate and mask a portion of each abrasive particle. In one aspect, the substrate can include at least one indentation. Such indentations can be in the form of scratches or lines carved into the substrate, discrete dimples, or impressions formed by elevating selected portions of the substrate surface. The indentations can be capable of orienting in and in some aspects, holding abrasive particles in a predetermined attitude and location. In one embodiment, the assembly can further comprise a plurality of abrasive particles engaged in the substrate and intermediate layer, in some embodiments, at predetermined attitudes and locations. The assembly can be placed in an aqueous electroplating environment. When placed in such environment, the assembly can retain the engaged and masked abrasive particles at the predetermined attitudes and locations.

[0009] In another aspect, methods are provided for making a tool that has a plurality of oriented abrasive particles coupled to a substrate by an electrodeposited material. The method may include providing an assembly as outlined above and securing a plurality of abrasive particles to the assembly so that at least a portion of each of the particles is masked by the intermediate layer. The method can further include coating exposed portions of the abrasive particles with an electrically conductive material. Further, a metal can be electrodeposited around the unmasked portions of the particles.

[0010] In yet another aspect, the present invention includes abrasive tools that, in some aspects, can be produced by the methods recited herein. Such tools generally include a plurality of abrasive particles attached by an electrodeposited material. This plurality of abrasive particles can have a portion of each abrasive particle exposed above the electrodeposited material, which has never been covered by the electrodeposited material. Further, the plurality of abrasive particles can each be arranged in accordance with a predetermined attitude and location and further arranged in a predetermined vertical pattern.

[0011] In still another aspect, the present invention includes methods of producing a tool with a working surface wherein the overall contours of the surface, exposure of abrasive particles above electroplated material, and even particle orientation is predetermined. This general contour of the tool can correspond to the contour of the substrate of the apparatus. The exposed portion of the particles, as masked by the intermediate layer, directly corresponds to the exposed portion of the working tool. Further, the particles can be oriented in the apparatus and held by the intermediate layer in a predetermined orientation during electroplating which will be the particle orientation of the working tool.

[0012] The above-recited features and advantages of the present invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIGS. 1a through 1g are various views showing a series of steps for making a tool in accordance with an embodiment of this invention;

[0014] FIG. 1a is a cross-sectional view of a first piece of a substrate in accordance with an embodiment of this invention;

[0015] FIG. 1b is a cross-sectional view of a substrate having indentations in accordance with an embodiment of this invention;
FIG. 1c is a cross-sectional view showing an assembly including a substrate and an intermediate layer in accordance with an embodiment of this invention;

FIG. 1d is a cross-sectional view showing an assembly including a template in accordance with an embodiment of this invention;

FIG. 1e is a cross-sectional view showing placement of abrasive particles on the assembly in accordance with an embodiment of this invention;

FIG. 1f is a cross-sectional view of the assembly with abrasive particles and a layer of electrodeposited metal in accordance with an embodiment of this invention;

FIG. 1g is a cross-sectional view of a tool including a tool backing in accordance with an embodiment of this invention;

FIGS. 2a through 2h are various views showing a series of steps for making a tool in accordance with another embodiment of this invention;

FIG. 2a is a cross-sectional view of a substrate showing creation of indentations or dimples in the substrate in accordance with another embodiment of this invention;

FIG. 2b is a cross-sectional view showing an assembly including a substrate with indentations and an intermediate layer in accordance with another embodiment of this invention;

FIG. 2c is a cross-sectional view of placement of abrasive particles on the assembly in accordance with another embodiment of this invention;

FIG. 2d is a cross-sectional view of orienting the abrasive particles to a predetermined attitude in accordance with an embodiment of this invention;

FIG. 2e is a cross-sectional view of coating the unmasked abrasive particles and part of the intermediate layer with an electrically conductive material, in accordance with an embodiment of this invention;

FIG. 2f is a cross-sectional view of the assembly with abrasive particles and a layer of electrodeposited metal in accordance with an embodiment of this invention;

FIG. 2g is a cross-sectional view of the tool with the assembly with the assembly removed in accordance with an embodiment of this invention; and

FIG. 2h is a cross-sectional view of the tool with a backing in accordance with an embodiment of this invention.

The above figures are provided for illustrative purposes only. It should be noted that actual dimensions of layers and features may differ from those shown.

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.

The singular forms "a," "an," and "the" include plural referents unless the context clearly dictates otherwise. Thus, for example, reference to "an abrasive particle" includes reference to one or more of such particles.

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

The term "indentation" refers to a depression into a substrate into which a portion of a particle can impress. The indentation can be capable of providing direction to orient a particle. An indentation can further be capable of at least partially holding the particle. Indentations can be in the form of scratches or lines, scores, discrete dimples or other shapes, or any combination thereof. Indentations can be formed by carving, scratching, punching, indenting, or otherwise compressing or removing material from a substrate. Also, indentations can be formed by elevating selected portions of the substrate surface, or adding material to a substrate surface, including a screen, mesh, or template with apertures.

As used herein, "insulating material" refers to a material or materials that can be used to form a mask in such a way as to effectively prevent accumulation of electrodeposited material on the masked surface.

As used herein, "predetermined pattern" refers to a non-random arrangement of either abrasive particles or apertures that can be determined prior to fabrication of a tool or device including such particles or apertures.

As used herein, "horizontal pattern" refers to an arrangement of either abrasive particles, apertures, or dimples across a surface to which they are, or are to be, attached, filtered-through or placed.

As used herein, "vertical pattern" refers to an arrangement of heights to which the exposed portions of abrasive particles extend above the working surface of a tool or tool substrate.

As used herein, "working surface" refers to the surface of a tool or tool substrate that, during operation, faces toward, or comes in contact with a work piece that is being polished, grinded, sanded, etc.

As used herein, "lattice" refers to a horizontal pattern in which the abrasive particles are equidistant from neighboring abrasive particles or, in the case of apertures, the apertures are equidistant from neighboring apertures.

As used herein, "post electrodeposition processing" refers to the dressing or grinding required in some conventional methods to expose the working surface of a tool.

As used herein, "mid-portion," when used in connection with abrasive particles, refers to a portion of the particle located between a first horizontal plane intersecting the top most point or end of the particle, and a second horizontal plane intersecting the bottom most point or end of the particle. In some cases the mid-point may include the portion which extends between 5%–95% of the full length between the top most point and bottom most point. In other cases, a mid-portion can include a middle ½ (i.e. from 25%–75% of the full length between the top most point and bottom most point). In yet other cases, the mid-point may be substantially half way between the top most point and bottom most point. However, a top most or bottom most point is not included in the mid-point.

As used herein, "end" when used in connection to abrasive particle refers to either the top most or bottom most portion thereof.
As used herein, “progresses” in reference to electrodeposition refers to the process wherein metal is deposited and then builds or proceeds in an identified direction or manner. Therefore, the metal is initially deposited at a first location and is built towards a second point, thus progressing to the second point.

As used herein, “holding” or “securing” refers to the coupling or supporting of particles in order to prevent the particles from falling from and/or moving on the surface to which they are coupled or supported. For example, in some embodiments, gravity may be sufficient to couple or support the particles to the surface.

As used herein, “template” refers to a device with a plurality of apertures used for positioning abrasive particles onto a substrate in a predetermined pattern. The predetermined pattern can be controlled by the configuration of the apertures on the template. In use, one side of the template can be positioned against the surface of a substrate with or without indentations, and abrasive particles can be spread over the other side. The apertures can be designed so that only one particle will fit in each aperture and fall through to contact the substrate surface. The apertures can also be designed so that it accommodates only particles having a grit size in a specified range. The particles in the apertures can contact the molding surface so that they can be secured thereto. The remaining unsecured particles can then be removed. The template can be removed or remain on the assembly. In one embodiment, the template can remain on the assembly and act as the conductive material. In such arrangement, the template could be electrically conductive. In another embodiment, a template can be used against a backing, such as tape or adhesive, to pre-arrange abrasive particles. The template can be removed and the patterned abrasive particles can be temporarily adhered to the backing. The backing can be used to transfer the pre-arranged particles to the assembly as desired. Once the particles are placed on or over the assembly, the backing can be used to apply force to the abrasive particles that can be used to orient and/or imbed the particles in the intermediate layer and/or on the substrate.

As used herein, “abrasive particle,” means any super hard crystalline, or polycrystalline substance, or mixture of substances and include but are not limited to diamond, polycrystalline diamond (PCD), cubic boron nitride (cBN), and polycrystalline cubic boron nitride (PCBN). Further, the terms “abrasive particle,” “grit,” “diamond,” “polycrystalline diamond (PCD),” “cubic boron nitride (cBN)” and “polycrystalline cubic boron nitride, (PCBN)” may be used interchangeably.

As used herein, “superhard” and “superabrasive” may be used interchangeably, and refer to a crystalline, or polycrystalline material, or mixture of such materials having a Vickers 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.

As used herein, “vibrate” means to oscillate an object, back and forth, up and down, or from side to side, in a rapid movement. Vibrations may be continuous, intermittent, continuously variable, in accordance with a vibrational program, etc. In one aspect, vibrations can be primarily one horizontal or primarily vertical.

As used herein, “electroplating environment” includes electrolytic fluid and current.

As used herein with respect to an identified property or circumstance, “substantially” refers to a degree of deviation that is sufficiently small so as to not measurably detract from the identified property or circumstance.

As used herein in connection with individual numerical numbers or numerical ranges, the term “about” refers to an actual number or range that is slightly above or below the exact value(s) articulated.

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 encompasses electrodeposition methods of making abrasive tools that allow greater control in the arrangement and securing of abrasive particles according to both vertical and horizontal patterns and in attitudinal arrangement, and that require little or no post electrodeposition processing of the working surface of the tool. In other words, the working surface results from the electrodeposition process itself. Applicant has also developed an assembly for use with this method as well as abrasive tools produced by this method.

In accordance with the present invention, an assembly for positioning and holding abrasive particles to be electroplated with a metal can include a substrate configured for receiving abrasive particles. The assembly can further include an intermediate layer configured to hold particles on the substrate and mask a portion of each abrasive particle while the
assembly is in an aqueous electroplating environment. In one aspect, the substrate can include at least one indentation. Such indentations can be capable of orienting and holding the abrasive particles. In a detailed embodiment, the substrate can include at least one dimple. In such case, the assembly can include a surface that has a plurality of dimples capable of orienting and holding abrasive particles in a predetermined attitude and location.

[0062] The substrate can be composed of any material that can be used to assist in orienting and holding abrasive particles. In one embodiment, the substrate can include polymers, such as polyethylene. In the second situation, the substrate can be a single piece of material and the indentations can be areas where material has been removed. Such removal can be the result of systematic stamping, digging, cutting, knurling, etc. FIG. 2a shows a substrate 10 being stamped or rolled with a stamper 20 to produce indentations, in this case in the form of dimples 30, in the substrate. Such stamper, for example, could include or be composed of steel and the substrate could be a softer material such as a polymer. Indentations created by the removal of material from a substrate can include compressing the substrate so as to create the indentations, e.g. dimples.

[0063] In another embodiment, the indentations of the assembly can be created by building up a substrate in a manner so as to form indentations. In one aspect, the substrate can be a plurality of pieces. An example of this embodiment is illustrated in FIGS. 1a-1b. FIG. 1a shows a substrate 40. To the substrate, a material 50 is attached to form indentations, in this case dimples 60. The additional material can be one or a plurality of pieces. The example, the material is one piece. The material can be a variety of shapes and designs. In one aspect, the additional material can produce a horizontal pattern. For example, the additional material can have a plurality of apertures that can form indentations when situated over the top of the solid piece 40.

[0064] The indentations of the substrate can serve to orient and hold abrasive particles in a predetermined attitude and location. The location can be greatly determined by the location and shape of the indentations, although other factors can also determine particle positioning. The shape and size of the indentation can orient an abrasive particle into a predetermined attitude. In another embodiment, the indentations can be of a size smaller than the average apex size of the abrasive particles used. As an abrasive particle can have apexes, edges, and faces, the dimples can be configured to hold one of the apex, edge, or face of an abrasive particle. Further, the indentations can be configured to selectively hold one of the apex, edge, or face of an abrasive particle.

[0065] The substrate of the assembly can directly affect the ultimate profile or shape of a produced abrasive tool. The indentations, along with the intermediate layer can hold and mask a portion of each abrasive particle, and can be removed following electrodeposition of metal. Therefore, the orientation of each particle into the indentations of the substrate, the amount of each particle masked by the assembly, and the horizontal placement of abrasive particles can greatly affect the working surface of a produced abrasive tool. As such, the shape of a vertical pattern to be imparted to a tool can be controlled by configuring the shape of the substrate. In one aspect, the substrate surface can be configured to have a shape that is inverse to a vertical pattern to be imparted to the abrasive particles on a tool substrate. For example, as shown in FIGS. 1a and 2c, the substrate 40 and 10 respectively, can have a surface 70 and 80 respectively, that can be substantially flat. It should be noted that the relative flatness or slope is taken along the overall surface and does not account for the dimples 60 and 30 respectively. In the case of the substrate with material removed to produce indentations, e.g. FIG. 2a dimples, the slope may be determined by the initial slope of the material prior to creation of indentations, assuming the indentations are of substantially uniform depth. Similarly, in the case of a plurality of pieces combining to form the substrate, the slope of the solid piece can determine the slope of the substrate, assuming the piece or pieces added to the solid piece are of a substantially uniform thickness.

[0066] As such, the shape of the substrate surface can be adapted to suit many applications for abrasive tools. For example, the substrate surface can be substantially flat, concave or convex, or it can include both convex and concave portions. In another example, which can be particularly useful for chemical mechanical polishing (CMP) applications, the concave shape of the molding surface can have a slope of about 1/1000, or concavity of about 1/1000. This last example can impart a convex shape with a slope of about 1/100 to the vertical pattern of a polishing tool, which is often desired in CMP applications.

[0067] It should be noted that the vertical patterning can also be affected by the shape, size and depth of the indentations. For example, in one embodiment, the indentations can be arranged in a predetermined horizontal pattern that provides for a clustering of indentations in a central region of the substrate configured to hold apexes. In one aspect, the indentations in the central region of the substrate can have a greater or lesser depth than the areas not in the central region of the substrate. In another embodiment, the indentations can be arranged in a predetermined horizontal pattern wherein a plurality of indentations configured to hold the faces of abrasive particles are arranged along the periphery of the substrate. In a further embodiment, the predetermined horizontal pattern may include a concentration of indentations in a central region of the substrate surface that are configured to hold apexes, a concentration of indentations along the periphery of the substrate surface that are configured to hold faces of abrasive particles, and a plurality of indentations arranged between the two that are configured to hold edges of abrasive particles. In such embodiments, the vertical arrangement of the indentations can create a profile that can be substantially flat, concave or convex, or it can include both convex and concave portions. Further, such design can include a horizontal pattern wherein the area of the apexes is denser, or includes a greater number of abrasive particles than the other regions. As with the slope of the substrate, the vertical pattern of the indentations can have a concavity of about 1/1000. The vertical pattern of the indentations can be determined not only on the depth of the indentations, but also the size and shape of the abrasive particles to be used, as would be apparent to one of ordinary skill in the art.

[0068] As previously mentioned, the assembly also includes an intermediate layer configured to hold the particles and mask at least a portion of each abrasive particle. The intermediate layer can be any material that can hold the particles and mask at least a portion of each. Although not required, in one embodiment, the intermediate layer can be insulating material. In one aspect, the intermediate layer can include an adhesive. FIGS. 1c, 1d and 2d show examples of assemblies with intermediate material. Although not required, each of the examples shown includes a sheet of
continuous material as the intermediate layer. FIG. 1c shows an intermediate layer 90 along the side of the dimpled substrate side 60. FIG. 1d shows an additional intermediate layer 100 resting on the substrate 40. The additional material can be in the form of a template for horizontal positioning of abrasive particles. FIG. 2b illustrates a single and continuous layer of an adhesive material 110 that at least partially fills the dimples 30 of the substrate 10.

[0069] The intermediate layer can be used to control protrusion height. The assembly can be configured to mask a predetermined amount of each abrasive particle, as defined by the thickness of the intermediate layer. In this manner, the abrasive particles can protrude through the intermediate layer to the substrate. The intermediate layer masks a portion of the abrasive particles from electrophoretic deposition. After electrophoresis, the substrate and intermediate layer can be removed. Such removal can include mechanical and/or chemical mechanisms, as well as others, and can include one or a plurality of steps. In a specific embodiment, the intermediate layer can be chemically dissolved and thereby removed from the electrophoretically deposited abrasive particles. Such chemical dissolution is particularly effective when the intermediate layer is or includes an adhesive. In that case, the substrate can be mechanically removed, and a solvent can be used for removal of the intermediate layer in a subsequent step. Once the substrate and intermediate layer are removed, the previously masked portion of the abrasive particles can function as the working surface of a tool. Therefore, the contour of the substrate translates into contours of the working surface of a tool. Additionally, the thickness of the intermediate layer translates into the exposure height of the abrasive particles.

[0070] Ultimately, the area of the abrasive particles that is effectively masked by the assembly will provide the working surface of the abrasive tool, showing portions of the abrasive particles. Therefore, the intermediate layer can be configured to mask various amounts of each abrasive tool. In one embodiment, the intermediate layer can be configured to mask about 5 vol % to about 70 vol % of each abrasive particle. In another embodiment, the intermediate layer can be configured to mask about 20 vol % to about 60 vol % of each abrasive particle. And in yet another embodiment, the intermediate layer can be configured to mask about 30 vol % to about 50 vol %. The intermediate layer, therefore, can be configured to mask nearly any amount of each abrasive particle, e.g. about 5 vol % to about 10 vol %; about 10 vol % to about 20 vol %; about 20 vol % to about 30 vol %; about 30 vol % to about 40 vol %; about 40 vol % to about 50 vol %; about 50 vol % to about 60 vol %; about 60 vol % to about 70 vol %; about 10 vol % to about 30 vol %; and about 50 vol % to about 70 vol %, for example. Such masking can vary according to the intended use, the abrasive particles used, the materials used for the intermediate material(s) and the intended electrophoretic deposited material. Further, the amount of each abrasive particle masked can vary across the assembly. For example, the intermediate layer can be configured to mask some abrasive particles more than others.

[0071] Unlike many methods of electrophoretic deposition, wherein the metal is electrophoretically deposited initially in a tip region, from one end of an abrasive particle, the electrophoretic deposition of the present invention can begin at a mid-portion of the abrasive particle and builds towards an end of the abrasive particle. In the case of masking, the electrophoresis can begin at the masking and build towards the unmasked end. Therefore, the end or periphery portion of each abrasive particle is masked and the metal is initially electrophoretically deposited at a mid- or central portion of each abrasive particle. For example, imagine an abrasive particle having opposing apexes. The first apex can be at least partially masked. Electrodeposition can begin at the masked portion (thus, a mid-portion) and proceed to build metal deposits towards the second apex. This example follows equally for opposing edges or sides. Furthermore, electrodeposition beginning at a mid-portion of the abrasive particle and progressing towards an end thereof works equally with irregularly shaped abrasive particles.

[0072] In one aspect of the present invention, the assembly can further comprise a plurality of abrasive particles engaged in the indentations and intermediate layer at predetermined attitudes and locations. In one embodiment, the abrasive particles can consist or comprise essentially of diamond, polycrystalline diamond (PCD), cubic boron nitride (CBN), and polycrystalline cubic boron nitride (PCBN). In one specific embodiment, the abrasive particles can be diamond particles.

[0073] In another aspect of the invention, a method is provided for making a tool that has a plurality of oriented abrasive particles. In an initial step, a plurality of abrasive particles can be secured to the substrate of the assembly as described herein. The abrasive particles can be secured such that at least a portion of substantially each particle is masked by the intermediate layer. The method can further include coating exposed portions of the abrasive particles with an electrically conductive material, and then electrophoresitically depositing a metal around the unmasked portions of the particles. In one embodiment, the assembly can be removed, revealing a tool, or portion of a tool having abrasive particles attached and/or exposed along the working surface.

[0074] In one embodiment, the method can include positioning the abrasive particles in a predetermined horizontal pattern. Such positioning can include using a template. In one aspect, the template can have apertures spaced in a lattice design. By using a template, the spacing between the particles can be controlled. Such control can provide a number of advantages. For instance, controlled spacing of the abrasive particles can result in increased performance by reducing excessive frictional force (or drag) and heat generation caused during the polishing process. In some applications, it is desired to regularly distribute the abrasive particles over the surface of the tool substrate. For such applications, the template can be used separate and apart from the assembly, or can be included in the assembly as at least part of the intermediate layer. When a template is used that does not remain a part of the assembly for the electrophoresitically depositing step, the template can be used to initially space the abrasive particles. This is the case with FIG. 2c, wherein the abrasive particles 120 are spaced apart using a template, not shown, and the particles, retaining the horizontal patterning, are temporarily secured to an adhesive backing 130. The adhesive backing can be, for example, an adhesive such as tape. The adhesive backing can then transfer the patterned abrasive particles to the assembly 115. Alternatively, the template can be a part of the assembly, as shown in FIG. 1e, wherein the template with apertures 100 is an intermediate layer of the assembly 105. Although horizontal spacing can be useful in some applications, it is not necessary in the present application. For a variety of reasons including time, cost effectiveness, potential application, etc., it may be useful to distribute the abrasive particles in a random manner.

[0075] In one aspect, the particles can be substantially evenly spaced, or at least substantially regionally evenly
spaced (for example central regions, periphery regions, etc.). The even spacing allows for equal concentrations of ions in the electrolytic fluid under electrodeposition conditions, and therefore can lead to substantially equivalent amounts of electrodeposited material securing each particle. This can help minimize particle retention by distributing substantially equal work load to each particle.

[0076] In other embodiments, the template can space the abrasive particles in a pattern that provides for at least one specified area on the assembly surface that has a higher concentration of abrasive particles than the remainder of the assembly surface. This can be particularly useful in CMP applications. For example, it may be desired to have a higher concentration of abrasive particles near the perimeter of a disc-shaped abrasive tool. The perimeter generally spins faster than the center of the disc-shaped tool and often there is more pressure on the leading edge of the disc. Additional patterns and configurations of abrasive particles may be found in Applicant's U.S. Pat. No. 6,884,155, and Applicant's co-pending U.S. patent application having Ser. No. 10/954,956 filed Sep. 29, 2004, each of which are incorporated herein by reference.

[0077] The method includes securing a plurality of abrasive particles to the assembly, such that at least a portion of substantially each particle is masked by the intermediate layer. In one embodiment, this step can include applying an orienting force to the abrasive particles. Such orienting force can include a force in a direction substantially normal to the surface of the substrate. This type of force is shown in FIG. 2d, wherein a press block 150, e.g., rubber sheet, is placed on the adhesive backing 130. A primarily downward force 140 can then be applied to the press block which acts to orient the abrasive particles 120 into a predetermined attitude. In the case wherein the substrate includes indentations, the abrasive particles will move and even rotate into position with the orienting force. Such movement, for example with an apex into a dimple, will alter the portion of the abrasive particle facing up. Using a press block which allows for the retraction of portions of the abrasive particles during orientation can be useful. For example, press blocks including rubber allow for portions of the abrasive particle, e.g., such as an opposite apex, to retract partially into the press block while the primary apex is oriented into the indentation. In this manner, the press block does not prohibit the necessary orientation motion of the abrasive particles, but rather encourages and allows for the movement. In another embodiment, a stiffer material can be used as the press block. In such case, it may be useful to have grooves or other indentations to properly receive portions of the abrasive particles while orienting. An orienting force can additionally or alternatively include a force in a direction substantially parallel to the surface of the substrate. In one embodiment, the force can be a vibrational force.

[0078] As mentioned above, the method for making a tool can include coating exposed portions of the abrasive particles with an electrically conductive material. In one embodiment, substantially all of the exposed portions of the abrasive particles can be coated with an electrically conductive material. In another embodiment, an electrically conductive material can be coated on the intermediate layer not covered with abrasive particles. Such coating is illustrated in FIG. 2e, wherein the electrically conductive material 160, is coated on the exposed abrasive particles 120 and the intermediate layer 110 of the assembly 115. Non-limiting examples of electrically conductive coating materials can include metals, e.g., chromium, silver; electrically conductive polymers, and electrically conductive ceramics. In one aspect, and with the embodiments that retain the template as part of the assembly through the electrodeposition process, the template can have a pre-coating of electrically conductive material. Further, the template can include or consist essentially of electrically conductive material and therefore act as the electrically conductive layer.

[0079] In another aspect, the electrically conductive material can be placed on the assembly prior to the application of abrasive particles. Such electrically conductive material can be placed on the intermediate layer in a manner that can be punctured by the abrasive particles. For example, an adhesive layer of desired thickness with a thin metal or metallic foil backing could be adhered to a substrate. The abrasive particles may then be planted into the adhesive by piercing through the foil. Subsequently, metal grease or other conducting material could be coated around the portions of the particles protruding out of the foil. Such assembly can then be placed in an electroplating bath and electroplated.

[0080] Another method of coating exposed portions of the abrasive particles with an electrically conductive material can include non-conductive electroless plating. Non-conductive electroless plating or coating is formed by the reduction of metal in solution and causes the metal to deposit on non-conducting materials, e.g. abrasive particles such as diamond. Thus, non-conductive electroless plating is distinct from electrodeposited and electrodeposition described for depositing metal on a conductive material. Non-limiting examples of metals that can be used for non-conductive electroless plating include copper and nickel.

[0081] As mentioned, the method includes electrodeposition of a metal around the unmasked portions of the particles. The metal can be selected from any material that can be electrodeposited on the assembly. Non-limiting examples of metals include nickel, chromium, copper, titanium, tungsten, tin, iron, silver, gold, manganese, magnesium, zinc, aluminum, tantalum, or alloys or mixtures thereof. In one specific embodiment, the metal can be nickel. In another embodiment, the metal can be a metallic composite material. In one aspect, such metallic composite materials can include at least one member selected from the group of nickel, chromium, copper, titanium, tungsten, tin, iron, silver, gold, manganese, magnesium, zinc, aluminum, tantalum, or alloys or mixtures thereof. In a specific embodiment, the metallic composite material can include nickel. The electrodeposited metal is illustrated in FIGS. 1f and 2f. In each figure, the electrodeposited metal is represented by the layer 170 of metal.

[0082] To produce a tool with exposed abrasive particles, the assembly can be removed from the electroplated abrasive particles. Such removal can be selected according to the materials of the assembly. In one embodiment, a chemical process can be used. In another embodiment, mechanical means can be used to remove the assembly. FIG. 2g shows the abrasive particles 120 attached by an electrodeposited layer of metal 170. The particles are oriented into a predetermined attitude and provide for a working surface 180 which requires little to no post-electrodeposition processing.

[0083] To more effectively use the abrasive tool, it may be desirable to attach a tool backing to the abrasive particles held by the electrodeposited layer of metal. Referring to FIGS. 2h and 1g, the tool backing 190 can be attached to the tool opposite the working surface 180 and on the electrodeposited surface. Although the composition and dimensions of the
tool backing is greatly dependent on the anticipated use of the tool, in one embodiment, the tool backing can comprise or consist essentially of an epoxy. In further embodiments, a tool substrate can be attached to the epoxy layer.

In another aspect of the invention, a tool is provided which can include a plurality of abrasive particles attached by an electrodeposited material. The material can be stored to secure the abrasive particles to one another. Further, the abrasive particles can each have a portion exposed above the electrodeposited material that has never been covered by electrodeposited material. Further, the abrasive particles can be arranged according to a predetermined vertical pattern. In further embodiments, the particles can be arranged according to a predetermined attitude and even location. Such location arrangement can be a horizontal pattern. This type of tool can provide greater and more even electroplating between particles, and therefore provide a stronger tool less-prone to failure and cracking. Further, this type of tool has better wear and work load distribution, compared to tools without a vertical pattern in abrasive particle exposure.

Such a tool can be produced according to the methods outlined herein. The tool can include a plurality of abrasive particles attached by an electrodeposited material, with a portion of each abrasive particle exposed above the electrodeposited material that has never been covered by the electrodeposited material. The plurality of abrasive particles can be arranged in a predetermined attitude and location and can be further arranged according to a predetermined vertical pattern. The vertical pattern can be uniform height above the substrate, a convex pattern, a concave pattern, or a pattern including both convex and concave areas. The predetermined location of the abrasive particles can be in accordance with a pattern, such as a lattice. Another pattern may include a higher concentration of abrasive particles coupled to a specified area than to other areas. The predetermined attitude of the abrasive particles can be substantially uniform, or can include a plurality of predetermined attitudes. In one embodiment, the predetermined attitude of the abrasive particles can include a selection of at least two of apexes, edges, and faces. For example, a tool can include abrasive particles with edges and apexes oriented towards a working surface. In a further embodiment, the predetermined attitude of the particles can be arranged according to a predetermined horizontal pattern. For example, the predetermined horizontal pattern can include a concentration of apexes in a central region of the tool surface, a concentration of faces along the periphery of the tool surface, and a plurality of edges arranged between the central region and the periphery of the tool surface.

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.

What is claimed is:

1. An assembly for positioning and holding abrasive particles to be electroplated with a metal, comprising:
a substrate having a surface configured for receiving abrasive particles; and
an intermediate layer configured to hold the particles on the substrate and mask a portion of each abrasive particle while the assembly is in an aqueous electroplating environment.

2. The assembly of claim 1, wherein the substrate includes at least one indentation.

3. The assembly of claim 2, wherein the indentations are capable of orienting and holding abrasive particles.

4. The assembly of claim 2, wherein the substrate includes at least one dimple.

5. The assembly of claim 2, wherein the substrate is a single piece of material and the indentations are areas where material has been removed.

6. The assembly of claim 2, wherein the substrate is a plurality of pieces with one piece being a solid piece of material and another having apertures and being situated over the top of the solid piece.

7. The assembly of claim 2, wherein the indentations are of a size smaller than an average apex size of the abrasive particles.

8. The assembly of claim 2, wherein the indentations are configured to hold an apex of an abrasive particle.

9. The assembly of claim 2, wherein the indentations are configured to hold an edge of an abrasive particle.

10. The assembly of claim 1, wherein the indentations are configured to hold a face of an abrasive particle.

11. The assembly of claim 1, further comprising a plurality of abrasive particles engaged in the substrate and intermediate layer.

12. The assembly of claim 11, wherein the abrasive particles are engaged at predetermined attitudes and locations.

13. The assembly of claim 5, wherein the abrasive particles are diamond particles.

14. The assembly of claim 1, wherein the substrate comprises a polymer.

15. The assembly of claim 1, wherein the substrate surface is substantially flat.

16. The assembly of claim 1, wherein the substrate surface is concave.

17. The assembly of claim 16, wherein the concave shape has a slope of about 1/1000.

18. The assembly of claim 1, wherein the substrate surface is convex.

19. The assembly of claim 1, wherein the substrate surface includes both convex and concave portions.

20. The assembly of claim 1, wherein the intermediate layer comprises a sheet of continuous material.

21. The assembly of claim 1, wherein the intermediate layer includes an adhesive.

22. The assembly of claim 1, wherein the intermediate layer comprises a template for guiding placement of particles.

23. The assembly of claim 1, wherein the intermediate layer is configured to mask about 5 vol% to about 70 vol% of each abrasive particle.

24. The assembly of claim 23, wherein the intermediate layer is configured to mask about 20 vol% to about 60 vol% of each abrasive particle.

25. The assembly of claim 24, wherein the intermediate layer is configured to mask about 30 vol% to about 50 vol% of each abrasive particle.

26. A method for making a tool having a plurality of oriented abrasive particles, comprising:
providing an assembly as in claim 1;
securing a plurality of abrasive particles to the assembly, such that at least a portion of each particle is masked by the intermediate layer;
coating exposed portions of the abrasive particles with an electrically conductive material; and
electrodepositing a metal around the unmasked portions of the particles.

27. The method of claim 27, wherein the step of securing the plurality of abrasive particles to the surface includes applying an orienting force to the abrasive particles.

28. The method of claim 27, wherein the orienting force includes a force in a direction substantially normal to the surface of the substrate.

29. The method of claim 27, wherein the orienting force includes a force in a direction substantially parallel to the surface of the substrate.

30. The method of claim 29, wherein the orienting force is a vibrational force.

31. The method of claim 26, comprising coating substantially all exposed portions of the abrasive particles with an electrically conductive material.

32. The method of claim 26, comprising coating an electrically conductive material on the intermediate layer not covered with abrasive particles.

33. The method of claim 26, further comprising removing the assembly from the electroplated abrasive particles.

34. The method of claim 33, wherein the removing step includes chemical processing.

35. The method of claim 33, further comprising attaching a backing material to the electroplated abrasive particles on the electroplated surface.

36. The method of claim 35, wherein the backing material is an epoxy.

37. The method of claim 26, wherein the metal is a member selected from the group consisting of: nickel, chromium, copper, titanium, tungsten, tin, iron, silver, gold, manganese, magnesium, zinc, aluminum, tantalum, alloys thereof; and mixtures thereof.

38. The method of claim 37, wherein the metal is nickel.

39. The method of claim 26, wherein the metal is a metallic composite material.

40. The method of claim 39, wherein the metallic composite material includes at least one member selected from the group consisting of: nickel, chromium, copper, titanium, tungsten, tin, iron, silver, gold, manganese, magnesium, zinc, aluminum, tantalum, alloys thereof; and mixtures thereof.

41. The method of claim 40, wherein the metallic composite material includes nickel.

42. The method of claim 26, wherein the abrasive particles are selected from the group consisting of diamond, polycrystalline diamond, cubic boron nitride, polycrystalline cubic boron nitride, and mixtures thereof.

43. The method of claim 42, wherein the abrasive particles are diamond particles.

44. A method for making a tool having a plurality of abrasive particles, comprising:
providing a substrate having a plurality of abrasive particles thereon, each abrasive particle having a portion between particle tip and the substrate masked, and further having an electrically conductive coating on exposed portions of the abrasive particles; and electrodepositing metal around the unmasked portions of the particles.