superabrasive particles 49 and substrate in the middle, with the SEDF preform 46 on one side, and the porous layer 48 on the opposite side. Fig. 16 is like Fig. 15, except that the positions of the superabrasive particles 49 and the substrate 50 are reversed.

Fig. 17 shows two SEDF preforms 46 and 46'. A porous layer 48 is between the preforms, and the superabrasive particles 49 with the substrate 50 are on the opposite side of one of the preforms.

The porous layer may take the form of a woven mesh, a nonwoven material, expanded foil, knitted materials and textile fabrics. Also, a material that is roll-compacted, extruded, sintered or the like can be used. Virtually any material can be used so long as the material is highly porous (about 30% to 99.5% porosity), having pores open to the surface and interconnected, with sufficient integrity to support the superabrasive particles and to restrain motion of the retaining powder in the process of sintering.

Presently, the best material known for use as porous layers are metallic non-woven materials, and particularly a nickel fiber powder non-woven mat, manufactured by National Standard, Woven production Division, Corbin KY, and sold under the trademark "Fibrex". The porosity of this mat is 85-98%; the fiber is 20 microns in diameter and is about 80 weight percent of the mat, while the powder is about 20 weight percent.

It has also been found that copper wire mesh, in the range of 20 to 200 mesh, works well as the porous layer. Some expanded metals (manufactured by Delker Corporation) have been used, for the same purpose.

Fig. 18 of the drawings illustrate an SEDF preform 51 after the preform 51 has been urged against a porous layer 52. The porous layer 52 is here shown as having some substantial thickness, and being made up of a plurality of cells 54 so the porous layer 52 comprises a cellular type of material. It will be seen, then, that the material of the preform 51 has been urged into the cells 54. It has been

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found desirable in some cases to compress the preform 51 with the porous layer 52 prior to applying heat and pressure during sintering. The material of the preform 51, being received in the openings, or cells, 54 of the porous layer 42, tends to stay within the openings and not to move laterally.

It should be understood that the role of the porous layer 52 can be limited to the restriction of flow of the material of the SEDF preform 51. Thus, a porous layer 52 may be made of a material having a melting point below the sintering temperatures. In this case, after at least a portion of the binder has been removed from the preform in the process of heating, and the retaining powder is at least partially solidified, the porous layer will melt onto the preform, and thereby modify the retaining composition. For example, a cobalt-nickel SEDF preform may utilize a porous layer made of copper, bronze, brass, zinc, aluminum, or various combinations of these, as well as other porous layers.

Another function of a porous layer 52 may be conduction of heat and/or electricity during heating of the preform. For example, a mesh or expanded foil of copper will readily conduct heat or electricity to facilitate uniform heating. Further, the porous layer may include superabrasive particles within the cells 54. A preform as shown in Fig. 18 may be placed against a porous layer 52 having superabrasive particles therein, or the porous layer may be used as a substrate in an arrangement such as that shown in Fig. 6 of the drawings.

In any arrangement, it must be realized that, if the porous layer is filled with superabrasive particles, the ability of the porous layer to absorb binder during heating is reduced. Thus, if one wish to provide a full, or nearly full, layer of superabrasive particles through the use of a porous layer, an additional porous layer may be needed, or desired, to absorb the binder and prevent displacement of the retaining powder.

Looking at Fig. 19 of the drawings, it will be seen that the SEDF preform of the present invention is admirably suited to mass production techniques. The arrangement shown in Fig. 19 includes rolls 55 and 56 for assembling a plurality of layers to be sintered. There is a roll of preform 58 to form one side of the assembly, and a roll of substrate 59 to form the opposite side of the assembly. Optionally, a roll of a porous layer 60 is placed between the preform 58 and the substrate 59.

The substrate 59 may have a plurality of superabrasive particles 61 previously placed thereon; or, as here illustrated, a dispenser 62 may place superabrasive particles on the substrate 59 during the assembling process. In either case it is contemplated that the substrate, or carrier, 59 will have an adhesive to hold the superabrasive particles 61 temporarily.

The SEDF preform 58 may take many forms as discussed above. The preform 58 may include a plurality of superabrasive and abrasive particles, or may not. Further, the preform may be placed on a substrate in order to give the preform greater integrity.

The porous layer 60 may or may not be included in the assembly. As is mentioned above, the preform 58 may utilize a porous layer as a substrate, or carrier, and this may be sufficient for some products. However, if one or more additional porous layers are desired, they may be fed to the assembly as shown in Fig. 19. Fig. 19 also shows separators 66 and 67. Such separators are disclosed in U. S. patent No. 5,203,880, "Method and Apparatus for Making Abrasive Tools", by the present inventor. In accordance with the disclosure in that patent, these separators assist in protrusion of the superabrasive particles through the retaining matrix, and in distribution of the temperature within the sinter mold during the sintering process. These separators 66 and 67 may or may not be attached to the SEDF preform assembly. When attached to the preform, the separators will be part of the assembly itself.

It should be understood that, in all techniques disclosed in the present application, separators such as the separators 66 and 67 may or may not be used. If separators are used, they may also be utilized as the substrate for SEDF preform (see numeral 22 in Figs. 5 and 6). It should be understood that, in the majority of the figures in the drawings, separators are not shown for the sake of simplification of the illustration.

Those skilled in the art will understand that the rolls 55 and 56 will urge the layers 58, 59 and 60, and separators 66 and 67 together into a single assembly 64. It is contemplated that the assembly 64 will then be cut into discrete pieces, or plates, 65 by a cutter 66. The individual plates 65 can be received by a conveyer 68 for transport to means for sintering.

Examples

Figs. 20 and 21 of the drawings show one assembly and one resulting sintered abrasive material respectively in accordance with the present invention. There is an SEDF preform 70 having superabrasive particles 71 distributed therein. The opposite side of the assembly is an SEDF preform 72 without abrasive particles. Between these two outside layers, there are two additional preforms 74 and 75, both having superabrasive particles distributed therein. Then, between the preforms 70 and 74 there is a porous layer 76; and between the preforms 74 and 75 there is a porous layer 78.

In Fig. 21 it can be seen that the superabrasive particles remain in layers; and, on one side, the superabrasive particles 71 are at the surface of the sintered assembly, while on the opposite side the preform 72 provides a backing without superabrasive particles. This sintered abrasive material can now be used to manufacture cutting and grinding tools.

The SEDF preform may have a profiled shape, which may or may not correspond to the shape of a compacting means, e.g. punches used for providing pressure during sintering. The

profiled SEDF preform, along with the non-profiled, or flat ones, are utilized by the present inventor for manufacturing abrasive articles according to U. S. patent No. 5,190,568 titled "Abrasive Tool with Contoured Surface".

Fig. 19A illustrates a one-sided profiled SEDF preform. One-way to manufacture the one-sided profiled SEDF preform includes the use of a profiled substrate 111, a binder-powder composition 112 being poured onto the substrate 111.

Fig. 19B illustrates the formation of a two-sided profiled SEDF preform. Fig. 19B shows two substrates, or walls, 114 and 115 and a binder-powder composition 116 between the walls 114 and 115. According to the method illustrated in Fig. 19B, the two-sided profiled SEDF preform is manufactured by pouring a binder-powder slurry between the two profiled walls 114 and 115, resulting in the formation of the two-sided profiled SEDF preform 116.

It should be understood that wall 114 and wall 115 may have different profiles, and each side of the SEDF preform has a profile corresponding to the profile (relief) of the respective wall. It also should be understood that the walls can be positioned vertically or horizontally; and, application of pressure and/or changing the distance between the walls in the process of solidification of the binder-powder composition 116 are optional.

A non-profiled, or flat, SEDF preform can be converted prior to sintering into a profiled one. The flat profile 118 can be shaped between profiled compacting means. Fig. 19C illustrates one of the processes for shaping a flat SEDF preform 118 into a profiled SEDF preform 119 by two profiled rolls or gears 120 and 121. The preferable arrangement does not require change of the thickness of the SEDF preform as a result of the shaping. This type of shaping does not require very great pressure because of the easy deformability of the SEDF preform.

Fig. 20 also-shows separators 66a and 67a placed against SEDF preforms 70 and 72 as a part of the assembly itself. Fig. 21 does not show these separators, indicating that at

least some of the separators have been removed from the sintered abrasive material in the process of after-sintering cleaning, or in the process of dressing the abrasive tool.

One method for utilization of the separators in combination with the SEDF preform is shown in Fig. 20A. The separator 100 is placed on one side of the assembly 103 that includes an SEDF preform 101, a layer of porous material 102 and a layer of superabrasive particles 104 on a substrate 105. A mesh type material 106 having openings 108 is applied against the separator 100; and, the preferable mesh type material 106 has orderly distributed openings 108. Under pressure provided by one or both of the punches 35a and 35b, the assembly 103 extrudes at least partially into openings 108 of the mesh type material 106, de forming the separator 100 and leaving imprints on the surface of the assembly 103. The whole assembly 103 is put into the sintering mold as is shown in Figs. 10 and 10A, and then sintered, providing that sintering under pressure is preferable. The pressure to extrude the assembly 103 into the openings 108 can be applied prior to sintering, outside of the sinter mold and/or within this sinter mold, and/or in the process of sintering. After sintering the mesh type material 106 is removed from the mold, as well as the separator 100. The removal of the mesh type material 106 from the sintered abrasive article is not a problem because the separator 100 prevents diffusion between the assembly 103 and the mesh type material 106. The resulting abrasive article will comprise a profile corresponding to the design of the mesh type material 106.

It should be understood that there are additional options (some being shown in Fig. 20A) that may or may not be implemented: the mesh type material 106 can be placed against both sides of the SEDF preform 101 for making two-sided profiled abrasive article (see separator 109 in Fig. 20A); another separator 110 can be used to separate mesh type material 106 from the punch 35a, and separator 115 can be used to separate another side of the assembly 103 from the punch 35b. It also should be understood that several

assemblies comprising SEDF preforms and the mesh material for extrusion can be sintered in stock as is shown in Fig. 10A. Furthermore, separators of different thicknesses and different types can be used for opposite sides of the SEDF preform 101. The mesh type material 106 for extrusion can be made from different materials, e.g. steel woven mesh, expanded metal, machined crags, honeycomb or the like. It is also preferable that openings in the mesh 106 be big enough to allow at least one superabrasive particle 104 to go therethrough. For example, diamonds have sizes of 0.015 to 0.200 mm (80-100 mesh) while the mesh type material for extrusion comprises openings of 1.00 to 0.850 mm (18 to 20 mesh). It is also preferable that the mesh type material 106 for extrusion does not melt under, sintering temperatures, and have a minimum deformability under the pressure that makes this mesh multiusable.

Figs. 22 and 23 of the drawings show an assembly and a sintered single layer cutting tool respectively. Fig. 22 illustrates the layers to be assembled, and includes a central porous layer 79 having a plurality of superabrasive particles 80 in the openings thereof. It should be noticed that the particles 80 are at least as wide as the layer 79, so the particles 80 extend completely through the porous layer 79.

Each side of the central layer 79 includes two SEDF preforms 81, 82 and 81', 82', separated by porous layers 84, 84'.

When the assembly is heated under pressure, the material shown in Fig. 23 results. The present inventor has used this method to produce abrasive articles with one layer of diamonds as shown. It should be understood, however, that the abrasive article can include as many layers as desired, in accordance with other disclosures herein.

Figs. 24 and 25 show the production of a no-diamond foot on a conventional diamond segment. Current methods are difficult to use because the foot 85 is quite thin, requiring that powder be distributed very thinly, yet very uniformly,

in a sinter mold. Using the methods and apparatus of the present invention, however, an SEDF preform 86 can be placed against the segment 88, and the retaining powder is readily distributed uniformly. As is discussed in detail above, the final thickness of the foot 85 can be easily calculated.

Figs. 26 and 27 show the use of a conventional green compact having randomly distributed abrasive and/or superabrasive particles in combination with preforms of the present invention, and porous layers having orderly arranged superabrasive particles. The central green compact 89 has a porous layer 90, 90' on each side thereof, then an SEDF preform 91, 91'. The outside comprises a porous, or cellular, layer 92, 92' having a plurality of superabrasive particles 94, 94' distributed therein in an orderly fashion.

The assembly of Fig. 26 can be compressed in the direction indicated by the arrows 95, or in the direction indicated by the arrows 96. The inventor has used this technique, with pressure in the direction of the arrows 95, to manufacture diamond segments for saw blades, and a ream saw blade.

Fig. 28 illustrates the making of a cut-off disk. Individual pieces 98, or a complete ring, of the SEDF preform can be prepared of the proper shape, and placed around the periphery of a core 99. From the foregoing discussion it will be understood that the pieces 98 may include any number of layers, may or may not include porous layers, and may have as many or as few superabrasive particles as desired.

After the pieces 98, or the ring, is assembled on the core 99, the assembly will be sintered (preferably under pressure) so the sintering of the preform and fixing the preform to the core 99 are performed in one step.

Following are some specific examples of use of the technology of the present invention:

1. a) Make an SEDF preform in the form of a plate or a tape from a diamond retaining composition, e.g., from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an

application of the superabrasive articles. Do not mix these retaining powders with diamonds in the process of making SEDF preform.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Put diamonds into openings of the mesh type material and temporarily retain them with an adhesive carrier. As an option, the mesh type material can be then removed.

d) Apply SEDF preform against the carrier that includes superabrasive particles. As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device e.g., between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g., up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

2. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of the diamond particles and a diamond retaining composition, e.g., from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) As an option, separators can be placed on at least one side of the preform as disclosed in U.S. patent

5,203,880, "Method and Apparatus for Making Abrasive Tools", forming an assembly.

d) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

e) Heat the assembly under pressure, e.g. up to 1040°C and 300 kg/cm^2, so called "hot compacting".

f) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

3. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of a first plurality of diamonds and a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Put a second plurality of diamonds into openings of the mesh type material and temporarily retain them with an adhesive carrier. As an option, the mesh type material can be then removed.

d) Apply SEDF preform, including the first plurality of diamonds against the carrier including the second plurality of diamonds. As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g. up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

It should be understood that the first and second pluralities of diamonds, and generally, any superabrasive particles, can be of the same or different origin, size, shape and physical-mechanical parameters.

4. a) Make an SEDF preform in the form of a tape from a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles. Do not mix these retaining powders with diamonds in the process of making SEDF preform.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Take the nickel non-woven mat of National Standard, cut it into the proper pieces.

d) Assemble a sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, apply pressure and/or an adhesive to improve the integrity of this assembly.

e) Put diamonds into openings of the mesh type material and temporarily retain with an adhesive carrier. As an option, the mesh type material can be then removed.

f) Apply this carrier including the superabrasive particles against the sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g. up to 1040°C and 300 kg/cm^2, so galled "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

5. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of the superabrasive particles and a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Take the nickel non-woven mat of National Standard, cut it into the proper pieces.

d) Assemble a sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, apply pressure and/or an adhesive to improve the integrity of this assembly. As another option separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g., up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

6. a) Make an SEDF preform in the form of a plate or a tape from a slurry mixture of the superabrasive particles and a diamond retaining composition, e.g. from Wall Colmonoy's setting powder 50, or from Kennametal's powder

N50, or from any other powdered composition suitable for an application of the abrasive articles.

b) Cut the preform with paper cutter or scissors into the shape suitable for the sintering mold and design of the abrasive articles.

c) Take the nickel non-woven mat of National Standard, cut it into the proper pieces.

d) Assemble a sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, apply pressure and/or an adhesive to improve the integrity of this assembly.

e) Put diamonds into openings of the mesh type material and temporarily retain with an adhesive carrier. As an option, the mesh type material can be then removed.

f) Apply this carrier including the superabrasive particles against the sandwich "SEDF preform--the nickel mat--SEDF preform". As an option, pressure and/or adhesive can be applied to hold the assembly together. As another option, separators can be placed on at least one side of the assembly as disclosed in U.S. patent 5,203,880, "Method and Apparatus for Making Abrasive Tools".

e) Place the assembly into a heating device, e.g. between heating plates or into a sintering mold. It can be several assemblies per one device.

f) Heat the assembly under a pressure, e.g. up to 1040°C and 300 kg/cm^2, so called "hot compacting".

g) Remove the sintered assembly from the device, clean and cut, if necessary, into pieces required by the design, then mount the pieces on a carrier, if necessary, to make the final product.

It should be understood that the preferred embodiments of the invention here presented comprise assemblies of superabrasive particles such as diamonds, cubic boron nitride or the like, distributed in an orderly fashion on a substrate, or a carrier, and a pre-made SEDF preform formed from metals, ceramics, epoxy materials with binders or other plastics. The assemblies of the above components are heated or sintered, preferably under an external pressure. The SEDF

preform may or may not include randomly distributed superabrasive particles therein; and, and a separator can be a part of the assembly itself to prevent contacting and/or diffusion between the SEDF preforms and the molding parts.

It will of course be understood by those skilled in the art that the particular embodiments of the invention here presented are by way of illustration only, and are meant to be in no way restrictive; therefore, numerous changes and modifications may be made, and the full use of equivalents resorted to, without departing from the spirit or scope of the invention as outlined in the appended claims.

Claims

1. In a method for making abrasive articles, wherein said abrasive articles comprise a quantity of a retaining powder and at least one plurality of superabrasive particles, said method including the steps of making a preform of said retaining powder, placing said plurality of superabrasive particles into said preform, and heating said preform, the improvement comprising the steps of making said preform of a binder and said quantity of retaining powder wherein the volume of said binder is greater than the volume of said quantity of retaining powder, so that said preform is soft, easily deformable and flexible.

2. In a method as claimed in claim 1, the further improvement wherein the said step of heating said preform includes the steps of heating said preform while exerting pressure on said preform.

3. In a method as claimed in claim 1, the improvement including the step of adding said superabrasive particles to said binder and retaining powder before the said step of making said preform.

4. In a method as claimed in claim 1, wherein the said step of placing said plurality of superabrasive particles into said preform comprises the step of placing said plurality of superabrasive particles on one side of said preform.

5. In a method as claimed in claim 1, the improvement wherein said step of placing said plurality of superabrasive particles into said preform comprises the step of randomly distributing said superabrasive particles.

6. In a method as claimed in claim 1, the improvement wherein said step of placing said plurality of superabrasive particles into said preform comprises the step of distributing said superabrasive particles in an orderly fashion.

7. In a method as claimed in claim 1, the further improvement wherein the said step of making said preform comprises the step of forming said preform on a substrate.

8. In a method as claimed in claim 7, the improvement including the step of placing said plurality of superabrasive particles on said substrate prior to the said step of forming said preform.

9. In a method as claimed in claim 8, the improvement wherein said superabrasive particles are randomly distributed on said substrate.

10. In a method as claimed in claim 8, the improvement wherein said superabrasive particles are distributed on said substrate in an orderly fashion.

11. In a method as claimed in claim 8, the improvement wherein said substrate includes a plurality of openings extending to the surface of said substrate, and including the step of placing said superabrasive particles in said openings of said substrate.

12. In a method as claimed in claim 1, the further improvement comprising the step of placing a porous layer against said preform for making an assembly prior to the said step of heating said preform, said porous layer having a plurality of openings extending to the surface thereof for restraining movement of said retaining powder and said superabrasive particles.

13. In a method as claimed in claim 12, the improvement including the step of placing said porous layer between said superabrasive particles and said preform.

14. In a method as claimed in claim 12, the improvement including the step of placing another preform against said porous layer prior to the said step of heating said preform.

15. In a method as claimed in claim 12, the further improvement wherein the said step of making a preform is carried out by making said preform on a substrate, said substrate having openings therein and acting as said porous layer.

16. In a method as claimed in claim 15, the improvement including the step of placing said superabrasive particles on said substrate prior to the step of making said preform.

17. In a method as claimed in claim 12, wherein the porous layer is selected to have a lower melting point than the retaining powder, and further including the step of heating the assembly sufficiently to melt said porous layer.

18. The product made in accordance with claim 15.

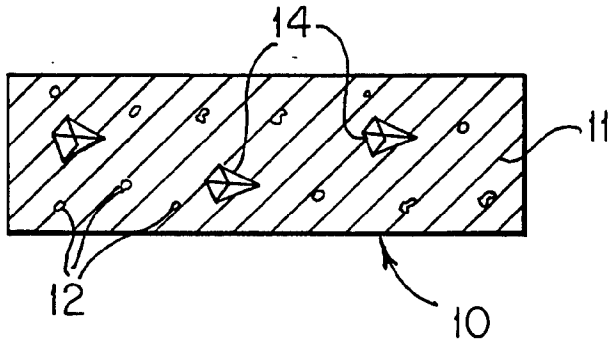


FIG. 1

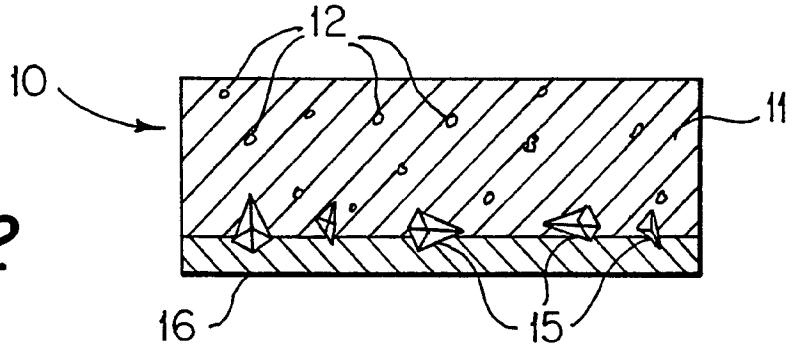


FIG. 2

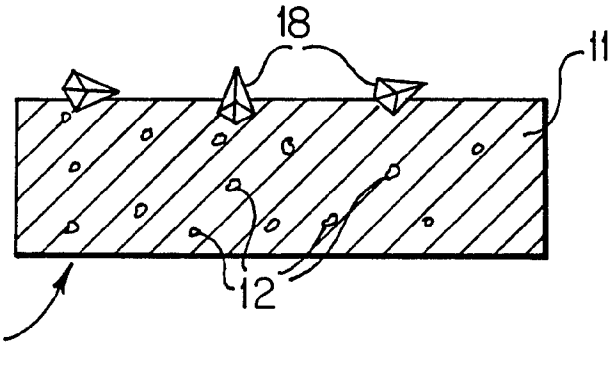


FIG. 3

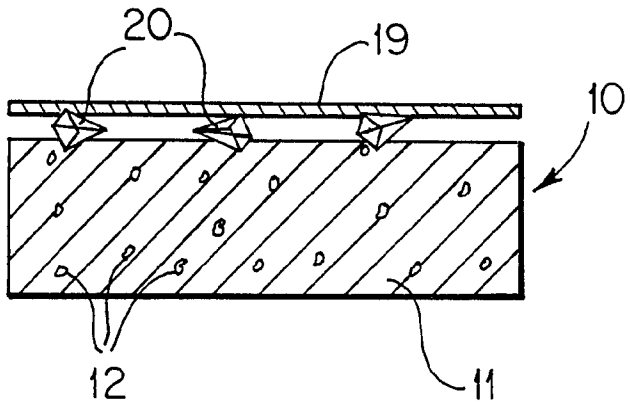


FIG. 4

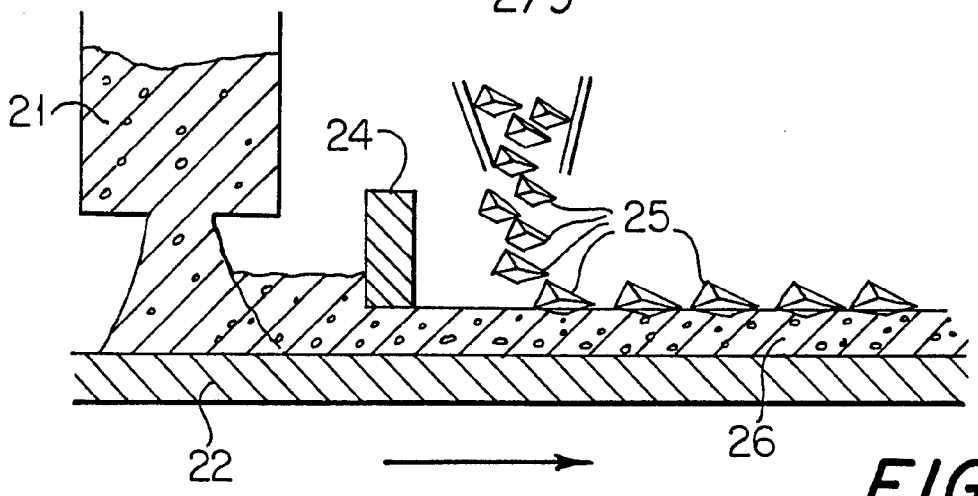


FIG. 5

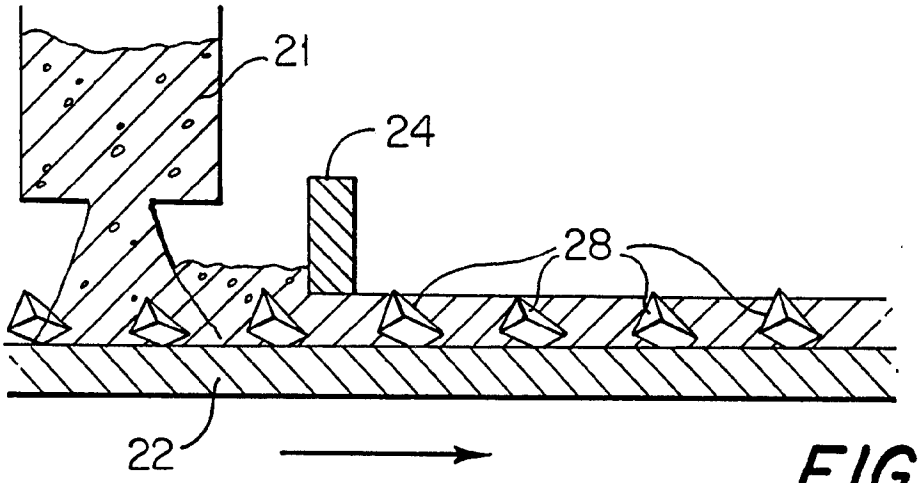


FIG. 6

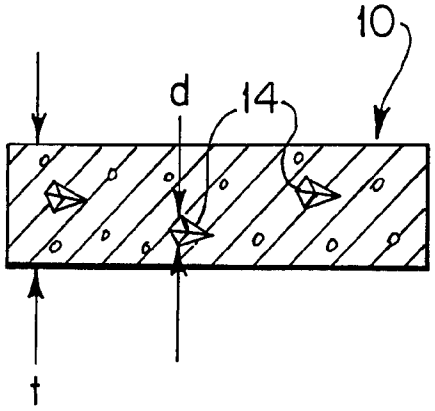


FIG. 7

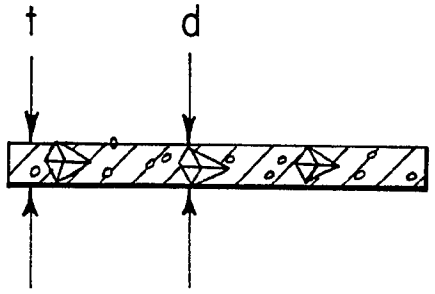


FIG. 8

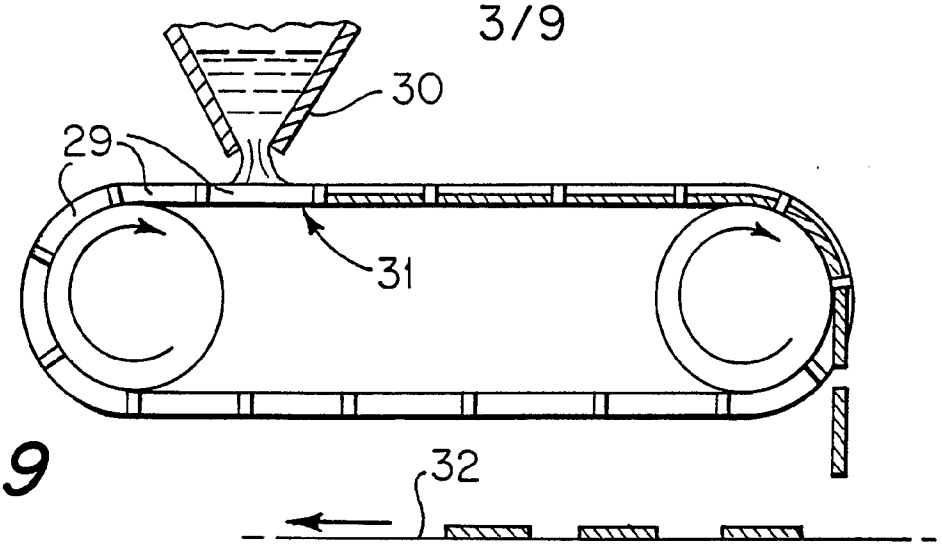


FIG. 9

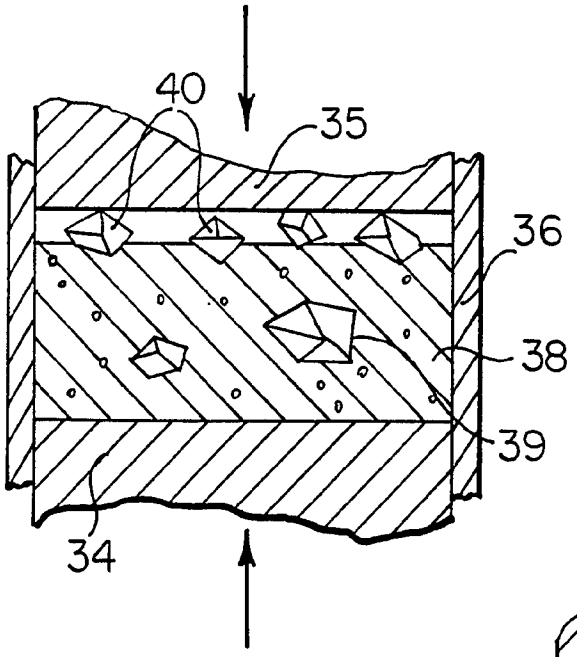


FIG. 10

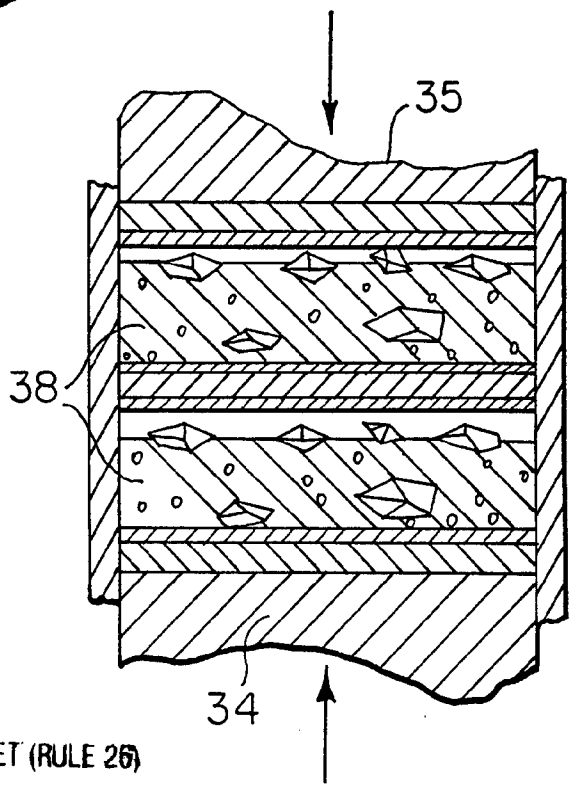


FIG. 10A

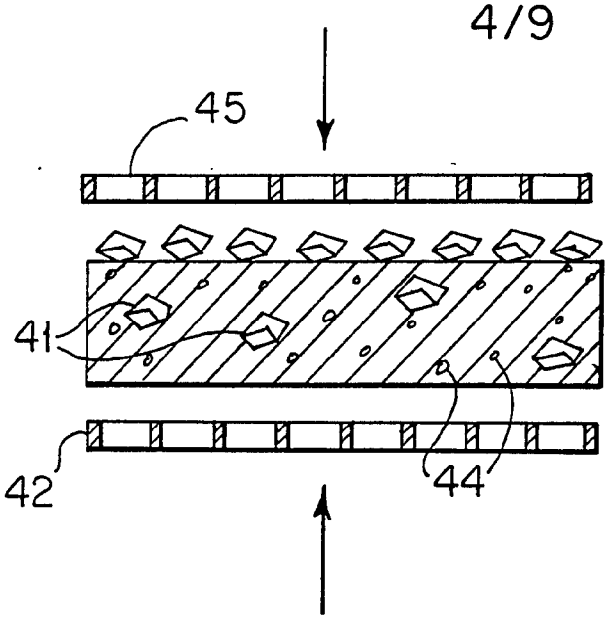


FIG. 11

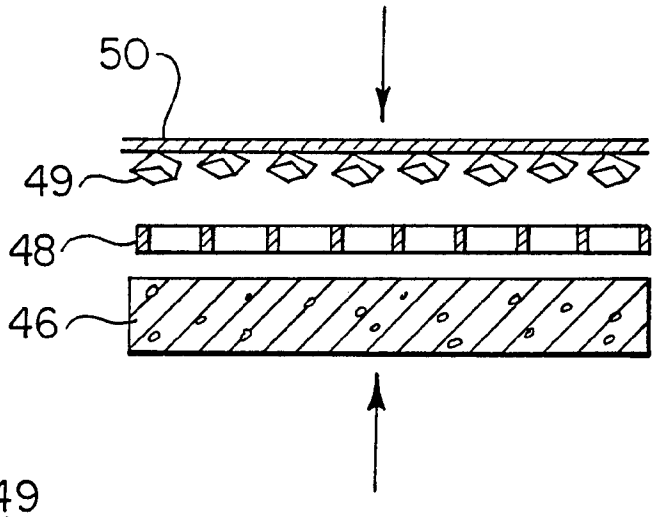


FIG. 12

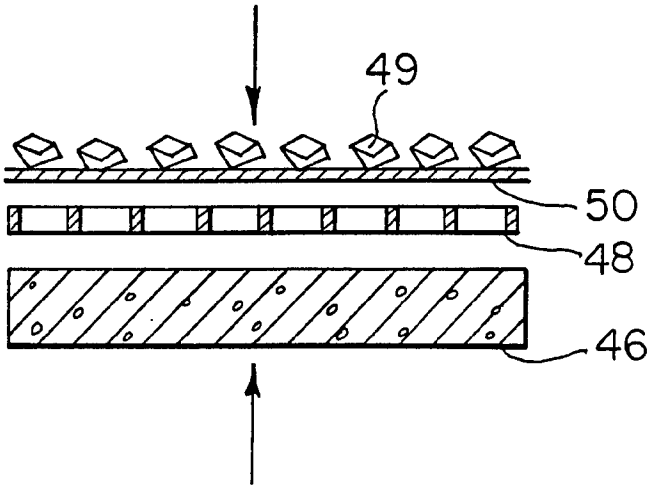


FIG. 13

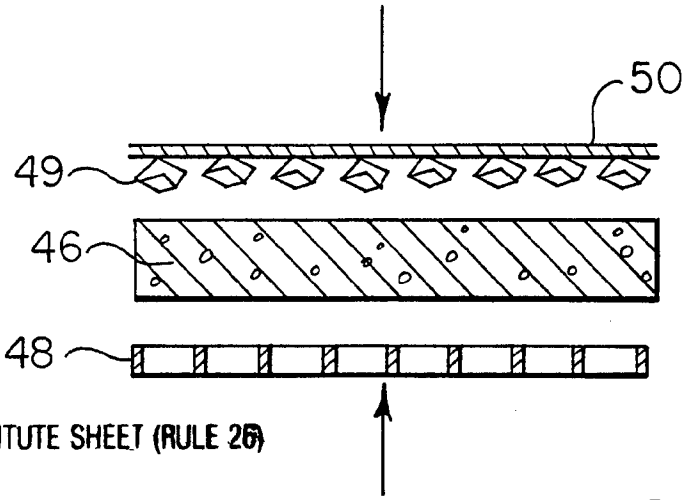


FIG. 14

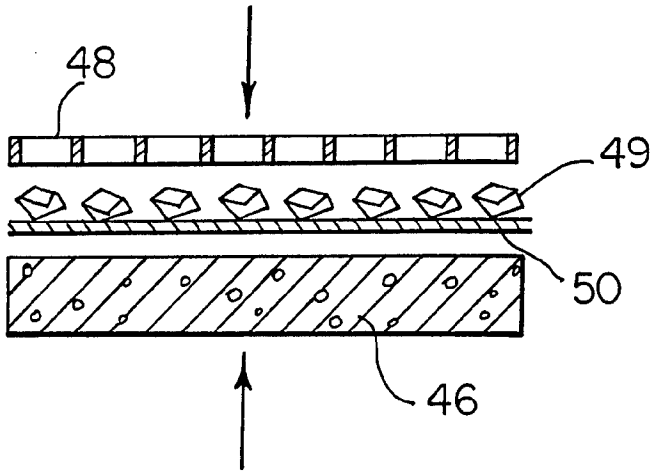


FIG. 15

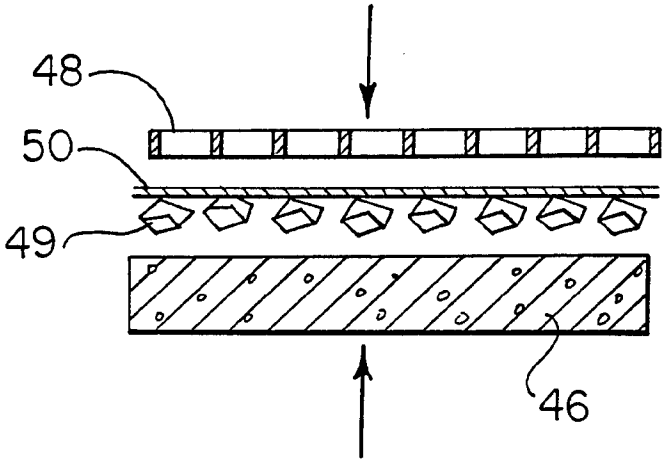


FIG. 16

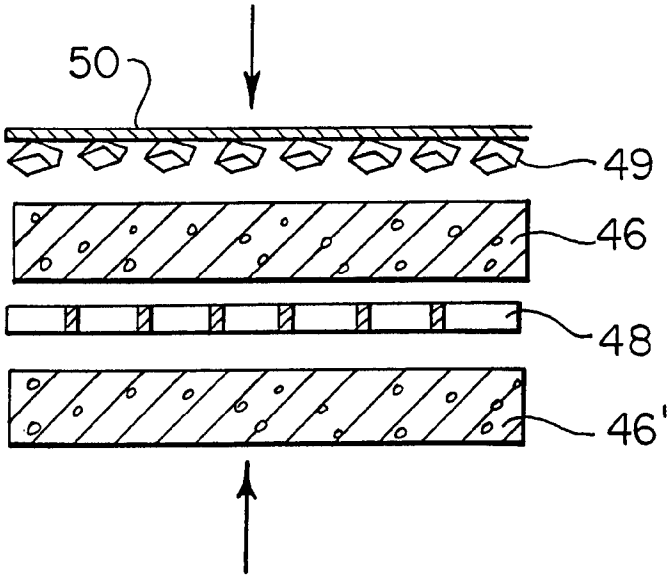


FIG. 17

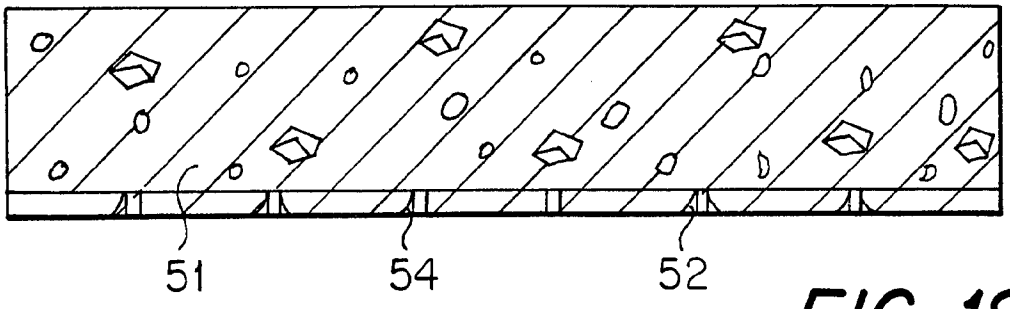


FIG. 18

Ex. 1003, Page 457

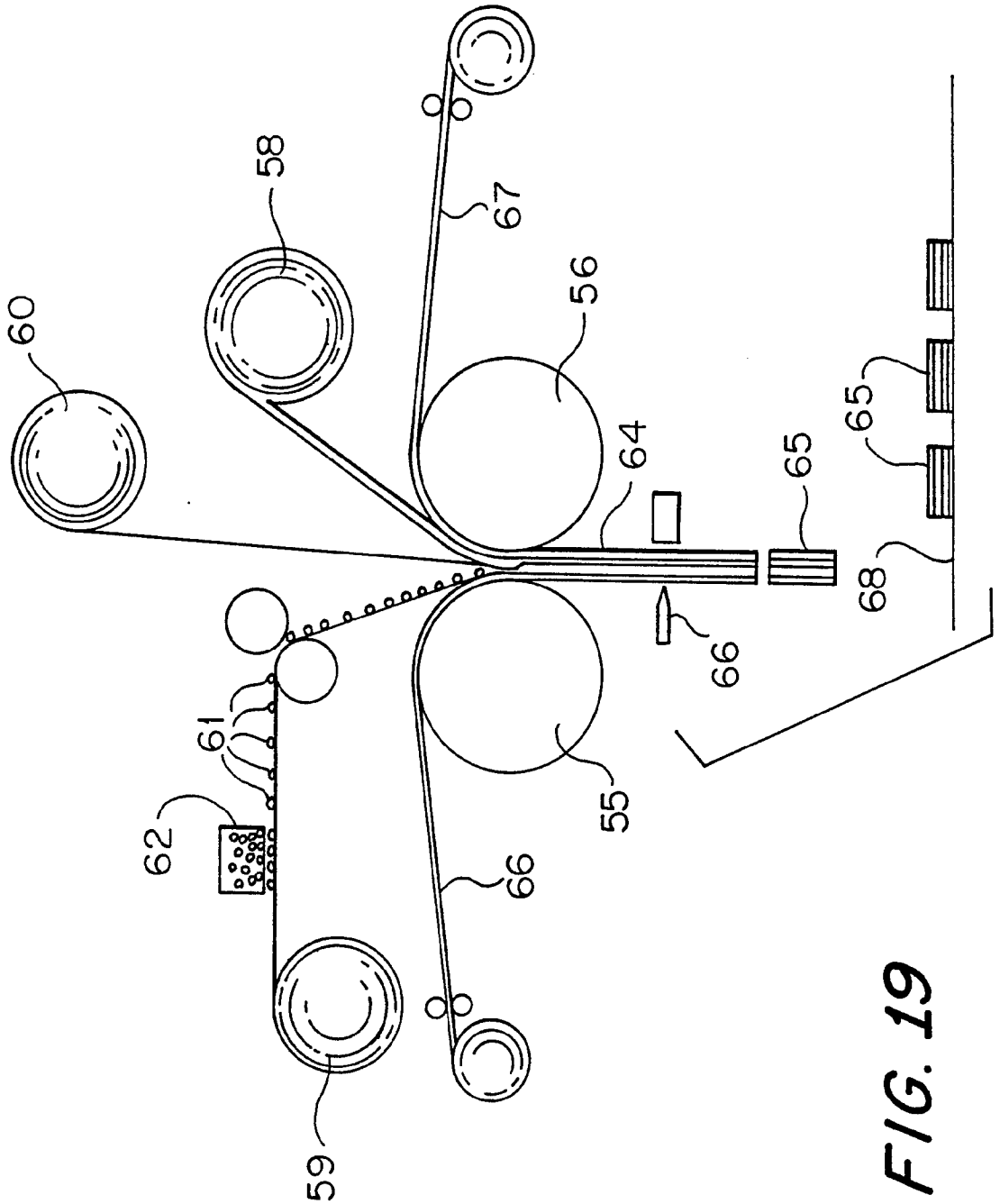


FIG. 19

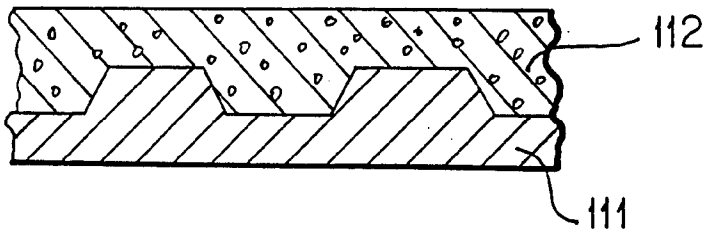


FIG. 19A

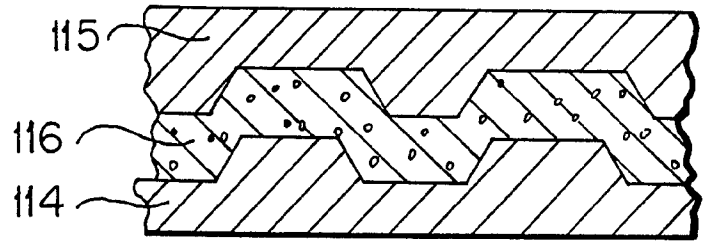


FIG. 19B

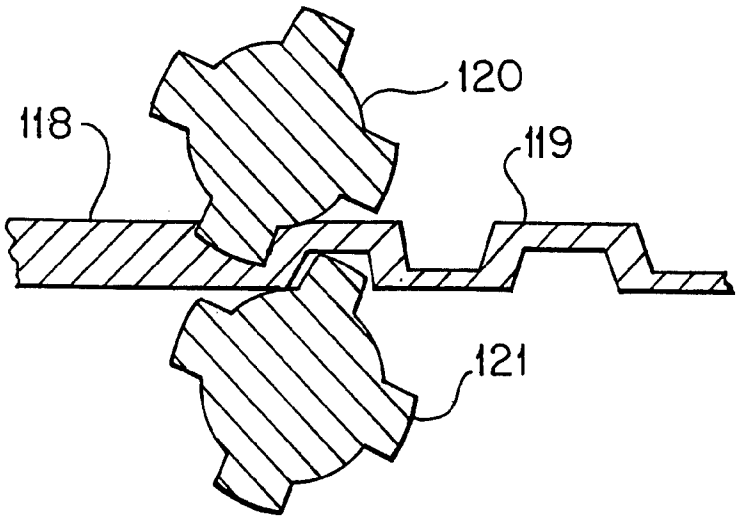


FIG. 19C

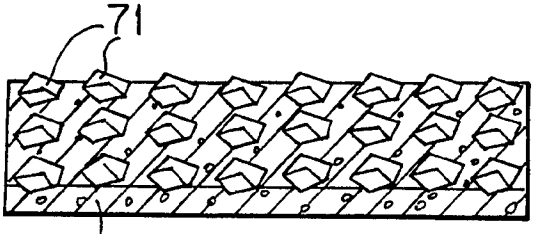


FIG. 21

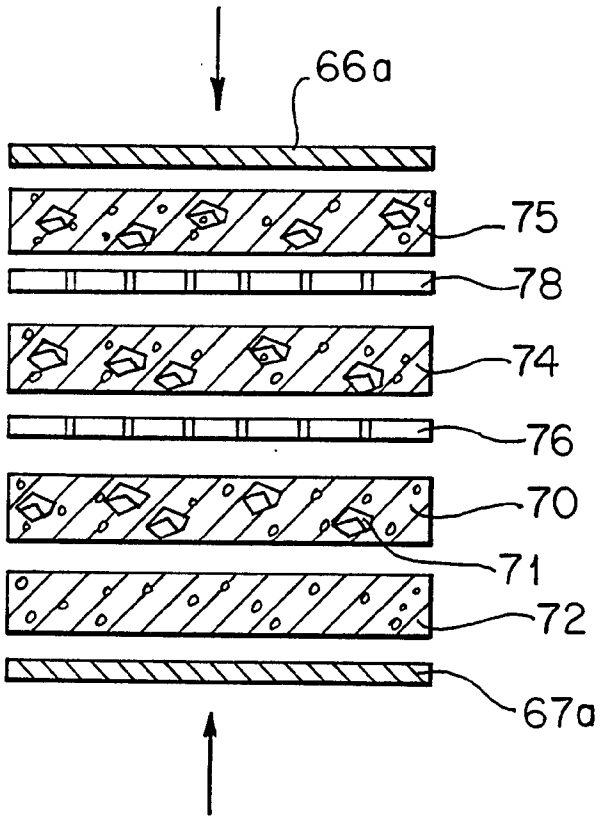


FIG. 20

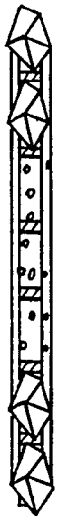


FIG. 23

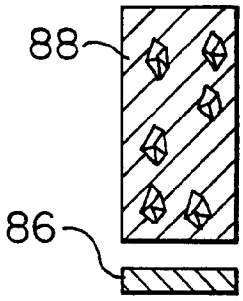


FIG. 24

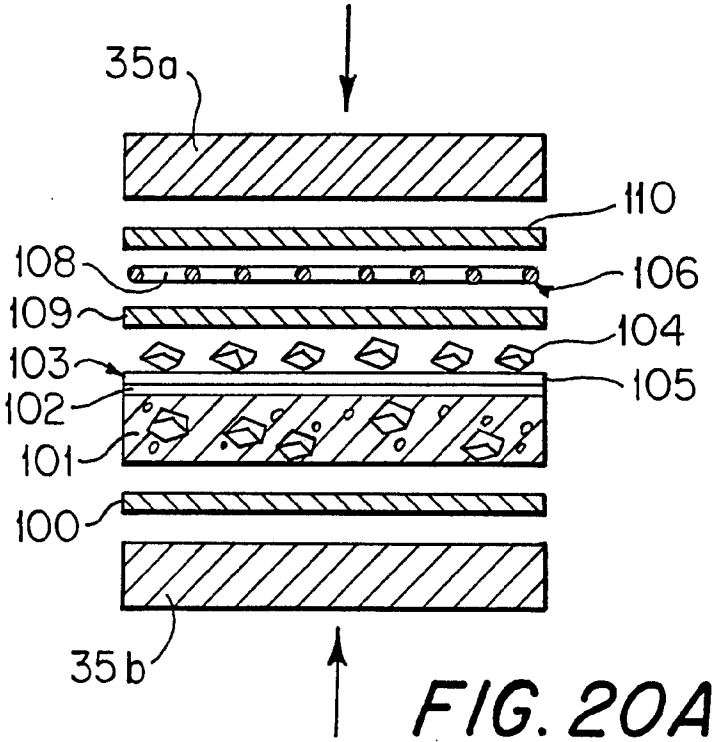


FIG. 20A

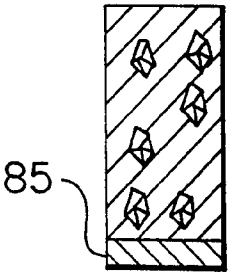


FIG. 25

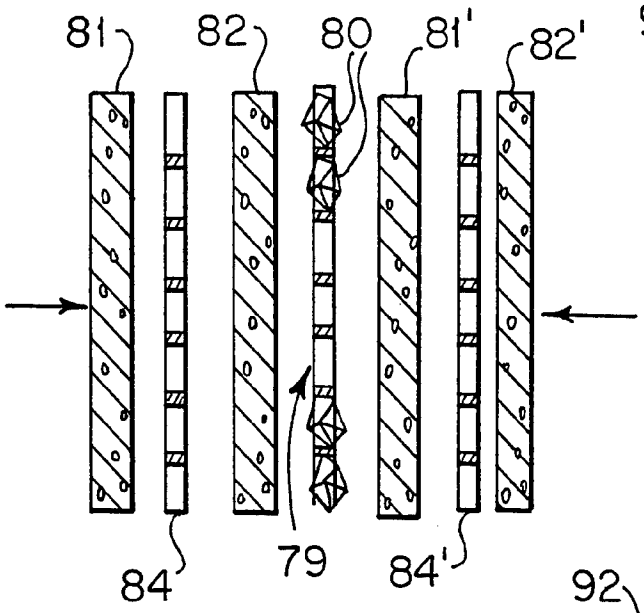


FIG. 22

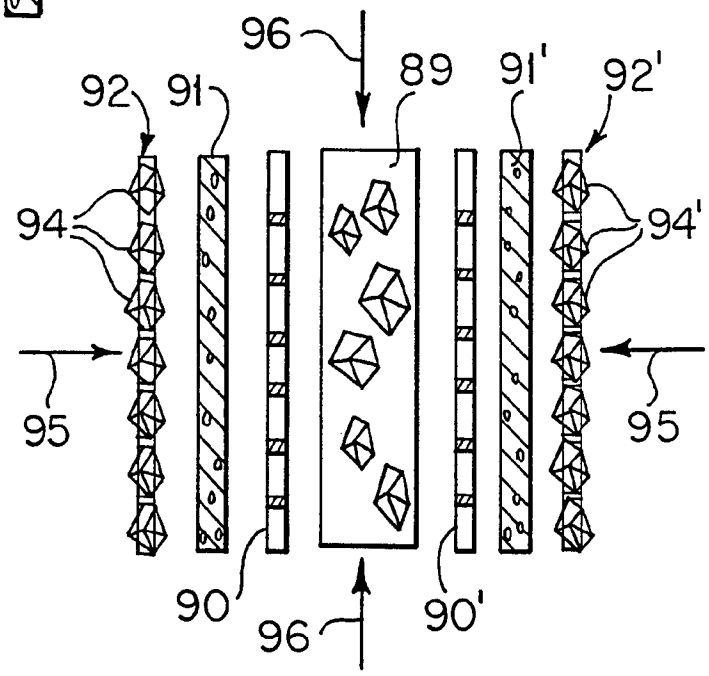


FIG. 26

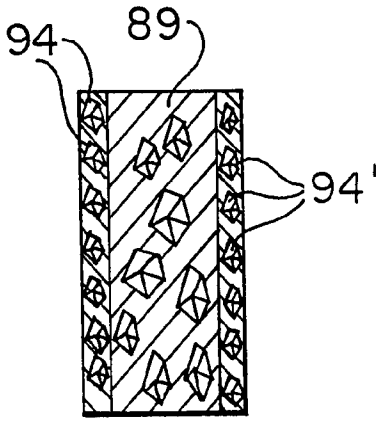


FIG. 27

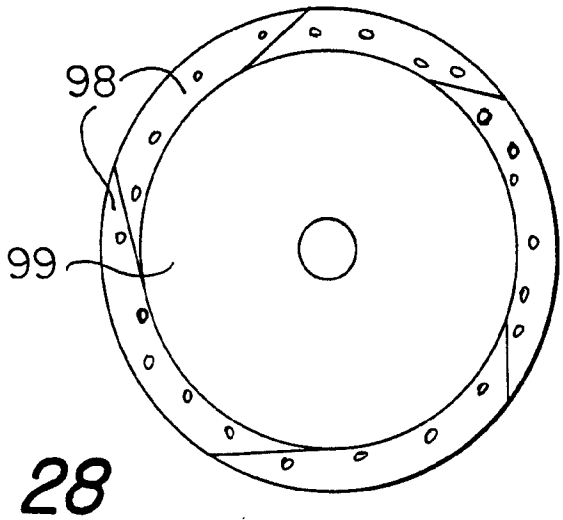


FIG. 28

INTERNATIONAL SEARCH REPORT

Inter ıal Application No
PCT/US 95/01503

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24D18/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24D B22F

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US,A,5 264 011 (BROWN LAWRENCE E ET AL) 23 November 1993 see column 6, line 57 - column 7, line 32; figure 1 ---	1
A	US,A,5 203 880 (TSELESIN NAUM N) 20 April 1993 cited in the application see claims ---	1
A	US,A,5 092 910 (DEKOK PETER T ET AL) 3 March 1992 cited in the application see claims ---	1
A	US,A,4 409 054 (RYAN EDWARD J) 11 October 1983 see claims ---	1
	-/--	

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

[X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
1 June 1995	20. 06. 95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax (+31-70) 340-3016	Eschbach, D

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INTERNATIONAL SEARCH REPORT

Interr ıal Application No
PCT/US 95/01503

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 242 955 (DRESSER IND) 28 October 1987 see page 4, line 28 - line 37	1
A	EP,A,0 533 443 (GEN ELECTRIC) 24 March 1993 see page 3, column 3, line 30 - column 4, line 21	1
A	EP,A,0 407 069 (UNICORN IND PLC) 9 January 1991 see abstract; figure 3	1
A	EP,A,0 204 195 (NORTON CO) 10 December 1986 see abstract; figure 1	1
A	US,A,5 221 294 (CARMAN LEE A ET AL) 22 June 1993 see column 4, line 39 - line 43	1

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INTERNATIONAL SEARCH REPORT

...formation on patent family members

Inter ...al Application No
PCT/US 95/01503

Patent document cited in search report	Publication date	Patent family member(s)		Publication date
US-A-5264011	23-11-93	NONE		
US-A-5203880	20-04-93	NONE		
US-A-5092910	03-03-92	US-A-	4925457	15-05-90
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		CA-A-	2025567	31-07-90
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		WO-A-	9009260	23-08-90
		US-A-	5049165	17-09-91
		US-A-	5190568	02-03-93
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		DE-T-	69010587	20-10-94
		JP-A-	3049874	04-03-91
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		KR-B-	9401132	14-02-94
US-A-5221294	22-06-93	US-A-	5160509	03-11-92

Espacenet

Bibliographic data: WO9427883 (A1) — 1994-12-08

CLOSURE

Inventor(s): KOEHN JOCHEN [DE]; HEYN KLAUS [DE] ± (KOEHN, JOCHEN, ; HEYN, KLAUS)

Applicant(s): ZELLER PLASTIK KOEHN GRAEBNER [DE]; KOEHN JOCHEN [DE]; HEYN KLAUS [DE] ± (ZELLER PLASTIK GMBH, ; KOEHN, JOCHEN, ; HEYN, KLAUS)

Classification: - international: ***B65D47/20; B65D47/24; B65D47/26;*** (IPC1-7): B65D47/20; B65D47/24; B65D47/26
- cooperative: **B65D47/2031; B65D47/244; B65D47/265;** B65D2101/0023

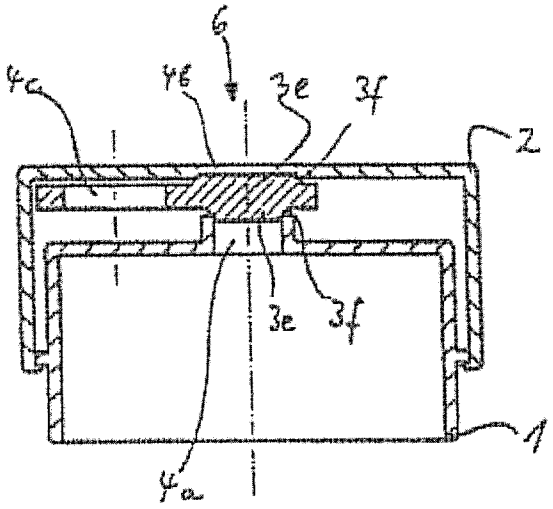
Application number: WO1994EP01695 19940525

Priority number (s): DE19934317550 19930526 ; DE19934343031 19931216

Also published as: ES2126120 (T3) EP0700354 (A1) EP0700354 (B1) AU6971694 (A) AT174295 (T)

Abstract of WO9427883 (A1)

A closure may be easily moved into an open and into a closed position and reliably seals an opening, for example of a container. To open and close the closure, a middle part (3) may be linearly moved or rotated between a top and a bottom part (2, 1). Pre-stressing the middle part (3) between top and bottom parts (2, 1) allows an opening to be sealed.



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INTERNATIONALE ANMELDUNG VERÖFFENTLICHT NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT)

(51) Internationale Patentklassifikation [5]: B65D 47/26, 47/24, 47/20

A1

(11) Internationale Veröffentlichungsnummer: **WO 94/27883**

(43) Internationales Veröffentlichungsdatum: 8. December 1994 (08.12.94)

(21) Internationales Aktenzeichen: PCT/EP94/01695

(22) Internationales Anmeldedatum: 25. Mai 1994 (25.05.94)

(30) Prioritätsdaten:

P 43 17 550.3	26. Mai 1993 (26.05.93)	DE
P 43 43 031.7	16. December 1993 (16.12.93)	DE

(71) Anmelder *(für alle Bestimmungsstaaten ausser US)*: ZELLER PLASTIK GMBH [DE/DE]; Barlstrasse 46, D-56856 Zell/Mosel (DE).

(72) Erfinder; und

(75) Erfinder/Anmelder *(nur für US)*: KOEHN, Jochen [DE/DE]; Bernkasteler Weg 29, D-56841 Traben-Trarbach (DE). HEYN, Klaus [DE/DE]; Obere Bergstrasse 14, D-56859 Bullay (DE).

(74) Anwalt: VOSSIUS & PARTNER; Siebertstrasse 4, D-81675 München (DE).

(81) Bestimmungsstaaten: AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, ES, FI, GB, HU, JP, KP, KR, KZ, LK, LU, LV, MG, MN, MW, NL, NO, NZ, PL, PT, RO, RU, SD, SE, SK, UA, US, UZ, VN, europäisches Patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI Patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Veröffentlicht

Mit internationalem Recherchenbericht.

Vor Ablauf der für Änderungen der Ansprüche zugelassenen Frist. Veröffentlichung wird wiederholt falls Änderungen eintreffen.

(54) Title: CLOSURE

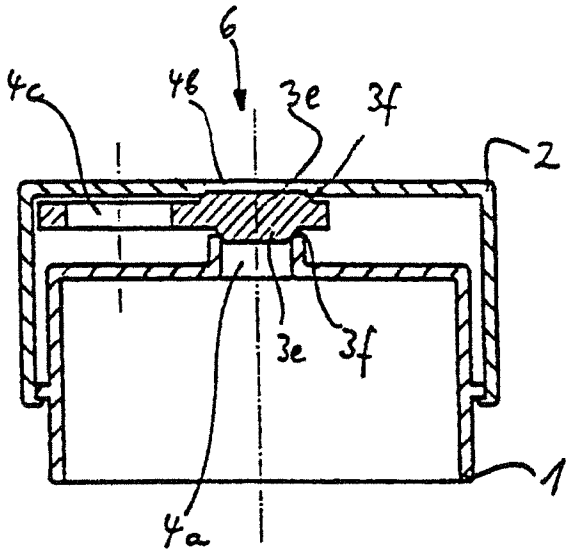
(54) Bezeichnung: VERSCHLUSS

(57) Abstract

A closure may be easily moved into an open and into a closed position and reliably seals an opening, for example of a container. To open and close the closure, a middle part (3) may be linearly moved or rotated between a top and a bottom part (2, 1). Pre-stressing the middle part (3) between top and bottom parts (2, 1) allows an opening to be sealed.

(57) Zusammenfassung

Es wird ein Verschluß zur Verfügung gestellt, der leicht in eine geschlossene und eine geöffnete Stellung bewegbar ist und zuverlässig eine Öffnung, z.B. eines Behälters abdichten kann. Das Öffnen und Schließen kann durch eine lineare Verschiebung oder Drehung eines Mittelteils (3) zwischen einem Ober- und einem Unterteil (2, 1) erfolgen, wobei eine Vorspannung zwischen dem Ober- und dem Unterteil (2, 1) das Mittelteil (3) auf einer Öffnung abdichten kann.



LEDIGLICH ZUR INFORMATION

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Verschluß

Die Erfindung betrifft einen Verschluß, insbesondere für einen Behälter mit pastösen bis flüssigen Füllgütern. Flüssigkeit. Der Verschluß läßt sich jedoch auch als Abschluß für Leitungen von insbesondere Flüssigkeiten einsetzen.

Der Erfindung liegt die Aufgabe zugrunde, einen Verschluß zur Verfügung zu stellen, der leicht zwischen einer geöffneten und einer geschlossenen Stellung bewegbar ist und zuverlässig eine Öffnung z.B. für Flüssigkeiten abdichten kann.

Die Aufgabe wird mit den Merkmalen der Patentansprüche gelöst.

Bei der Lösung geht die Erfindung von dem Grundgedanken aus, ein Mittelteil zwischen einem Unterteil mit einer Öffnung und einem auf dem Unterteil drehbar angeordneten Oberteil anzuordnen, wobei das Mittelteil mit dem Oberteil in kraftschlüssiger Verbindung steht und die Öffnung durch lineare

Verschiebung, Verschwenken oder durch eine über eine zahnradartige Verbindung übertragene Drehbewegung verschließt, und wobei alternativ oder zusätzlich das Oberteil gegen das Unterteil elastisch vorspannbar sein kann und diese Vorspannung das Mittelteil gegen die Öffnung abdichtend drückt.

Im folgenden wird die Erfindung anhand der Zeichnungen näher erläutert. Es zeigen:

Fig. 1 einen Querschnitt einer erfindungsgemäßen Ausführungsform im geöffneten Zustand,

Fig. 2 die erfindungsgemäße Ausführungsform gemäß Fig. 1 im geschlossenen Zustand,

Fig.3 und 4 die erfindungsgemäßen Ausführungsformen gemäß Figuren 1 und 2 mit einem zusätzlich eingebautem Ventil,

Fig. 5 einen Querschnitt längs der Linie A-A' in Fig. 4 mit einem Pendelschieber,

Fig. 6 einen Querschnitt längs der Linie A-A' in Fig. 4 mit einem Drehschieber,

Fig. 7 eine erfindungsgemäße Ausführungsform des Pendelschiebers bzw. Drehschiebers gemäß Figuren 5 und 6 im Querschnitt längs der Linie B-B',

Fig. 8 eine weitere erfindungsgemäße Ausführungsform eines Drehschiebers,

Fig. 9 einen Querschnitt durch eine weitere erfindungsgemäße Ausführungsform,

Fig. 10 einen Querschnitt längs der Linie C-C' in Fig. 9,

Fig. 11 einen Querschnitt längs der Linie D-D' in Fig. 9,

Fig. 12 einen Querschnitt durch eine weitere erfindungsgemäße Ausführungsform,

Fig. 13 einen Querschnitt längs der Linie E-E' in Fig. 12,

Fig. 14 einen Querschnitt längs der Linie F-F' in Fig. 12,

Fig. 15 einen vergrößerten Teilquerschnitt längs der Linie G-G' in Fig. 12,

Fig. 16 eine vergrößerte Darstellung einer Originalitätssicherung gemäß Fig. 12,

Fig. 17a einen Querschnitt durch eine weitere erfindungsgemäße Ausführungsform,

Fig. 17b einen Querschnitt längs der Linie H-H' in Fig. 17a, und

Fig. 18 einen Teilquerschnitt durch eine weitere Ausführungsform.

Fig. 1 zeigt eine erfindungsgemäße Ausführungsform eines Verschlusses in geöffneter Stellung. Der Verschluß besteht aus einem Unterteil bzw. Grundkörper 1, einem Oberteil bzw. einer Drehkappe 2 und einem zwischen den beiden angeordneten verschiebbaren Mittelteil 3. Der Grundkörper 1 und die Drehkappe 2 sind als gegeneinander gewölbte elastisch verformbare Membranen ausgebildet, die miteinander durch eine Öffnung 4c im Mittelteil 3 hindurch ausgerichtete Öffnungen 4a und 4b aufweisen. Die Drehkappe 2 ist drehbar am Grundkörper 1 gehaltert. Die Öffnungen 4a und 4b sind vorzugsweise wie in den vorstehend beschriebenen Ausführungsformen mittig in bezug zur Drehachse angeordnet, so daß beim Verdrehen des einen Verschlußteils gegenüber dem anderen die Öffnungen zueinander ausgerichtet bleiben.

Beim Schließen des Verschlusses wird das Mittelteil 3 durch Drehen der Drehkappe 2 über eine kraftschlüssige Verbindung, z.B.einen Mitnehmer 14 oder eine zahnradartige Verbindung 9 (Figuren 5 und 6) in den von den Öffnungen 4a und 4b ausgebildeten Durchlaß 6 gebracht. Dabei werden wobei der membranartig ausgebildete Grundkörper 1 und die Drehkappe 2 auseinandergebogen, so daß sie durch Vorspannung fest auf das Mittelstück 3 drücken und dieses den Durchlaß 6 abdichtet. Das Mittelteil 3 kann wahlweise als Pendelschieber 3a (Fig, 5) oder als Drehschieber 3b (Fig. 6) ausgebildet sein.

Wie in der Figur deutlich erkennbar, weist das Mittelteil einen dickeren Abschnitt auf, der aus einander gegenüberliegenden Erhabenheiten 3e an der Unterseite und der Oberseite gebildet wird. Diese Erhabenheiten 3e sind in Größe und Form den zugehörigen Öffnungen 4a, 4b, derart angepaßt, daß diese den Durchlaß dichtend verschließen, wenn das Mittelteil 3 in die Schließstellung gebracht wird. Die Erhabenheiten 3e gehen mit einer umlaufenden schrägen Fläche 3f in die umgebenden Flächenteile des Mittelteils 3 über. Diese Schrägflächen bilden in vorteilhafter Weise die Dichtflächen mit den anliegenden Kanten der zugehörigen Öffnungen 4a, 4b im Unterteil 1 bzw. Oberteil 2. Die Schrägflächen 3f bewirken eine Ausrichtung der jeweiligen Erhabenheit 3e in den zugehörigen Öffnungen 4a, 4b, die durch die zwischen dem Oberteil 2 und dem Unterteil 1 vorhandene Vorspannung selbsttätig beim Einrasten des Mittelteils 3 in der Schließlage erfolgt. Die entsprechende seitliche Beweglichkeit der Teile zueinander wird durch ein vorgesehenes Spiel erreicht. Die Schrägflächen 3f haben außerdem den Vorteil, daß beim Öffnen des Verschlusses die Erhabenheiten 3e die Öffnungen 4a, 4b bzw. die umlaufenden Kanten im Unterteil 1 und Oberteil 2 voneinander wegdrücken.

Die Figuren 3 und 4 zeigen die erfindungsgemäße Ausführungsform gemäß Figuren 1 und 2 in ihrer geöffneten Stellung mit einem Ventileinsatz 13 im Bereich der Öffnung 4a des Grundkörpers 1. Der Ventileinsatz 13 besteht aus elastischem Material. Dieser ist in Fig. 3 in ausgestülpter Position und in Fig. 4 in eingesetzter Position gezeigt, wobei das Mittelteil 3 die Öffnung des Ventileinsatzes 13 abdichtet. Vorzugsweise wird als Ventileinsatz das in der US-PS-4,991,745 oder der EP-A-395 380 beschriebene Ventil verwendet.

Fig. 5 zeigt eine erfindungsgemäße Ausführungsform des Mittelteils 3 als Pendelschieber 3a. Der Pendelschieber 3a wird bei einer Drehbewegung α der Drehkappe 2 durch einen an der Drehkappe 2 befestigten Mitnahmestift 14, der in einen

Schlitz 5 im Pendelschieber 3a eingreift, um die Strecke H linear waagerecht verschoben, wobei die Ventilöffnung 13 entweder geöffnet oder geschlossen wird. In den beiden Endstellungen wird der Pendelschieber 3a durch zwei Federnasen 7 jeweils mit einer Aussparung 8 gehalten.

Fig. 6 zeigt den Querschnitt A-A' gemäß Fig. 4 mit einer erfindungsgemäßen Ausführungsform des Mittelstückes 3 als Drehschieber 3b. Der Drehschieber 3b wird durch einen Drehbewegung α der Drehkappe 2 über eine zahnradartige Verbindung 9 um 180° in die geöffnete oder geschlossene Stellung gedreht.

Fig. 7 zeigt einen Querschnitt durch den Pendelschieber 3a oder den Drehschieber 3b längs der Linie B-B' in den Figuren 5 und 6. Die Schieber weisen seitlich eine keilförmige Verdickung 10 an der Ober- und Unterseite auf, die die Membranen des Grundkörpers 1 und der Drehkappe 2 beim Übergang in die geschlossene Stellung des Schiebers auseinanderpressen.

Fig. 8 zeigt eine Draufsicht auf eine weitere erfindungsgemäße Ausführungsform eines Drehschiebers 3b im geschlossenen Zustand. Der Drehschieber weist ein nierenförmiges Langloch 11 und eine am Kreisumfang angeordnete keilförmige Verdickung 10 auf. Das Langloch 11 ermöglicht es z.B. einem vorstehenden Ventil 13 sich zurückzuziehen, bevor der Drehschieber 3b in die geschlossene Stellung gleitet.

Fig. 9 zeigt eine weitere erfindungsgemäße Ausführungsform mit einem Pendelschieber 3c. Der Mitnehmer 14 ragt durch einen Schlitz 23 im Pendelschieber 3c in eine Aussparung 24 in einer Führungsplatte (nicht dargestellt). Dadurch wird eine bessere Sicherung gegen ein Herausrutschen des Mitnehmers 14 bei einer gegebenenfalls vorhandenen unbeabsichtigten Vertikalbewegung des Oberteils 2 erreicht, die beispielsweise bei einem vorhandenen Spiel, Stößen oder Verbiegungen des Oberteils auftreten kann. Der Pendelschieber 3c

ist im Querschnitt U-förmig ausgebildet und weist auf jeder Seite zwei Schenkel 25 auf, die unter der Zeichenebene liegen und gestrichelt dargestellt sind Außerdem weist der Pendelschieber 3c seitlich eine federnde Nase 7 auf, die in zwei Aussparungen 8 in einer der Führungsschienen 15 einrastbar ist. Die Nachgiebigkeit der Nase 7 wird durch einen benachbarten, im Pendelschieber 3c angeordneten Schlitz 26 erreicht. Außerdem weist das Unterteil 1 vier dem Oberteil 2 zugewandte Anschläge 27 auf, an die zwei am Oberteil 2 angeordnete Vorsprünge 28 anschlagen und so die Drehbewegung des Oberteils 2 stoppen, wenn der Pendelschieber die geöffnete bzw. die geschlossene Stellung des Verschlusses erreicht hat, und als Anschlag zum Auf- und Abschrauben des Verschlusses auf einen Behälter dienen können.

In Fig. 10 ist ein Querschnitt längs der Linie C-C' in Fig. 9 dargestellt. Der Verschluß befindet sich in geschlossenem Zustand, und der Pendelschieber 3c verschließt die Entnahmeöffnung 4a mit dem Ventileinsatz 13. Zwischen dem Unterteil 1 und dem Pendelschieber 3c ist eine Führungsplatte 20 angeordnet, auf der der Pendelschieber 3c gleitet und die mit Stiften 22 in dem Unterteil 1 arretiert ist. Die Führungsplatte 20 haltert im Klemmsitz den Ventileinsatz 13. Der Verschluß ist über eine Verschraubung 18 an seinem Unterteil mit einem Behälter 19 verbunden, wobei eine umlaufende Dichtlippe 34 das Unterteil 1 gegen das Innere des Behälters 19 abdichtet. Das Unterteil 1 liegt seitlich mit einer umlaufenden Fläche 29 an dem Behälter 19 an, wobei der Innenraum zwischen dem Unterteil 1 und dem Behälter 19 abgedichtet wird. Das Oberteil 2 ist auf dem Unterteil 1 drehbar mittels zweier umlaufender, ineinander eingepaßter elastischer Lippen 30 gehaltert.

Fig. 11 zeigt einen Querschnitt längs der Linie D-D' in Fig, 9. Es ist der U-förmige Querschnitt des Pendelschiebers 3c mit dem Schenkeln 25 in den Führungsschienen 15 der Führungsplatte 20 zu erkennen.

Fig. 12 stellt den Querschnitt einer weiteren erfindungsgemäßen Ausführungsform dar. In dieser Ausführungsform ist das Mittelteil 3 als Schwenkteil 3d ausgebildet, das am Rande des Verschlusses um einen Zapfen 16 schwenkbar ist. Das Schwenkteil 3d wird durch einen am Oberteil 2 befestigten Mitnehmer 14, der durch einen Schlitz 23 in dem Schwenkteil 3d in eine Aussparung 24 in einem Führungsring 21 ragt, durch Drehen des Oberteils 2 in eine geöffnete oder geschlossene Stellung des Verschlusses geschwenkt. Das Schwenkteil 3d hat im wesentlichen die gleiche Funktion wie das Mittelteil 3 bei den anderen Ausführungsformen und hat eine Öffnung 4c, die mit den Öffnungen 4a und 4b ausgerichtet werden kann.

Das Unterteil 1 weist zwei Ausschnitte 1a auf, in die das Schwingteil 3d in der offenen bzw. geschlossenen Stellung des Verschlusses hineinragt. Dadurch kann der Schwenkwinkel des Schwengteils weiter vergrößert werden.

Der Verschluß weist ferner eine Originalitätssicherung 17 mit einer Sollbruchstelle 17a auf, die bei einer erstmaligen Verwendung des Verschlusses abgeschert wird. Ferner weist der Verschluß zwei Anschläge 27 und zwei Vorsprünge 28 am Oberteil 2 auf. Die Anschläge 27 dienen als Raststellen für die offene oder geschlossene Stellung des Verschlusses, wobei jeweils eine federnde Nase 7, der im Schwenkteil 3d ein Schlitz 26 benachbart ist, hinter dem Anschlag 27 einrastet. Außerdem dienen die Anschläge 27 als Anschläge an die Vorsprünge 28 zum Auf- und Abschrauben des Verschlusses auf einen Behälter.

Fig. 13 zeigt einen Querschnitt längs der Linie E-E' in Fig. 12, wobei der Verschluß geschlossen ist. Der Führungsring 21 ist zwischen dem Schwenkteil 3d und dem Unterteil 1 angeordnet und haltert den Ventileinsatz 13 im Klemmsitz. Der Verschluß ist mittels der Verschraubung 18 mit einem Behälter

19 verbunden und weist eine Abschraubsicherung 31, 31a zwischen dem Behälter 19 und dem Unterteil 1 auf. Das Unterteil 1 ist gegen den Behälter 19 abgeschlossen und sitzt mittels einer umlaufenden Dichtwulst 32 auf dem Behälter 19 auf. Eine radial nach außen vorspringende Stufe am Unterteil 1 erlaubt das leichte Aufdrehen des Verschlusses auf die Abschraubsicherung des Behälters. Die Abschraubsicherung wird von mehreren am Unterteil 1 im Bereich der Stufe 33 angeordneten Vorsprüngen 31 und von damit in Eingriff bringbaren Vorsprüngen 31a am Behälter 19 gebildet.

Fig. 14 ist ein Querschnitt längs der Linie F-F' in Fig. 12. Unterhalb der Schnittebene sind die Anschläge 27 zu erkennen, die auf dem Grundkörper 1 stehen.

Fig. 15 zeigt einen vergrößerten Teilquerschnitt längs der Linie G-G' in Fig. 12. Dabei ist der vom Oberteil 2 herabragende Mitnehmer 14 in dem Schlitz 23 des Schwenkteils 3d und der Vorsprung 28 am Oberteil 2 zu erkennen. In der vergrößerten Darstellung von Fig. 15 ist deutlich sichtbar, daß das Schwenkteil 3d im mittleren Bereich gefertigt ist, und in einem Übergangsbereich Schrägflächen 3f aufweist, an die die innenliegende Kante der Entnahmeöffnung 4b im Oberteil 2 bzw. 4a des Führungsrings 21 anliegt. Die Verdickung im mittleren Bereich des Schwenkteils 3d ist in Größe und Form an der zugehörigen Entnahmeöffnung 4b bzw. 4a angepaßt. Aufgrund der Vorspannung der Deckelfläche des Oberteils 2 in Richtung des Unterteils 1 bzw. des Führungsrings 21 wird ein dichter Abschluß der Entnahmeöffnung 4b im Oberteil 2 und der Entnahmeöffnung 4a im Unterteil 1 bzw. dem Führungsring 21 mittels des dazwischen angeordneten Mittelteils erreicht. Durch die Schrägflächen 3f entlang des Umfangs der Verdickung bzw. der Erhabenheit können Fertigungstoleranzen ausgeglichen werden und eine Selbstzentrierung des Mittelteils gegenüber den beiden Öffnungen erreicht werden. Diese Funktion der Erhabenheiten am Mittelteil sind in gleicher

Weise bei den anderen hierin beschriebenen Ausführungsformen gegeben.

Fig. 16 zeigt eine vergrößerte Darstellung der Originalitätssicherung 17 mit der Sollbruchstelle 17a gemäß Fig. 12. Die Originalitätssicherung 17 ist über eine Dünnstelle 17a am Außendurchmesser des Grundkörpers 1 angeordnet. Die Originalitätssicherung 17 ragt durch eine Öffnung 2a an der Drehkappe 2, vorzugsweise in Form eines an der Unterkante beginnenden Schlitzes nach außen und ist durch einen Griff 17b nach dem Abbrechen entfernbar. Gleichzeitig verhindert der Griff 17b, daß die Originalitätssicherung 17 bei der Relativbewegung von Grundkörper 1 und Drehkappe 2 nach innen gezogen wird. Bei der erstmaligen Drehung der Drehkappe 2 schlägt diese an ihrer Öffnung 2a an die Originalitätssicherung 17 an und bewirkt ihr Abscheren von dem Zapfen 16.

In den Figuren 17a und 17b wird eine weitere erfindungsgemäße Ausführungsform gezeigt, wobei das Oberteil 2 einen ovalen Querschnitt aufweist. Ein solcher Querschnitt paßt z.B. gut zu einem Behälter mit ovaler Form. Fig. 17b ist ein Querschnitt längs der Linie H-H' in Fig. 17a. Das Oberteil 2 verschiebt das als Pendelschieber ausgebildete Mittelteil 3 von der geschlossenen in die geöffnete Stellung des Verschlusses durch eine Drehung um 180°. Dadurch ist das ovale Oberteil 2 sowohl in der geöffneten als auch geschlossenen Stellung mit der ovalen Form des Behälters ausgerichtet. In Fig. 17b ist zusätzlich zu Fig. 17a der Mitnehmer 14 eingezeichnet. Dieser läuft beim Öffnen oder Schließen auf einem Halbkreis K.

Die vorstehend beschriebenen Verschlüsse können durch eine Schraubverbindung, ein Aufprellsystem oder durch Aufspritzen mit einem Behälter verbunden werden. In Fig. 18 ist ausschnittsweise dargestellt, wie bei einem tubenförmigen Behälter die Folie 19a des Behälters am Unterteil 1 des Verschlusses angespritzt ist. Das Folienmaterial 19a überdeckt

in einem Kantenbereich die Oberseite des Unterteils 1. Hierdurch wird in vorteilhafter Weise die Tube direkt mit dem Verschluß verbunden.

Patentansprüche

1. Verschluß, mit

(a) einem Unterteil (1), das eine Entnahmeöffnung (4a) aufweist,

(b) einem Oberteil (2) mit einer korrespondierenden Entnahmeöffnung (4b), wobei eines der Verschlußteile (1 oder 2) gegen das andere verdrehbar ist, und

(c) einem Mittelteil (3), das in eine erste Stellung, in der die Entnahmeöffnungen (4a, 4b) frei sind, und eine zweite Stellung, in der es die Entnahmeöffnungen (4a, 4b) verschließt, bewegbar ist,

wobei

(d) das Mittelteil (3) linear verschiebbar, verschwenkbar oder in Umfangsrichtung beweglich angeordnet ist, und

(e) ein an dem verdrehbaren Verschlußteil (1 oder 2) oder am Mittelteil (3) angeordneter Mitnehmer (14) derart kraftschlüssig mit dem jeweils anderen Teil in Verbindung steht, daß durch Drehen der Verschlußteile (1, 2) gegeneinander das Mittelteil (3) in die erste oder zweite Stellung bewegt wird.

2. Verschluß, mit

(a) einem Unterteil (1), das eine Entnahmeöffnung (4a) aufweist,

(b) einem Oberteil (2) mit einer korrespondierenden Entnahmeöffnung (4b), wobei eines der Verschlußteile (1 oder 2) gegen das andere verdrehbar ist, und

(c) einem Mittelteil (3), das in eine erste Stellung, in der die Entnahmeöffnungen (4a, 4b) frei sind, und eine zweite Stellung, in der es die Entnahmeöffnungen (4a, 4b) verschließt, bewegbar ist,

wobei

(d) das Unterteil (1) oder das Oberteil (2) eine erste Umfangsfläche aufweist,

(e) das Mittelteil (3) eine zweite Umfangsfläche aufweist, und

(f) die erste und zweite Umfangsfläche derart kraftschlüssig, vorzugsweise mit einer zahnradartigen Verbindung (9), in Eingriff stehen, daß durch Drehen der Verschlußteile (1, 2) gegeneinander das Mittelteil (3) in die erste oder zweite Stellung bewegt wird.

3. Verschluß, mit

(a) einem Unterteil (1), das eine Entnahmeöffnung (4a) aufweist,

(b) einem Oberteil (2) mit einer korrespondierenden Entnahmeöffnung (4b), wobei eines der Verschlußteile (1 oder 2) gegen das andere verdrehbar ist, und

(c) einem Mittelteil (3), das in eine erste Stellung, in der die Entnahmeöffnungen (4a, 4b) frei sind, und eine zweite Stellung, in der es die Entnahmeöffnungen (4a, 4b) verschließt, bewegbar ist,

wobei

(d) das Oberteil (2) drehbar an dem Unterteil (1) gehaltert ist und die Entnahmeöffnungen (4a, 4b) einen Durchlaß (6) ausbilden können,

(e) das Oberteil (2) und das Unterteil (1) gegeneinander elastisch vorspannbar sind,

(f) das Mittelteil (3) zwischen dem Unterteil (1) und dem Oberteil (2) angeordnet ist und durch eine Drehung des Oberteils (2) in die erste oder zweite Stellung des Verschlusses bewegbar ist, und

(g) das Mittelteil (3) in der zweiten Stellung zwischen den beiden Öffnungen (4a, 4b) angeordnet ist und durch die Vorspannung zwischen der Drehkappe (2) und dem Grundkörper (1) den Durchlaß (6) zwischen ihnen abdichtet.

4. Verschluß nach Anspruch 1 oder 2, dadurch gekennzeichnet, daß das Oberteil (2) und das Unterteil (1) gegeneinander elastisch vorspannbar sind.

5. Verschluß nach Anspruch 1, 3 oder 4, dadurch gekennzeichnet, daß das Mittelteil (3) als Pendelschieber (3a, 3c) ausgebildet ist, der in Führungsschienen (15) geführt wird.

6. Verschluß nach Anspruch 5, dadurch gekennzeichnet, daß der Pendelschieber (3a; 3c) einen U-förmigen Querschnitt aufweist und mit seinen Schenkeln (25) in den Führungsschienen (15) geführt wird.

7. Verschluß nach Anspruch 1, 3 oder 4, dadurch gekennzeichnet, daß das Mittelteil (3) als Schwenkteil (3d) ausgebildet ist, das um einem auf dem Unterteil (1) befestigten Zapfen (16) schwenkbar ist.

8. Verschluß nach einem der Ansprüche 1 bis 7, dadurch gekennzeichnet, daß das Mittelteil (3) auf seiner Unterseite und/oder Oberseite mindestens eine Erhabenheit (3f) aufweist, die in Form und Größe an die jeweils zugehörige Entnahmeöffnung (4a, 4b) angepaßt ist und in der zweiten Stellung in die Entnahmeöffnungen rastend und dichtend eingreift.

9. Verschluß nach Anspruch 8, dadurch gekennzeichnet, daß zur Originalitätssicherung eine Blockierung (17) zwischen dem Oberteil (2) und dem Mittelteil (3) angeordnet ist, die eine Sollbruchstelle (17a) aufweist.

10. Verschluß nach einem der Ansprüche 1 bis 9, dadurch gekennzeichnet, daß in der Entnahmeöffnung (4a) ein Ventileinsatz (13) angeordnet ist.

11. Verschluß nach einem der Ansprüche 1 bis 10, dadurch gekennzeichnet, daß das Unterteil (1) durch eine Verschraubung (18) oder ein Prellverschlußgestell mit einem Behälter (19) verbunden ist oder bei tubenförmigen Behältern vorzugsweise am Behälter (19a) angespritzt ist.

12. Verschluß nach einem der Ansprüche 1 bis 11, dadurch gekennzeichnet, daß das Oberteil (2) einen ovalen Querschnitt aufweist.

13. Verschluß nach einem der Ansprüche 1 bis 12, dadurch gekennzeichnet, daß zwischen dem Mittelteil (3) und dem Unterteil (2) eine Führungsplatte (20) oder ein Führungsring (21) angeordnet ist, auf dem das Mittelteil (3) gleitet.

14. Verschluß nach Anspruch 13, dadurch gekennzeichnet, daß die Führungsplatte (20) mittels Stiften (22) im Unterteil (1) gehaltert ist.

15. Verschluß nach einem der Ansprüche 1 bis 14, dadurch gekennzeichnet, daß das Mittelteil (3) eine keilförmige Verdickung (10) an der Ober- und Unterseite aufweist, die das Unterteil (1) und das Oberteil (2) beim Übergang in die geschlossene Stellung des Verschlusses auseinanderpressen.

16. Verschluß nach einem der Ansprüche 1 bis 15, dadurch gekennzeichnet, daß das Mittelteil (3) kreisförmig ist und ein nierenförmiges Langloch (11) aufweist.

17. Verschluß, gekennzeichnet durch eine beliebige Kombination von einzelnen Merkmalen der Ansprüche 1 bis 16.

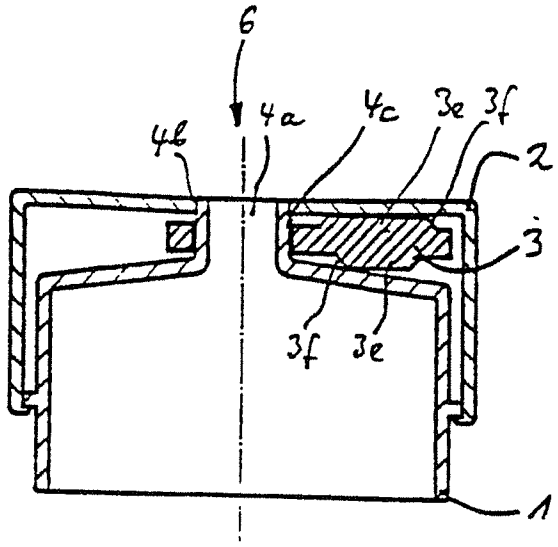


Fig. 1

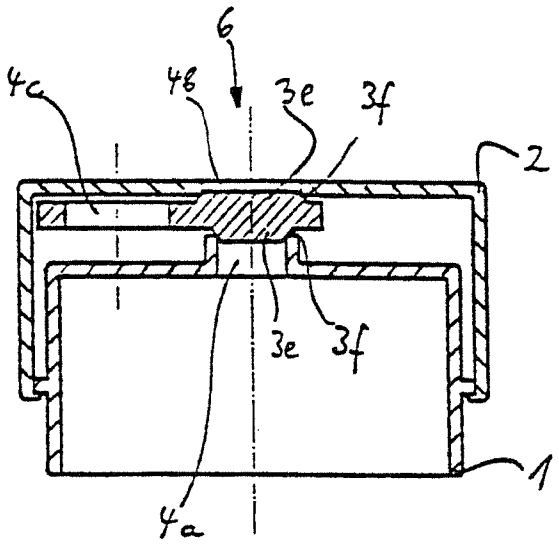


Fig. 2

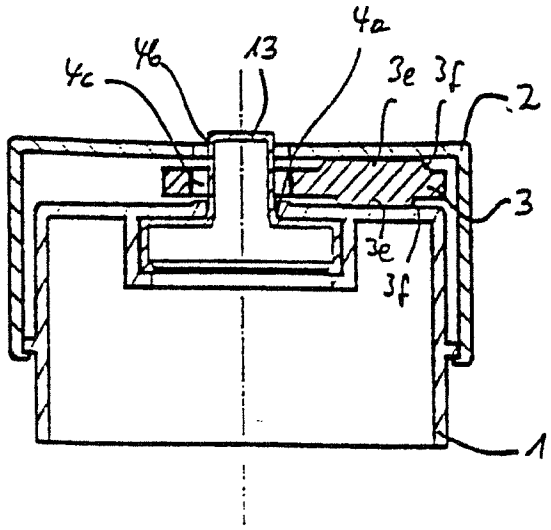


Fig. 3

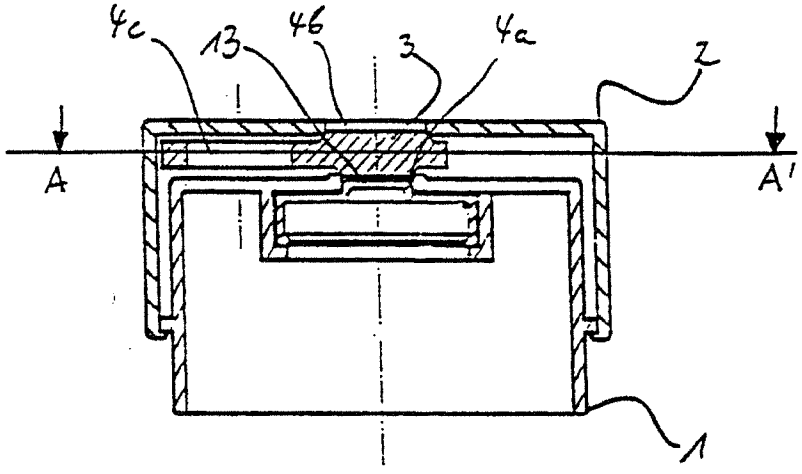


Fig. 4

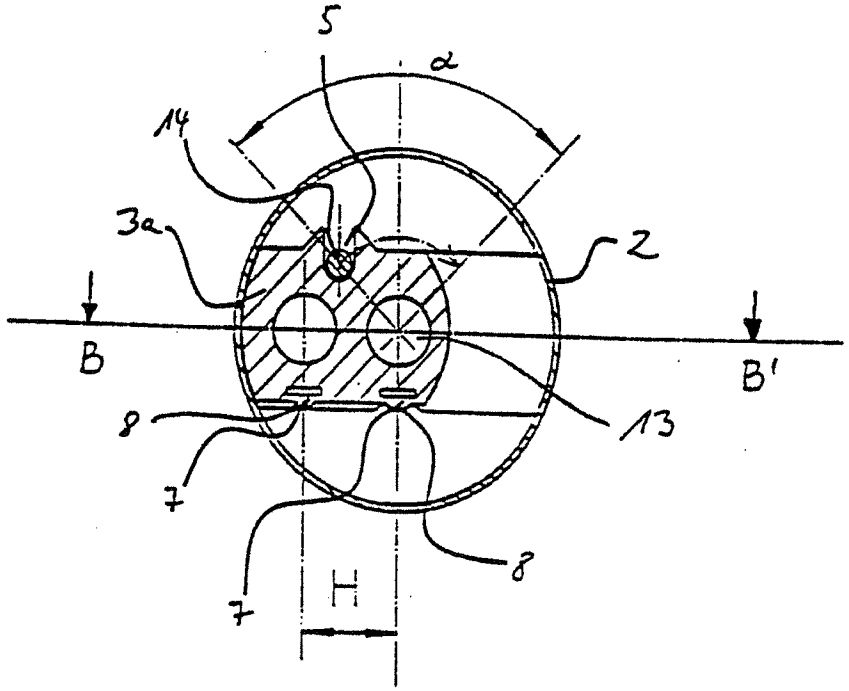


Fig. 5

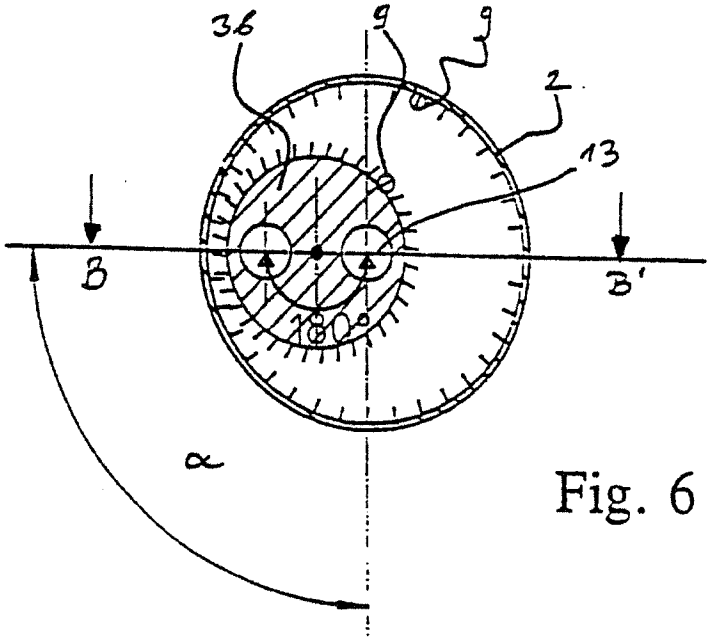


Fig. 6

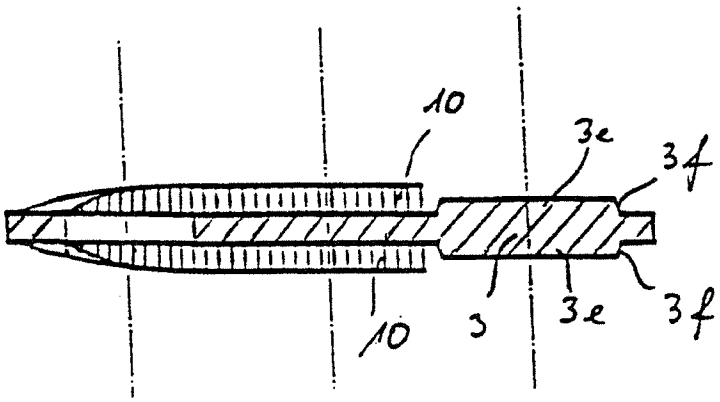


Fig. 7

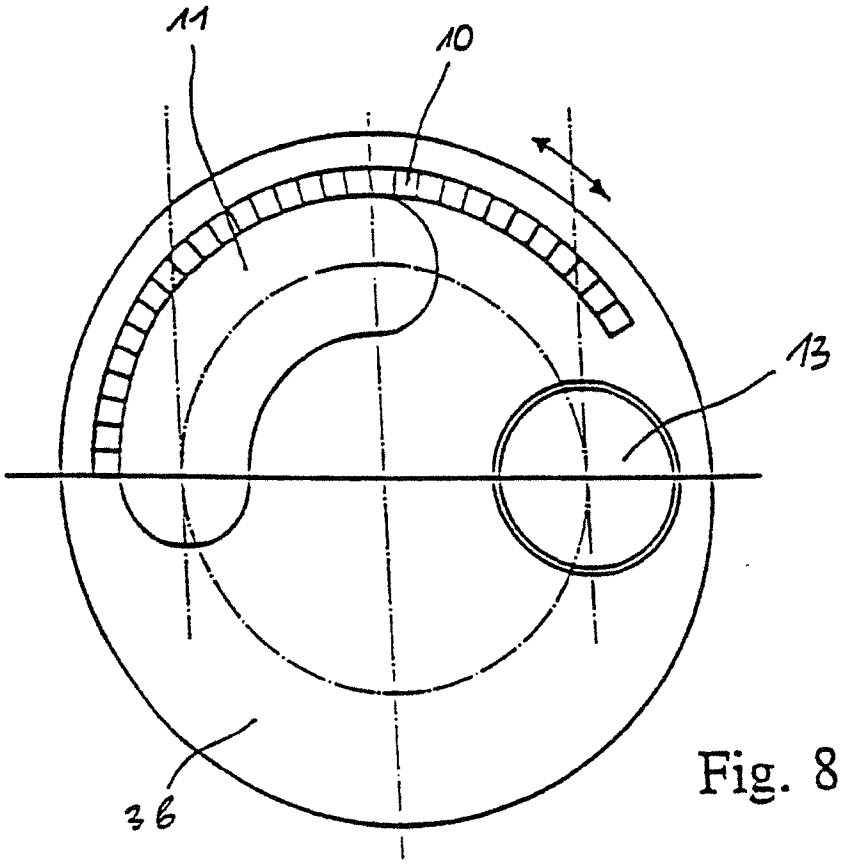


Fig. 8

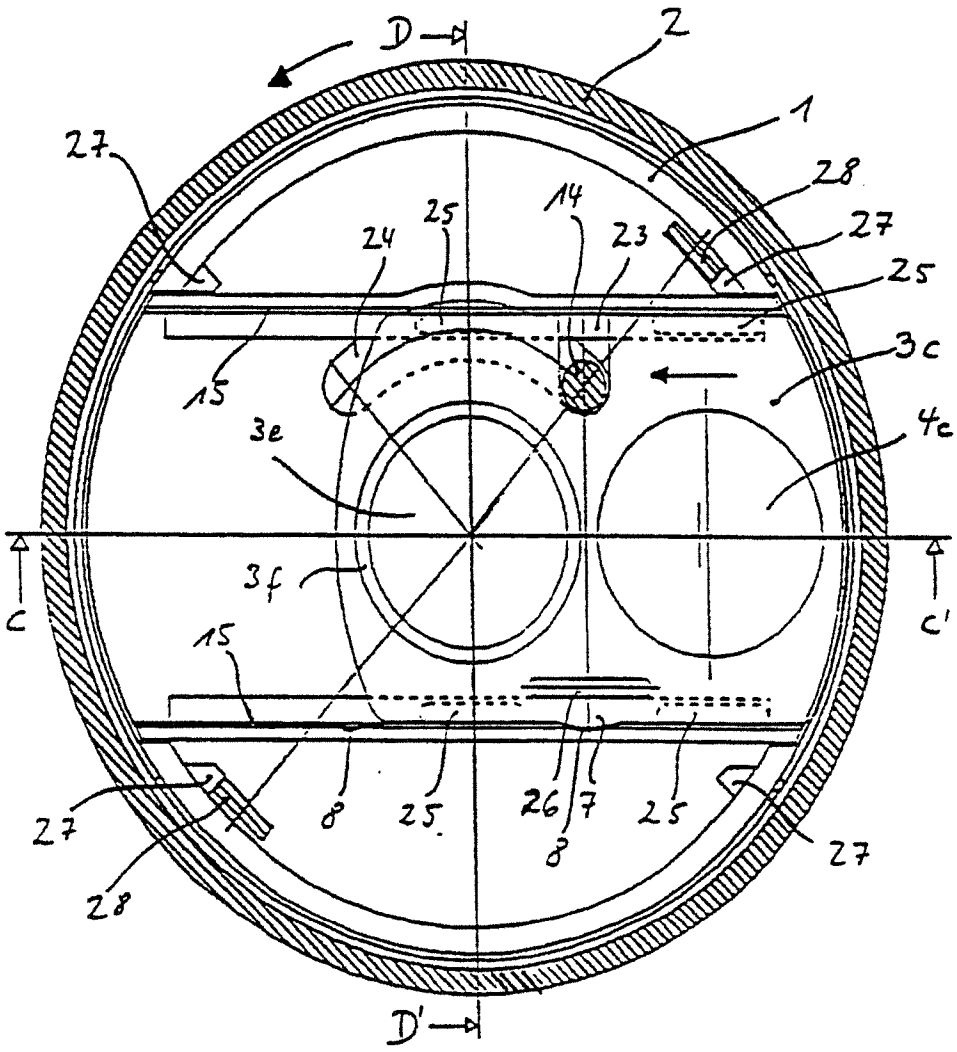


Fig. 9

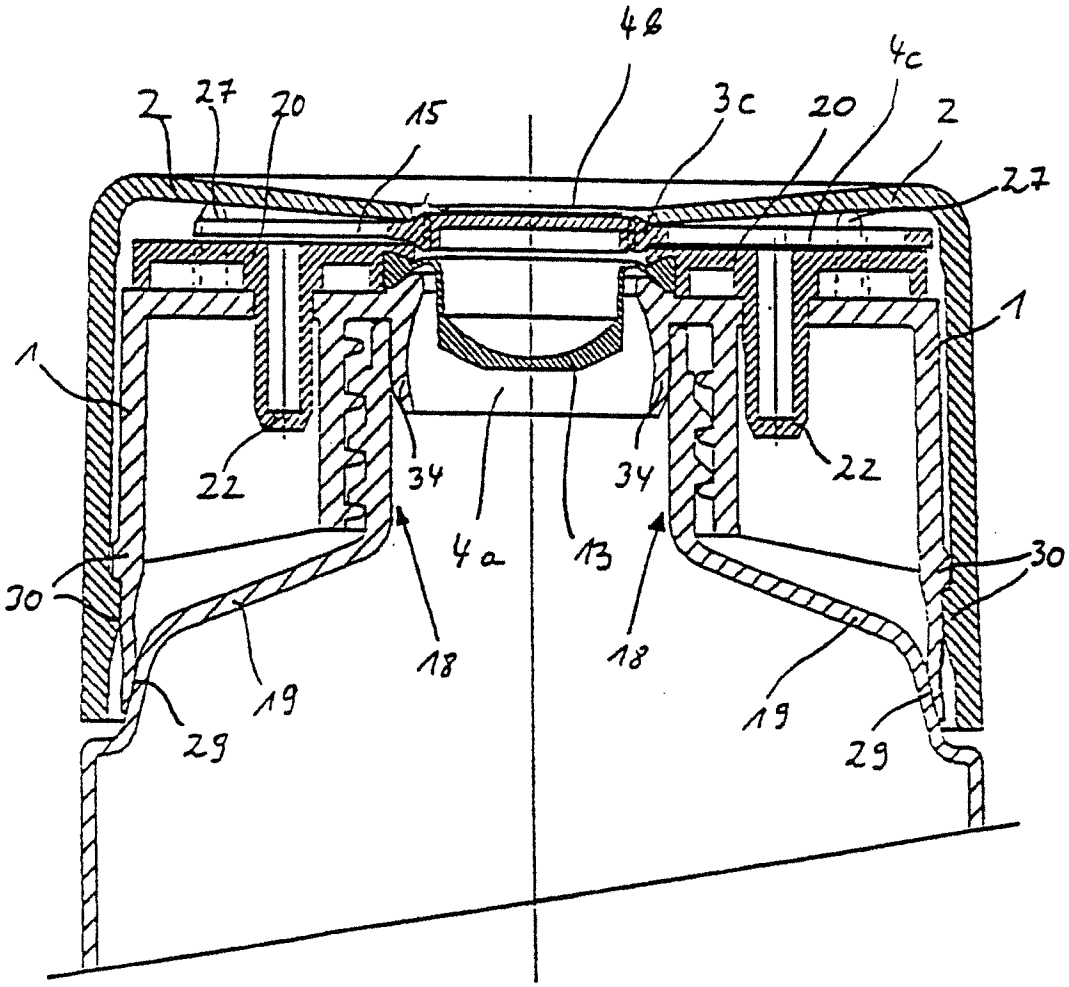


Fig. 10

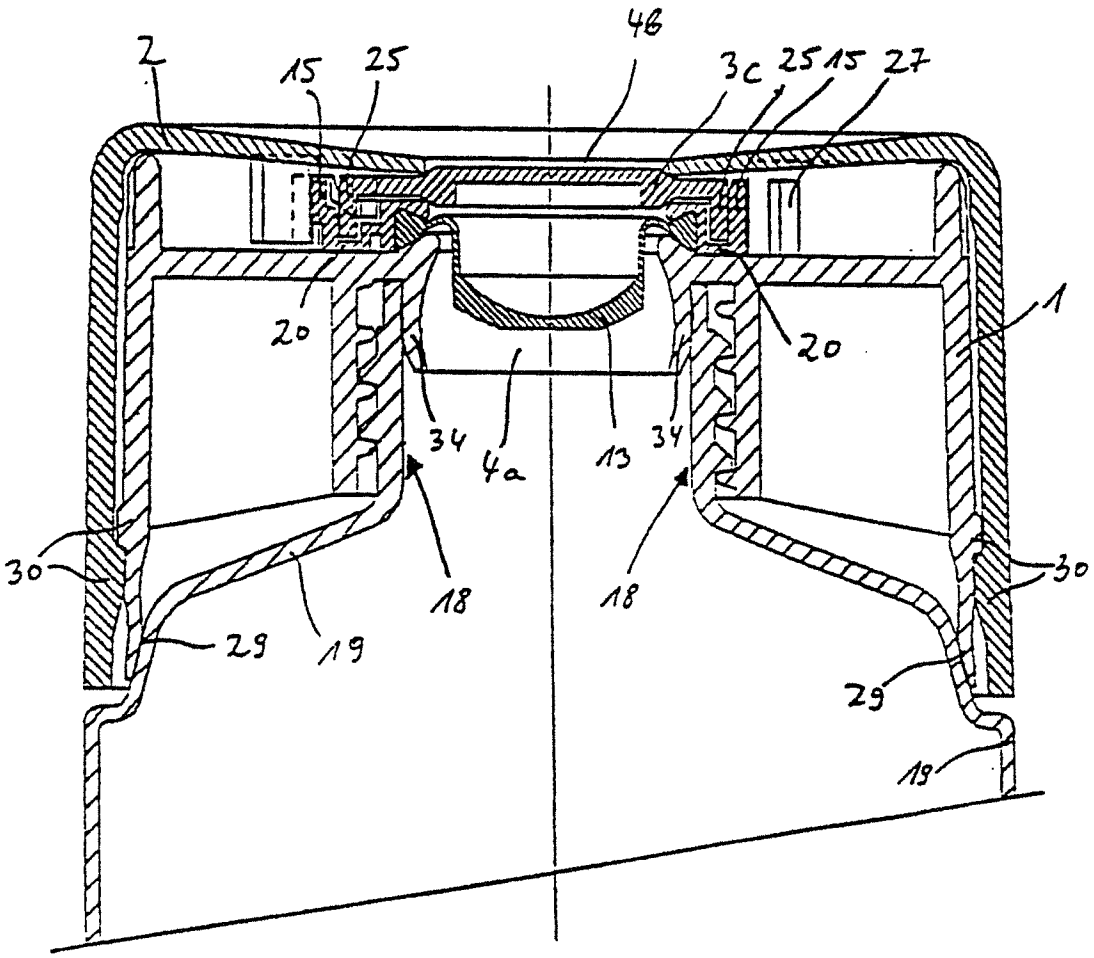


Fig. 11

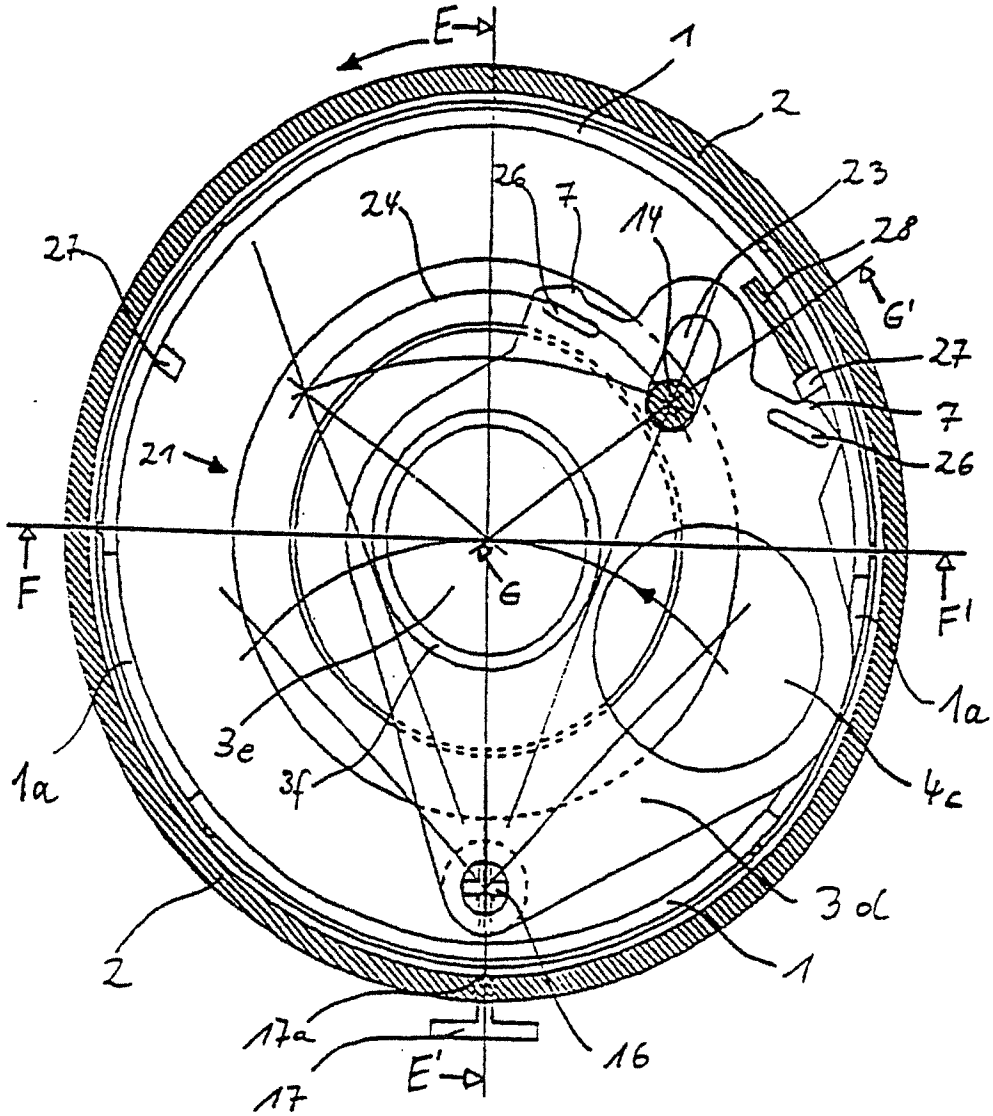

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Fig. 12

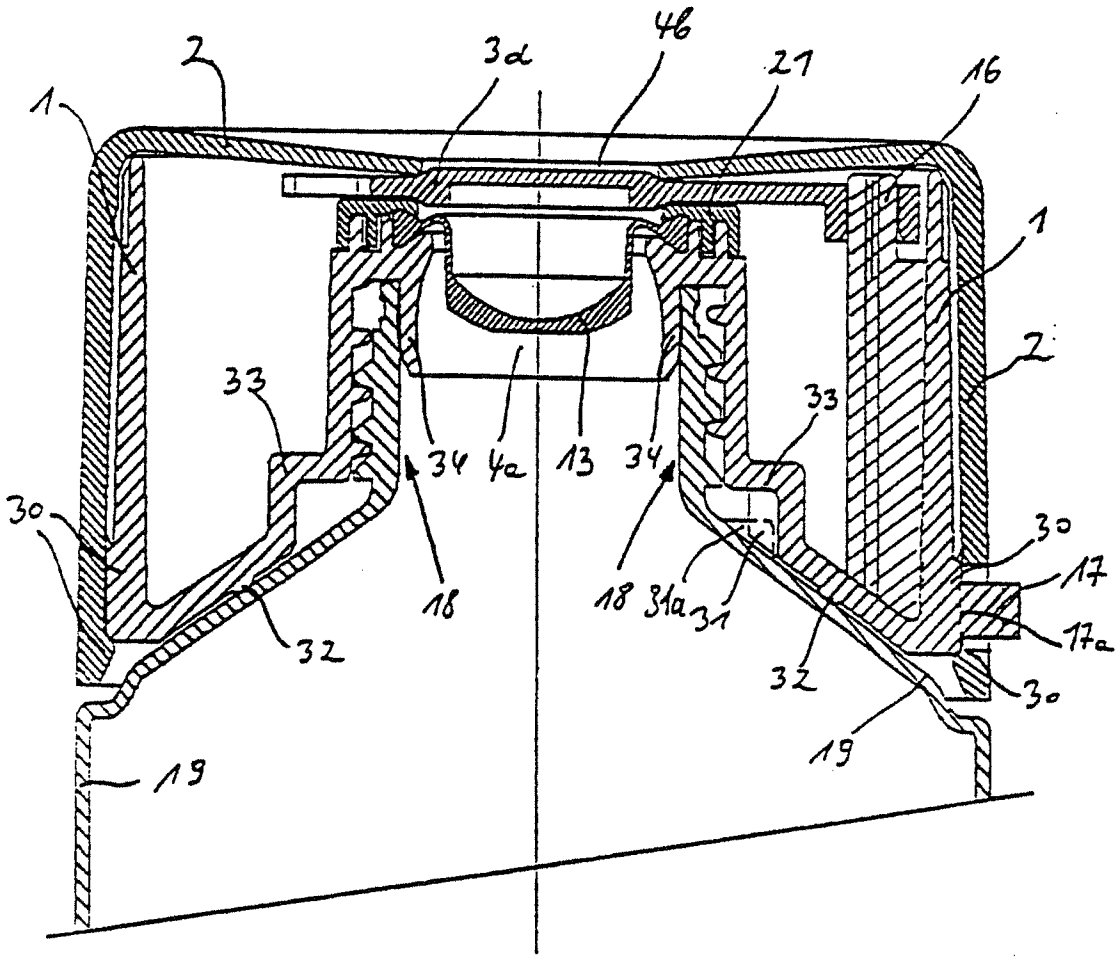

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Fig. 13

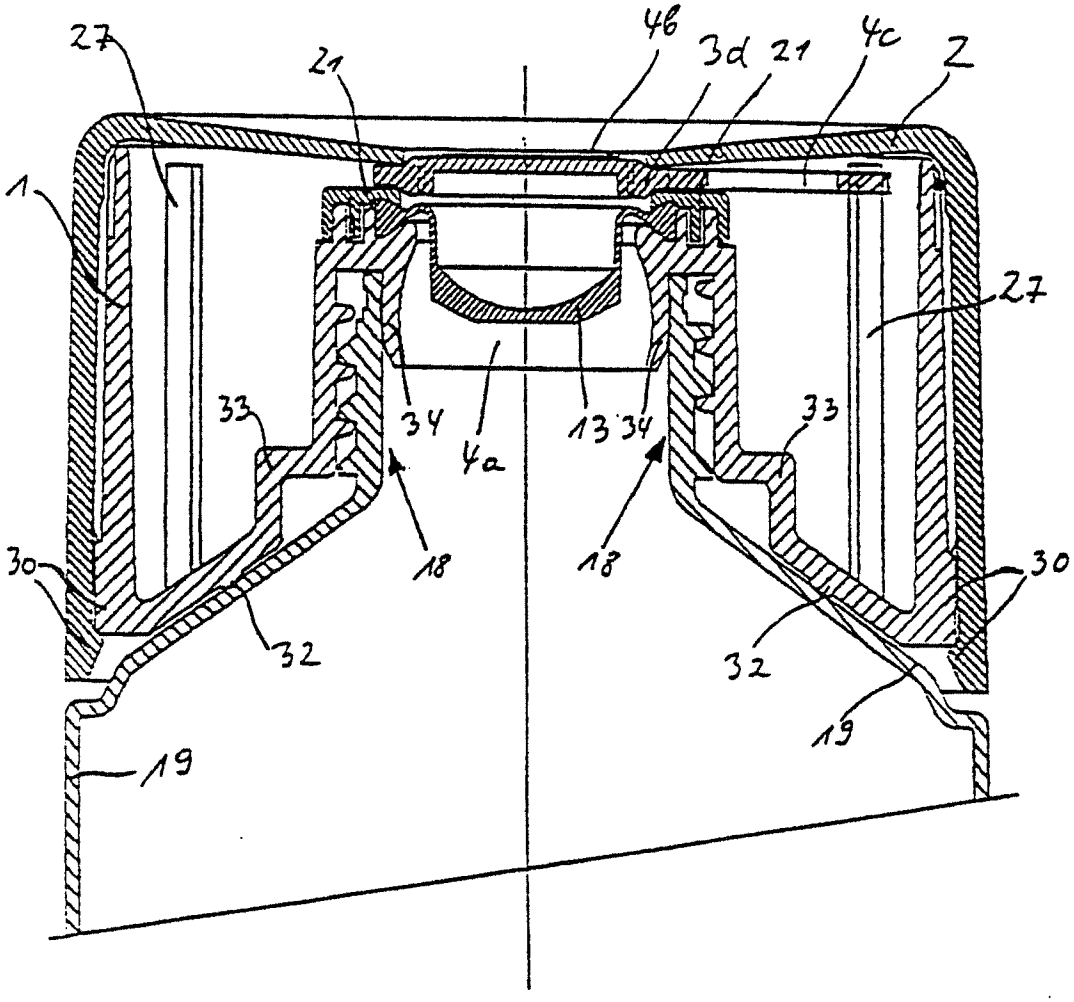


Fig. 14

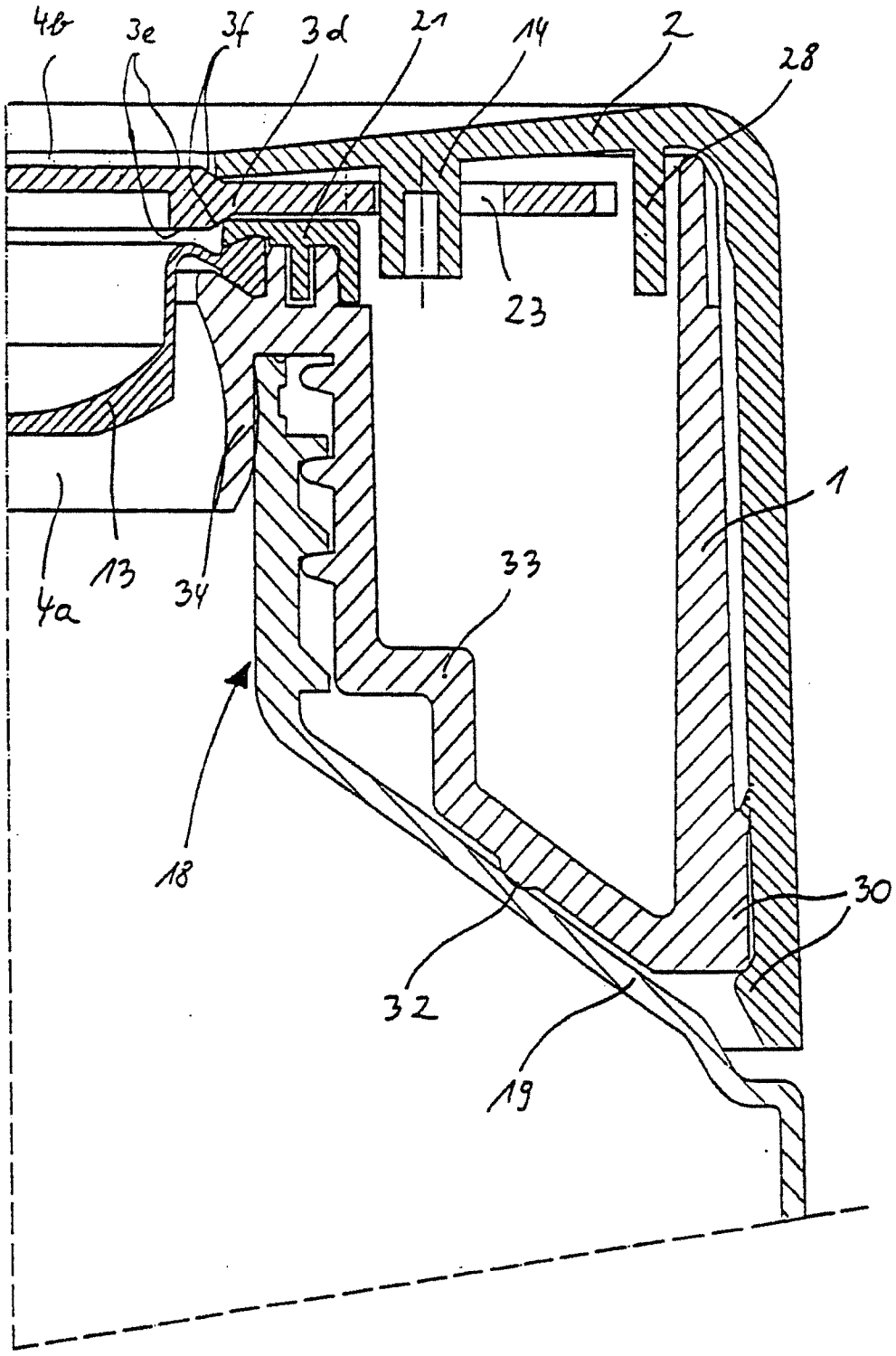


Fig. 15

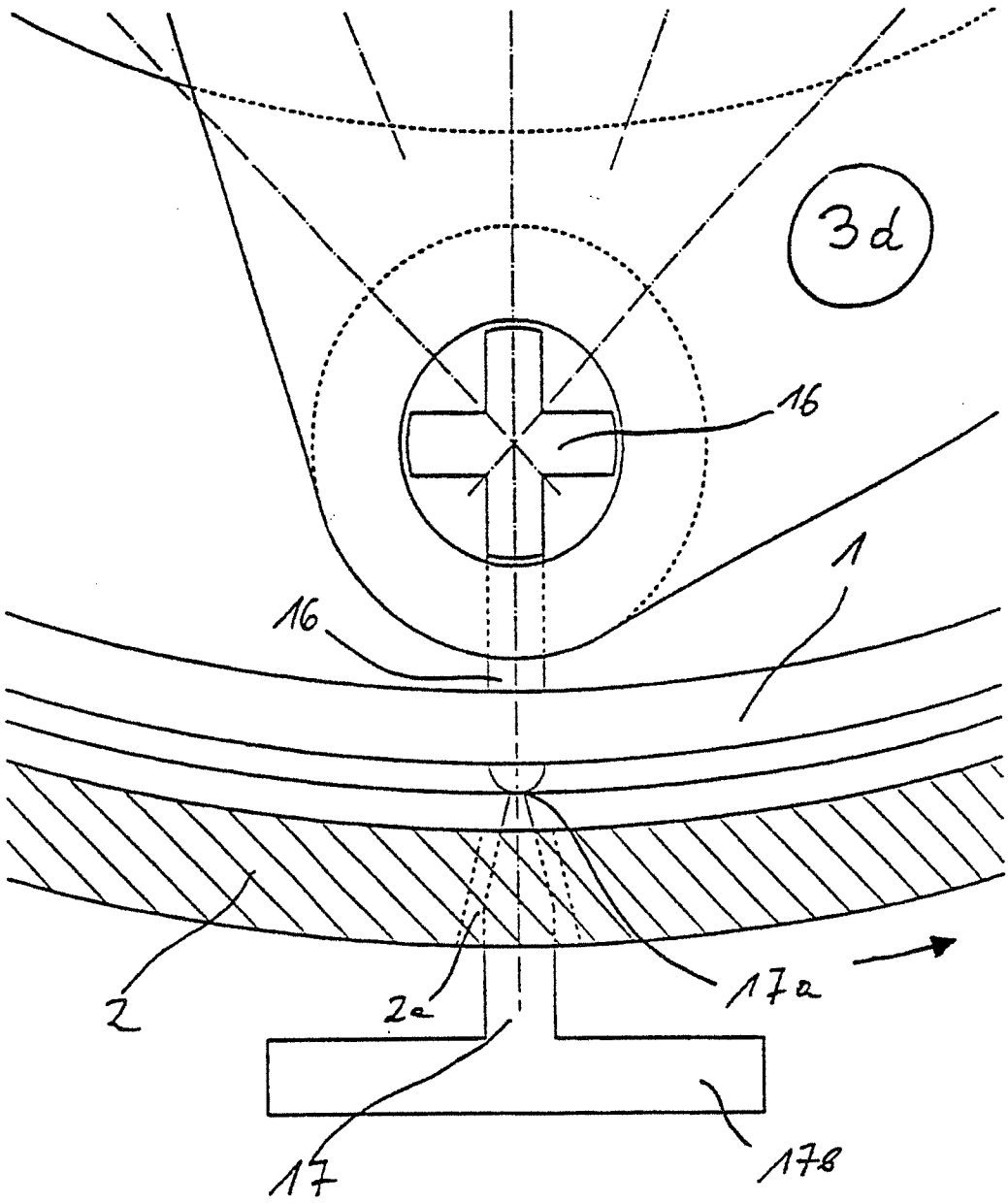


Fig. 16

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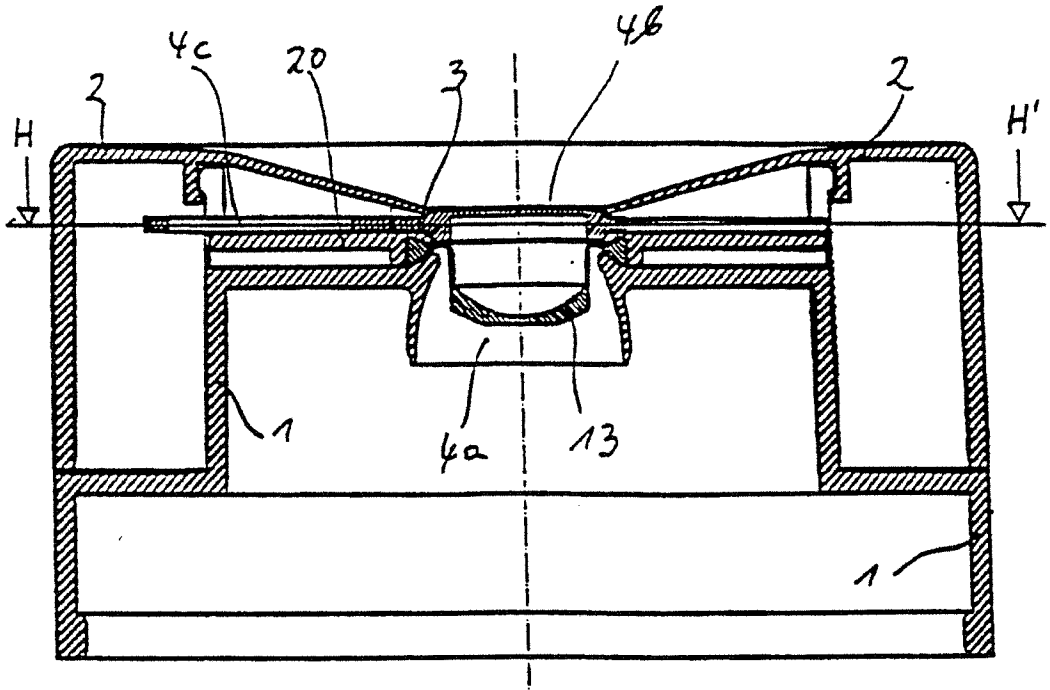


Fig. 17 a

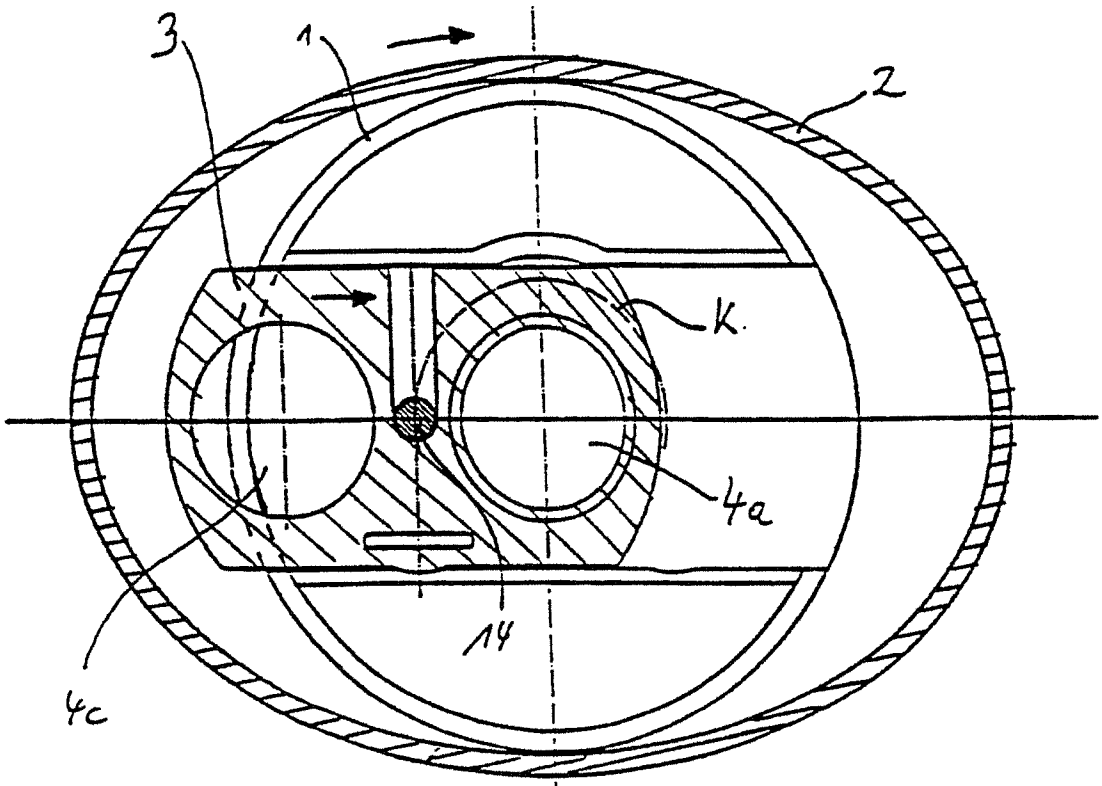


Fig. 17 b

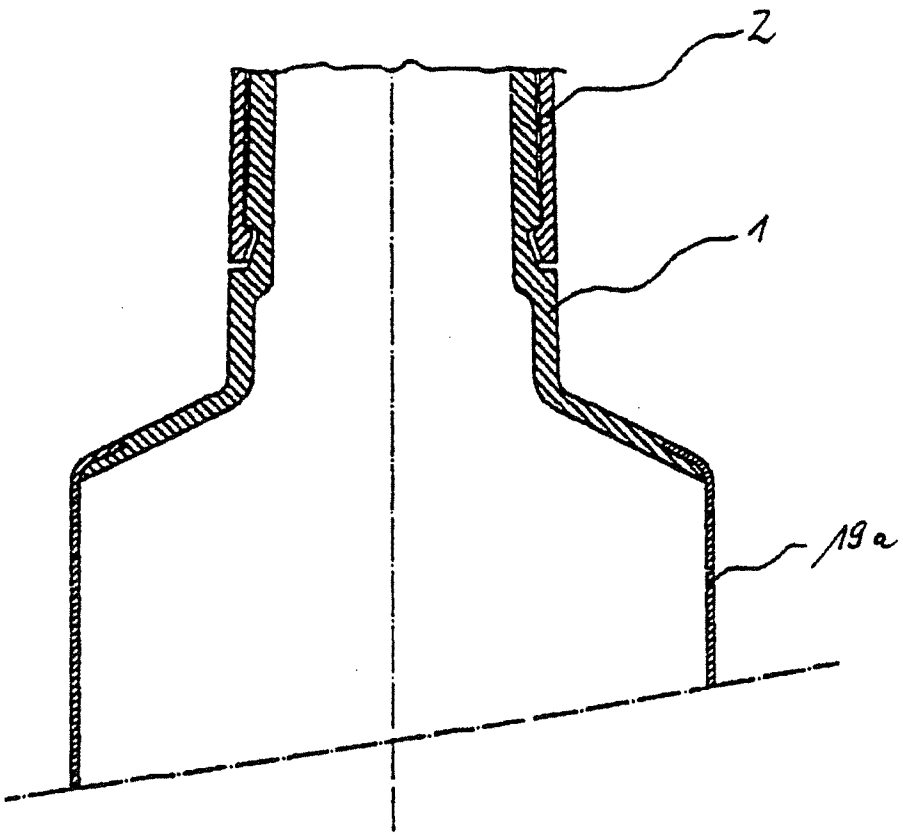


Fig. 18

INTERNATIONAL SEARCH REPORT

Interm al Application No
PCT/EP 94/01695

A. CLASSIFICATION OF SUBJECT MATTER
IPC 5 B65D47/26 B65D47/24 B65D47/20

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 5 B65D

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US,A,2 082 691 (FARRELLY) 1 June 1937	1,2,5-7, 11,13, 14,17
Y	see page 1, right column, line 38 - page 3, left column, line 11; figures 1-12	9,16
X	US,A,5 199 617 (BENNETT) 6 April 1993	1,2,7,8, 11,17
	see figures 1-8	
X	GB,A,521 672 (THORN) 28 May 1940	1,2,7, 11,17
	see figures 1-6	
	-/--	

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Date of the actual completion of the international search	Date of mailing of the international search report
30 September 1994	11. 10. 94

Name and mailing address of the ISA	Authorized officer
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X	US,A,3 446 406 (TROTT) 27 May 1969 see column 5, line 55 - column 7, line 35; figures 1-19	1-4,7,8, 11,13, 15,17
X	DE,C,924 857 (NEUGEBAUER) 9 May 1956 see page 2, line 9 - line 91; figures 1A,B	1,2,7, 10,17
X	US,A,2 106 364 (THORN) 25 January 1938 see figures 1-20	1,2,7,17
Y	DE,U,92 06 097 (COMBITOOL AG) 20 August 1992	9
A	see page 3, line 24 - page 4, line 19; figures 2,3	3,4
Y	FR,A,2 093 327 (HILCOSAN BECHER & DOSENFABRIK) 28 January 1972 see figure 3	16
A	GB,A,2 088 838 (DRDLIK) 16 June 1982	
A	DE,A,15 36 129 (LEITZ) 5 March 1970	

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US-A-2082691		NONE	
US-A-5199617	06-04-93	NONE	
GB-A-521672		NONE	
US-A-3446406	27-05-69	NONE	
DE-C-924857		NONE	
US-A-2106364		NONE	
DE-U-9206097	20-08-92	NONE	
FR-A-2093327	28-01-72	NONE	
GB-A-2088838	16-06-82	NONE	
DE-A-1536129	05-03-70	NONE	

Intern ales Aktenzeichen
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A. KLASSIFIZIERUNG DES ANMELDUNGSGEGENSTANDES
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X	US,A,5 199 617 (BENNETT) 6. April 1993 siehe Abbildungen 1-8	1,2,7,8, 11,17
X	GB,A,521 672 (THORN) 28. Mai 1940 siehe Abbildungen 1-6	1,2,7, 11,17

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Europäisches Patentamt, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Berrington, N

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PCT/EP 94/01695

C.(Fortsetzung) ALS WESENTLICH ANGESEHENE UNTERLAGEN

Kategorie*	Bezeichnung der Veröffentlichung, soweit erforderlich unter Angabe der in Betracht kommenden Teile	Betr. Anspruch Nr.
X	US,A,3 446 406 (TROTT) 27. Mai 1969 siehe Spalte 5, Zeile 55 - Spalte 7, Zeile 35; Abbildungen 1-19	1-4,7,8, 11,13, 15,17
X	DE,C,924 857 (NEUGEBAUER) 9. Mai 1956 siehe Seite 2, Zeile 9 - Zeile 91; Abbildungen 1A,B	1,2,7, 10,17
X	US,A,2 106 364 (THORN) 25. Januar 1938 siehe Abbildungen 1-20	1,2,7,17
Y	DE,U,92 06 097 (COMBITOOL AG) 20. August 1992	9
A	siehe Seite 3, Zeile 24 - Seite 4, Zeile 19; Abbildungen 2,3	3,4
Y	FR,A,2 093 327 (HILCOSAN BECHER & DOSENFABRIK) 28. Januar 1972 siehe Abbildung 3	16
A	GB,A,2 088 838 (DRDLIK) 16. Juni 1982	
A	DE,A,15 36 129 (LEITZ) 5. März 1970	

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US-A-2082691		KEINE	
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GB-A-521672		KEINE	
US-A-3446406	27-05-69	KEINE	
DE-C-924857		KEINE	
US-A-2106364		KEINE	
DE-U-9206097	20-08-92	KEINE	
FR-A-2093327	28-01-72	KEINE	
GB-A-2088838	16-06-82	KEINE	
DE-A-1536129	05-03-70	KEINE	

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INTERNATIONAL APPLICATION PUBLISHED UNDEI WO 9606732A1

(51) International Patent Classification 6 :
B32B 5/16, B24D 3/00, 3/02, C09C 1/68, C09K 3/14, C30B 23/00, 25/00, 28/12, 29/04, 31/00, H01L 29/04, 31/0312, 31/036

A1

(11) International Publication Number: **WO 96/06732**

(43) International Publication Date: 7 March 1996 (07.03.96)

(21) International Application Number: PCT/US95/10195

(22) International Filing Date: 11 August 1995 (11.08.95)

(30) Priority Data:

08/299,240	31 August 1994 (31.08.94)	US
08/322,681	12 October 1994 (12.10.94)	US

(71)(72) Applicant and Inventor: ROBERTS, Ellis, E. [US/US]; P.O. Box 6310, Los Osos, CA 93412 (US).

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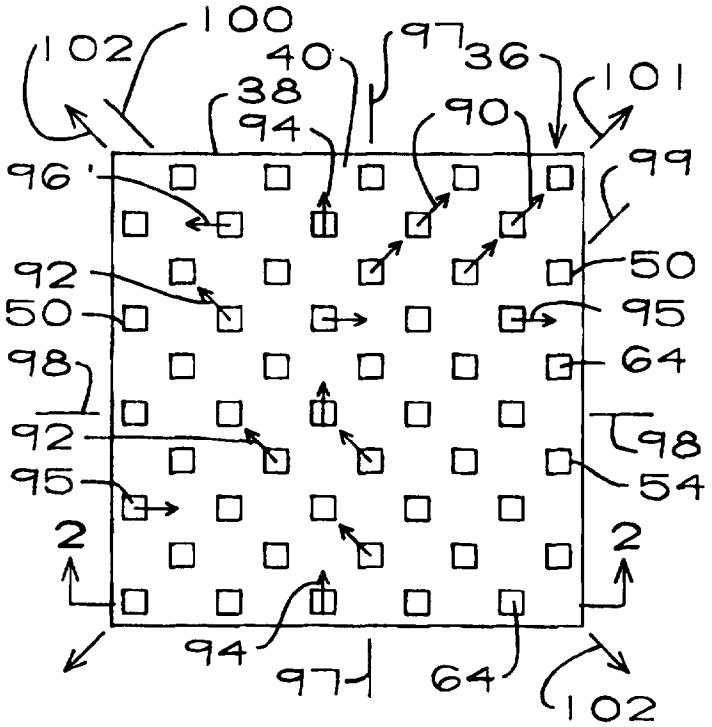
(81) Designated States: AU, JP, KR, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.
With amended claims.

(54) Title: ORIENTED CRYSTAL ASSEMBLIES

(57) Abstract

An article of manufacture comprising synthetic single crystals (50, 60, 350) of uniform size and shape selected from the group consisting of diamond or cubic boron nitride and held in a formation (figs. 1, 10, 19, 33) with selected crystallographic directions of the crystals oriented in the same direction so that the crystals as a group exhibit a common crystallographic direction (101, 102, 248, 360, 670, 672) which may selectively be the hardest or near-hardest direction, and a method of making such an article. Such orientation takes advantage of the hardness properties of the individual crystals by imparting such properties to the assembly. Various embodiments of the article are thus useful as an abrasive, a bearing, a heat sink or a semiconductor.



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Description

Oriented Crystal Assemblies

Technical Field

This invention relates to oriented crystal assemblies and more particularly to an article of oriented single synthetic crystals and to a method for making such an article.

Diamond has numerous physical properties that are well known and which have great utility for industrial purposes but which in the past have not been fully exploited. These properties include abrasion and wear-resistance, thermal conductivity, electrical insulation, and receptivity to the deposit of a layer of diamonds by chemical vapor deposition.

The very high degree of abrasion resistance exhibited by diamond varies with the crystallographic direction of hardness by a factor of as much as about one hundred times, and this most resistant direction is along the diagonal of a cubic face in the plane of the face. Diamond crystals also have another direction of high hardness along a line tangential to an edge of the crystal; crystals of cubic boron nitride (CBN) have a similar direction of high hardness.

Until the present invention, however, it has not been recognized how to take advantage of such crystallographic directions of hardness of diamond , CBN, and perhaps other materials, when these materials are employed to make an article having wear-resistant or abrasive qualities and other desired characteristics. Thus, the prior art devices have not optimized the hardness characteristics of a hard surface including particles of diamond and CBN.

Background Art

In abrasives, for example, the grits or particles of the prior art have been incorporated in a backing member in either a random manner or an oriented manner. The prior art orientation has been to disperse the grits uniformly (U.S. Patent No. 4,925,457), to arrange planar faces of the grits so they seat flat against a workpiece (U.S. Patent No. 3,230,672), or to orient the grit particles by electrostatic or electromagnetic means (U.S. Patent Nos. 4,240,807 and 5,203,881).

Although these orientations may provide useful abrasive articles, these and like prior art abrasive or wear-resistant articles have failed to take advantage of the maximum hardness available in the abrasive materials used, such as diamond and CBN. The concept of orienting particles in a backing member so as to transfer to the abrasive or wear-resistant surface as a whole the hardness qualities of the individual particles per se has not been recognized. Thus, it has not been known how to control the hardness of the surface either to insure that the resulting surface would have the maximum hardness possible or to provide a predetermined degree of hardness for abrasive or bearing applications.

For semiconductor applications, the Geis et al. PCT application and related article (WO 92/01827 published 6 February 1992, and Geis et al. "Large-Area Mosaic Films Approaching Single-Crystal Quality," *Applied Physical Letters*, Vol. 58, No. 22 (3 June 1991), 2485-2487) recognize that diamond's excellent electrical properties have not been fully utilized. These references teach the placing of synthetic diamond seed crystals of 0.10 mm diameter or less in spaced complementary pits or grooves, and subsequently growing a film about the seeds by chemical vapor deposition. Geis et al. intentionally separate the seed crystals to enable the CVD crystal growth to envelope the seeds. Thus, although Geis et al. state that such placement orients the crystallographic directions, their method creates spaces or gaps between adjacent seed crystals. They state that at the point where adjacent crystals merge, there is the possibility that crystal defects may occur. Moreover, Geis et al. is concerned with electrical applications and thus does not teach how to produce an abrasive or bearing surface having a crystallographic direction of maximum abrasive resistance.

Disclosure of the Invention

The present invention involves an article of manufacture comprising synthetic single crystals of uniform size and shape selected from the group consisting of diamond or cubic boron nitride and held in a formation with selected crystallographic directions of the crystals oriented in the same direction and to a method of making such an article. The article is useful as an abrasive, a bearing, a heat sink or a semiconductor.

It is an object of the present invention to maximize the characteristics of a surface composed of hard materials such as diamond, CBN, and perhaps other materials, to produce an article having various industrial uses, such as abrasives, bearings, heat sinks and semiconductors.

Another object is to provide an article composed of synthetic single crystals of diamond, CBN, and perhaps other materials, having their crystallographic directions oriented in the same direction.

It is a further object of this invention to take advantage of the fact that synthetic single crystals of diamond and CBN have predetermined crystallographic directions lying along lines in contact with certain portions of their crystals, by aligning these directions when the crystals are positioned in a working formation.

It is also an object to take advantage of the fact that diamond and CBN are commercially synthesized in shapes and sizes that permit single crystals of these materials to be oriented with their crystallographic directions aligned.

A further object is to provide an article including a formation of synthetic single crystals for abrading a workpiece which, as contrasted with prior art tools: abrades faster; lasts longer; requires less frequent replacement and adjustment; is less costly to operate; maintains tolerances longer; saves abrasive material; requires less power; and minimizes dulling or flatting of grains.

Another object is to provide a method for making the article of the present invention.

Brief Description Of The Drawings

Fig. 1 is a plan view of one embodiment of an abrasive article made in accordance with the present invention but showing the article on a greatly enlarged scale from actual size.

Fig. 2 is a cross-sectional view taken along line 2-2 of Fig. 1.

Fig. 3 is an isometric view of a single, synthetic, cubic crystal of diamond as used in the article of Fig. 1 but greatly enlarged from Fig. 1.

Fig. 4 is an isometric view of a single, synthetic, predominately cubic crystal of diamond, but with small octahedral facets, as used in the present invention and also greatly enlarged from actual size.

Fig. 5 is an enlarged view of a face of the cubic crystal of Fig. 3 showing directional lines of hardness and the Miller indices of the cube face and hardness directions.

Fig. 6 illustrates a step of the method of the present invention and specifically is an isometric view of a corner of a template containing three cubic crystals oriented by the template into desired positions.

Fig. 7 illustrates a portion of an alternate form of template used in practicing the method referred to in regard to Fig. 6.

Fig. 8 illustrates another step of the method of the present invention and specifically is a cross section of the template and crystals therein, as if taken along line 8-8 of Fig. 6 when the template is full of crystals, and further showing a backing member of epoxy overlaying the crystals and the template.

Fig. 9 is a cross-section taken along the same plane as Fig. 8 but showing the backing member and the crystals, that is the abrasive article, removed from the template.

Fig. 10 is a plan view of another embodiment of an abrasive article made in accordance with the present invention and also shown on a greatly enlarged scale from actual size.

Fig. 11 is a cross-sectional view taken along line 11-11 of Fig. 10.

Fig. 12 is an edge view of the cubic diamond crystal of Fig. 3, although on a reduced scale from Fig. 3, showing its orientation as used in the article of Fig. 10, but enlarged from Fig. 10, and further showing its second hardest directional line of hardness and Miller index.

Fig. 13 is a face view of the diamond crystal of Fig. 12.

Fig. 14 illustrates a step of an embodiment of the present method used to make the article shown in Fig. 10 and specifically is an isometric view of a corner of a template containing two cubic crystals oriented by the template into desired positions which differ from the positions of Fig. 6.

Fig. 15 illustrates a step similar to that illustrated by Fig. 8 but pertains to the method of making the article shown in Fig. 10 and specifically is a cross-section of the template and crystals therein, as if taken along line 15-15 of Fig. 14 when the template is full of crystals, and further showing a backing member of epoxy overlaying the crystals and the template.

Fig. 16 is a cross-section along the same plane as Fig. 15 but showing the article of Fig. 10 removed from the template.

Fig. 17 is a plan view of a portion of a variation of the second embodiment of an abrasive article made in accordance with the present invention.

Fig. 18 is an isometric view of part of a template for use in making the variation shown in Fig. 17.

Fig. 19 is a plan view of a third embodiment of an abrasive article made in accordance with the present invention using tetrahedral cubic boron nitride crystals and also shown on a greatly enlarged scale from actual size.

Figs. 20 and 21 are partial cross-sectional views taken along lines 20-20 and 21-21, respectively, of Fig. 19.

Fig. 22 is a greatly enlarged isometric view of a tetrahedral crystal of cubic boron nitride as used in the article of Fig. 19 but greatly enlarged from Fig. 19 and showing Miller notations for two of the faces of the crystal.

Fig. 23 is a face view of the crystal of Fig. 22 on a reduced scale and also showing a Miller notation.

Fig. 24 is an edge view of the crystal of Fig. 23 but turned ninety degrees therefrom and again showing a Miller notation.

Fig. 25 is a fragmentary isometric view similar to Fig. 18 but showing a template used to make the article of Fig. 19.

Figs. 26 and 27 are cross-sectional views similar to Figs. 15 and 16 but showing steps for making the article of Fig. 19 and taken along the same plane as Fig. 21.

Fig. 28 is an isometric view of a corner of a template used to make a variation, not shown, of the embodiment shown in Fig. 19.

Figs. 29 and 30 are schematic views showing how the articles of the present invention are used in a tool to surface a workpiece along a linear path but specifically showing the article of Fig. 19.

Figs. 31 and 32 are schematic views showing how the articles of the present invention are used in a tool to surface a workpiece along a rotary path but specifically showing articles made in accordance with the embodiment of Fig. 17.

Fig. 33 is a plan view, enlarged approximately two times actual size, of an assembly of synthetic cubic crystals of diamond, or like material, made in accordance with the present invention.

Fig. 34 is an elevation or edge view of the assembly of Fig. 33.

Fig. 35 is an isometric view of formation of synthetic cubic diamond crystals illustrating the aligned crystallographic directions of hardness by directional arrows and Miller indices. Again, the crystals and thus the assembly are enlarged from actual size. It is

also noted that the crystals shown in Fig. 35 are in fact cubic, although they may not appear so because of the rules of isometeric projection.

Fig. 36 is an isometric view of a corner of the assembly of Fig. 35 showing a binder applied to the crystals and showing in dashed lines the edges of crystals under the binder.

Fig. 37 is also an isometric view of the initial steps of assembling cubic diamond crystals into an integrated formation by placing the crystals in side-by-side contact on the bottom flat surface and in the corner of a tray inclined toward the corner. The scale is reduced from Fig. 35 but is still much larger than actual size.

Figs. 38a-38d are enlarged schematic views which illustrate additional steps of the method of this invention.

Figs. 39a-39f are also enlarged schematic views which illustrate additional steps of the method of this invention.

Detailed Description

Article of Manufacture- First Embodiment

The first embodiment of the present invention is a wear-resistant or abrasive article 36 (Figs. 1 and 2) which includes a square backing member 38 of plastic or metal that has a mounting surface 40 and a back surface 42. A plurality of single synthetic cubic crystals 50 of diamond have first portions 52 individually embedded in a backing member formation and second portions 54 projecting outwardly from the mounting surface.

The use of single, synthetic diamond crystals, 50 in Fig.3 and 60 in Fig.4, is important to the present invention, and thus reference is now made to certain details about such crystals. In general, these crystals are regular polyhedrons but are produced in various specific shapes, namely, perfect cubes (Fig. 3); a range of cubo-octahedrons where the crystal faces vary from predominately cubic and minimally octahedron (Fig. 4) to predominately octahedron and minimally cubic (not shown); and perfect octahedrons (not shown). It is preferred to use perfectly cubic crystals, as shown in Fig. 3, or predominately cubic crystals where the cubic faces predominate and the octahedral facets are minimal in size, as shown in Fig. 4. The principles of this invention, however, apply to other shapes of the cubic crystal system, to which diamond belongs, as will be understood in the subsequent description of the third embodiment of this invention using cubic boron nitride (CBN).

The cubic crystal 50 (Fig. 3) represents the described commercially available synthetic single diamond crystals which are up to about 1 mm in size. The crystal 50 has six side faces 64, twelve edges 70, and eight corners 74. These faces are of course square and are referred to in the art and herein as cubic faces or as being in cubic planes.

The cubo-octahedral crystal 60 (Fig. 4) also represents commercially available synthetic single diamond crystals and has six faces 82, which are commonly referred to as cubic faces since that is their predominate shape, and eight smaller octahedral facets 84 at the corners. Crystal 21 is thus referred to as a predominately cubic crystal since the octahedral facets are relatively small as compared to the cubic faces.

With reference to Fig. 5, a brief description is set forth of certain known crystallographic characteristics of a synthetic single diamond crystal, as 50 and 60, which are fully exploited in the present invention. Fig. 5 shows one of the faces 64 of the crystal 50. The crystal has crystallographic directions of maximum abrasive resistance or hardness in the plane of this cube face along the diagonal lines 90, 90 ′ and 92, 92 ′ of the face. It also has crystallographic directions of minimum abrasive resistance or hardness along lines 94, 94 ′ and 95, 95 ′ which are forty-five degrees from the diagonals or directions of maximum resistance. Therefore, the crystal exhibits degrees of directional hardness ranging from the diagonal maximum directional lines to the right-angular minimum directional lines. These lines of hardness may also be described as being tangential to their respective faces of the crystal. The appropriate Miller notations for the face and directional lines are denoted in Fig. 5. In view of the symmetry of the crystallographic structure of diamond crystals, each face of the crystal has the same crystallographic directions of hardness within the plane of its face.

Brief reference to certain nomenclature regarding the symmetry of crystals, as 50 or 60, (Figs. 3 and 4) will be useful in the subsequent description. As is known, the crystal has several planes of symmetry. One such plane is referred to in the art as a cubic plane which is an orthogonal plane which cuts through the crystal between and parallel to a pair of opposite faces, as 64. Another plane of symmetry is referred to in the art as a dodecahedral plane and is a diagonal plane that cuts through the crystal and contains a pair of opposite edges, as 70. The crystal also has several axes of symmetry one of which is represented, for example, by the letter y in Fig. 3 and passes through the center and

opposite faces of the crystal and is perpendicular to such faces. Reference will be made to these planes and axes in the following description and claims.

Having described known characteristics of single synthetic cubic diamond crystals 50, 60, the present invention is primarily concerned with the orientation of these crystals in a predetermined manner in the article 36, one embodiment of which is shown in Figs. 1 and 2. It is to be noted that Fig. 1 is drawn about four times actual size since the single synthetic cubic diamond crystals available are up to about 1 mm in size. It is also noted that for ease of illustration only perfectly cubic crystals are shown in Fig. 1 although in actual practice some of the crystals may be predominately cubic, as 60, and thus may have small octahedral facets 84.

In Figs. 1 and 2, each crystal 50 is individually mounted in the backing member 38, with its first or mounting portion 52 (Fig. 2), which is approximately half of the crystal, embedded in the backing member, and its second or abrading portion 54, which the other approximate half of the crystal, outside of the backing member. Another way of expressing the orientation of each crystal in the assembly is to state that each crystal is mounted in the formation with one of its cubic planes parallel to the mounting surface 40. The face 64 of each crystal at the extremity of the abrading portion 54 is referred to as an abrading face and is parallel to the mounting surface 40 and coplanar with the abrading faces of all the other crystals. These coplanar abrading faces thus define a working surface 96 for the article 36.

Incidentally, the amount of extension of the crystals 50 into or out of the backing member 38 is important to proper functioning of the article 36, but it is not a feature of the present invention. In the embodiment shown in Fig. 1, it is preferred that the mounting portions 52 of the crystals 50 are embedded in the backing member a distance of about 0.6 mm, sufficient to hold the crystals securely in the backing member so as to prevent their dislodgment when force is applied to the crystals upon workpiece engagement, while providing sufficient workpiece engaging surfaces. Specific techniques for bonding abrasive particles, such as the crystals 50, 60, in a plastic or metal backing member are well-known but are subsequently briefly generally described herein as a part of the subject method.

The crystals 50 in the embodiment of Fig. 1 are preferably uniformly distributed about the backing member 38 in a checkerboard pattern and for this reason are arranged in orthogonal rows, indicated by lines 97, 98, and diagonal rows indicated by lines 99,

100, relative to the square backing member. The rows are in spaced relationship, and adjacent crystals in each row are spaced from each other. It is to be understood that the specific square shape of the backing member, the specific checkerboard pattern or row formation, the specific crystal spacing, and the density or concentration of crystals shown in Fig. 1 are not essential to the invention and may be varied depending on the application of the article 36.

Of prime significance to the invention, however, is the orientation of the crystals 50 relative to each other. With reference to Fig. 1, the crystals are individually fixed in the backing member 38 with their maximum directions of crystallographic hardness, as 90, 90 ', aligned along parallel diagonals of the formation which run in NE/SW directions, to use a compass analogy. Likewise, the directions 92, 92 ' are aligned along the NW/SE diagonals. It will of course be apparent that orientation of the crystals is not limited to such specific compass directions nor to the orientation of the article on the drawing sheet. With such an orientation, the lines of maximum hardness directions of the crystals in each diagonal row 99 are aligned along common lines, as 101, 102, and these common lines of all the diagonal rows are parallel with each other. Stated otherwise, corresponding lines of maximum hardness directions of individual crystals are either in alignment, or parallel, with corresponding lines of maximum hardness of all the other crystals. Also, these lines 90, 90 ' and 92, 92 ' of maximum hardness are tangential to their respective face extremities 64, lie in the working surface 96, and are parallel to the mounting surface 40 of the backing member 38.

It is to be observed that as used herein and in crystallographic terminology, the words "align" and "aligned" mean pointing in the same direction, but can also mean being coincident with a single line. Thus, the lines of maximum hardness 90 of the crystals 50 in Fig. 1 are "aligned" in the sense that they all point in a NE direction in Fig. 1, whereas those directional lines 90 of the crystals in a given diagonal row are "aligned" in that they are coincident along a common line.

Conversely, corresponding lines, as 94, of minimum hardness directions of all the crystals 50 (Fig. 1) in each of the NS orthogonal rows 98 are in alignment, as represented by common lines, as 104 and 106, and all of the corresponding minimum hardness lines in each such row are parallel with those in the other NS rows. The same is true for the EW

rows. The lines of minimum hardness are thus also tangential to their respective face extremities 64, lie in the working surface 96, and are parallel to the mounting surface 40.

Therefore, it will be understood that the array, group, backing member, or formation of crystals 50 (Fig. 1) exhibits common directional lines, as 101 and 102, of maximum hardness which run diagonally of the backing member 38 and are parallel to the mounting surface 40. If the working surface 96 (Fig. 2) is moved across a workpiece (Figs. 29-32) in one of these diagonal directions, such as NE/SW, the crystals will exhibit their maximum hardness to the workpiece. Conversely, if the working surface is moved relative to a workpiece in the direction at forty-five degrees from common line 102, that is in a NS or EW direction, the surface will exhibit its minimum hardness to the workpiece. The working surface formed by the crystals thus exhibits common directions of maximum and minimum hardness and all the degrees of hardness in between, just like an individual crystal. With the present invention, then, the characteristics of an single crystal are imparted to the entire array of crystals.

With reference to Fig. 2, since the abrading portions 54 of the crystals 50 project outwardly of the backing member 38 equidistantly from the mounting surface 40 with their faces 64 defining the planar working surface 96, the crystals are able to contact a workpiece, not shown, simultaneously and thus apply force to the workpiece in an even manner. Wear on the crystals, and abrasion action on a workpiece, are therefore uniformly distributed.

Method of Making the First Embodiment of the Article

The method for making the first embodiment of the article 36 (Fig. 1) of the present invention is described with reference to Figs. 6-9. The method employs a template 120, only a portion of which is shown in Fig. 6. The template has a top surface or plate 122 and a plurality of half-cubic shaped recesses, wells, or pockets 124 extending downwardly into the body of the template from the top surface and serving as receptors for the crystals 50. Each recess may be described as having the shape of a part of a cube cut along one of its cubic planes. Since only a portion of the template 120 is shown, only a few of the recesses are shown. It will be understood, however, that a complete template is slightly larger than the abrasive article 36 and has the same number and formation of recesses as there will be crystals in the article to be made. Thus, a complete template for making the article shown in Fig. 1 includes fifty recesses in ten rows of five each, running

in both the length and the width of the template, with the recesses in adjacent rows offset from each other.

The recesses 124 (Fig.6) in the template 120 are of uniform shape and size. Each recess has a length and width (that is, the dimensions which lie in the plane of the surface 122) slightly greater than the edge dimensions of a cubic crystal 50, and a depth not quite as deep as such edge dimension. Thus, in this embodiment of the method, the recesses are slightly larger than 1 mm square and are about 0.6 mm deep. Each recess has a bottom wall 126, and side and end walls 128 and 130 which are at right angles to the bottom wall. The recesses may be configured with slightly beveled inside corners, not shown, similar to the shape of the facets 84 of the predominately cubic crystals 60 (Fig. 4) that have minor octahedral facets.

Significantly, the recesses 124 (Fig. 6) are oriented in the template 120 in positions which will orient the crystals 50, 60 so that their corresponding crystallographic maximum hardness directions, as 90, are aligned. Thus, all of the side walls 128 are parallel with each other, and all of the end walls 130 are parallel with the other end walls. To achieve equidistant projection of the crystals from the backing member mounting surface 40, all of the bottom walls 126 are in a common plane 138 (Fig. 8).

Alternatively, a modified template 120a (Fig. 7) with modified recesses 124a may be used. Here, the bottom wall 126a of each recess 124a is angled upwardly a few degrees from the common plane 138. More specifically, the bottom wall 126a is angled diagonally upwardly from one bottom corner of the recess to the diagonally opposite corner. It will be understood that corresponding corners, for example, all the NE corners, are similarly tilted upwardly so as to make the angulation uniform throughout the template 120a.

The templates 120 or 120a (Figs. 6 and 7) are made of plastic, such as polyethylene or tetrafluoroethylene, or of metal, such as steel or aluminum, and are shaped by casting the plastic or metal against a master form, not shown, having cube-shaped protrusions. Alternatively, the template is made by stamping or pressing plastic or metal stock with an appropriately shaped master multiple projection die or a single cube-shaped die, again not shown since such metal-working techniques are well known in the art.

In carrying out the method of the present invention, a supply of synthetic single diamond crystals 50, 60 of cubic or predominately cubic shapes and of approximately the

same size, currently about 1 mm, is selected. It is important to size the crystals by precision screening, preferably using screens with square openings. Further shape control by automated single crystal weighing or settling in a fluid using Stokes Law may be used.

With the top surface 122 (Fig. 6) of the template 120 maintained in a generally horizontal plane, crystals 50, 60 are deposited on the top surface and spread thereover and thus lie in random orientation about the top surface. More crystals are deposited than there are recesses 124 so as to insure a quantity sufficient to fill all the recesses. The template is vibrated or tapped and, if necessary, slightly tilted to cause the crystals individually to gravitate into and be received by the recesses. Because of the complementary shapes of the recesses and the crystals and the slightly larger recess size relative the crystal size, crystals are individually accommodated into the recesses where they each stabilize, with one bottom face 64 of each crystal lying flat on the bottom wall 126 of its recess and with its side faces 64 in adjacent parallel relation to the side and end walls 128 and 130. The crystals project from the top surface 122 of the template a distance less than their edge dimension, preferably about 0.4 mm in the illustrated embodiment. If the template 120a using inclined bottom walls 126a is employed, as shown in Fig. 7, corresponding top corners 74 of the crystals 50 are tipped up relative to their diagonally opposite top corners along a diagonal, as 99 (Fig. 1), of the template. While all of the recesses are being filled or after they are filled, the template is inclined slightly and again vibrated or tapped in order to remove excess crystals from between the rows, so that the top surface 122 is clean of crystals while maintaining the crystals in the recesses into which they were received and in their oriented positions therein.

Each recess 124 or 124a (Figs. 6 and 7) is thus temporarily filled with a crystal 50 or 60, and the crystals are thus oriented with all of their corresponding crystallographic directions of maximum hardness 90, 90 ′ and 92, 92 ′aligned and the corresponding directions of minimum hardness, as 94, 94 ′ and 96, 96 ′, likewise aligned. The bottom faces 64 of the crystals lie flat against the bottom walls 126 of their recesses and thus coplanar with plane 138, and the first or mounting portions 52 of the crystals protrude outwardly from the template.

The subject method next involves steps for fixing the crystals 50, 60 in the described orientation and for removing them from the template, as 120 (Fig. 6). The template used has a non-adhesive top surface 122 and non-adhesive recess walls 126, 128

and 130, which can be accomplished by making the template of polyethylene or tetrafluoroethylene as previously suggested. A layer 150 (Fig. 8) of uncured plastic, such as an epoxy resin, is applied over the top surface 122, covering and completely immersing the mounting portions 52 of the crystals in the plastic. This layer is then cured and upon curing, this overlay of plastic becomes the backing member 38 fixing the crystals in their positions of crystallographic alignment with the faces 64 resting against the bottom walls 126 of the recesses 124 in their coplanar relationship. The backing member and the array of crystals are then removed as a unit from the template thereby yielding the article 36 (Fig. 9).

In its basic form, the article 36 (Figs. 1, 2 and 9) comprises only one layer of crystals 50 and may be of any practical surface area with any practical number of crystals, limited only by the particular use or application of the article. By way of example only, the article 36 includes fifty crystals, each measuring about one millimeter square, in a backing member 38 measuring about 25 mm x 25 mm x 5 mm.

If desired for some applications, multiple articles, as 36, may be bonded together in edge-to-edge coplanar relation to form a much larger surface area, not shown. Also, multiple articles may be bonded together in stacked, layered relation, also not shown. In any case, all the crystals are positioned so that their crystallographic directions are oriented in the same direction, in accordance with the principles of this invention.

Article of Manufacture-Second Embodiment

The second embodiment of the article is identified by numeral 236 in Figs. 10 and 11. This article also conveniently includes a square backing member 238 having a mounting surface or area 240. Synthetic single diamond crystals 50, and/or 60, are used for this embodiment and are the same as used for the first embodiment in Fig. 1. As before, the crystals are preferably uniformly distributed about the mounting surface and are positioned in orthogonal and diagonal rows in a checkerboard pattern. The second embodiment differs from the first embodiment, however, in the orientation of the crystals, but this different orientation still aligns selected hardness directions.

Again, it is helpful to set forth certain crystallographic principles as a foundation for understanding the second embodiment. With reference to Fig. 12 and 13, it is known that the second hardest crystallographic direction of hardness of a diamond crystal 50 or 60 is along a line 248 which is tangential to an edge 70 of the crystal and also

perpendicular to the diagonal 249 (Fig. 13) of the crystal which intersects such edge. The appropriate Miller notation for this second hardness directional line is denoted in the drawings. It will be understood that there is a similar second hardest directional line tangential and perpendicular to each edge of the crystal. It is also to be noted that the crystal 50 has another axis of symmetry represented by the diagonal 249, and that this axis passes through one edge of the crystal, through the center of the crystal, and through the opposite edge and is perpendicular to such edges.

To take advantage of this second hardest direction, the crystals 50 (Figs. 10 and 11) are individually mounted in the backing member 238 so that a dodecahedral plane of each crystal is co-planar with the mounting surface 240, or is slightly on one side or the other of such mounting surface and parallel to it. It follows, then, as best visualized in Fig. 11, that the dodecahedral plane which is perpendicular to the first-mentioned dodecahedral plane is perpendicular to said mounting surface. With such mounting, the approximate half of each crystal on one side of the mounting surface is embedded in the backing member, and the other approximate half is outside the backing member. Of greatest significance, all the exposed edges 70a, which are referred to as abrading edges, of the crystal-halves are parallel to, or in alignment with, each other; are equidistant from and parallel to the mounting surface; and together define a working surface 250 (Fig. 11). Thus, the crystals are oriented in the backing member so that their crystallographic directions of hardness as indicated by the lines 248 (Fig. 10) are aligned with, or parallel to, such directional lines of all the other crystals, depending on whether their crystals are in the same EW row 252 or in a parallel EW row.

Thus, when the abrading edges 70a (Figs. 10 and 11) of the article 236 are in contact with and moved relatively to a workpiece, not shown, in the direction of the lines 253, 254 (that is, the EW direction in Fig. 10), the combined effect of aligned hardness directions of the crystals 50 is presented to the workpiece. Although the hardness direction 248 is not the hardest direction of the crystal, it is the next-to-the-maximum hardness direction and thus allows an improved abrasive force to be applied by the crystals, as contrasted with non-aligned directions of hardness of grits, particles or crystals which are randomly positioned with regard to crystallographic direction, as practiced by the prior art.

Method of Making the Second Embodiment of the Article

The article 236 (Fig. 10) is made in a manner similar to the article 36 (Fig. 1), except that a different template 260 (Fig. 14) is utilized to accommodate the different orientation of the crystals 50. In template 260, only a portion of which is shown in Fig. 14, recesses 264 are in the shape of an approximate cube-half, when the cube is cut along a dodecahedral or diagonal face-plane thereof. In other words, the recesses are V-shaped with a ninety degree included angle. In general, the parameters for constructing the template and the recesses are the same as for template 120 (Fig. 6). That is, the recesses are slightly larger than the crystals so as to facilitate accommodation of the crystals therein, and they have end walls 265 and side walls 266 that meet at bottom corners or edges 268 which are tangent to and lie in a common plane 270 (Fig. 15).

An alternative template 280 (Fig. 18) may be used with the second embodiment of the method. This template has V-shaped recesses, grooves or troughs 282 having side walls 284, end walls 286, and bottom edges 288, which are the same shape as the recesses 264 except that they extend almost the full length or width of the template, being enclosed by the end walls 286.

As with the method described with reference to Figs. 6-9, a similar method is followed to make the article 236 (Fig. 10). In brief, sorted, substantially uniformly sized crystals 50 are distributed in a random manner over the template 260, or 280, and the template is vibrated to cause the crystals to fall into the recesses 264, or 282. In the recesses 264, there is one crystal per recess, but with recesses 282, a line of crystals is accommodated with adjacent faces 64 of adjacent crystals preferably being in contact. Again, the templates 260 or 280 are inclined slightly and vibrated or tapped to remove excess crystals while maintaining the oriented crystals in the recesses.

Next, an uncured plastic layer 290 (Fig. 15) is placed over the template 260, or 280, to cover the protruding portions of the crystals 50 and then is allowed to cure and harden. When cured, the plastic layer becomes the backing member 238 with the crystals fixed therein and is removed from the template thereby resulting in the article 236 (Figs. 16 and 11).

Article of Manufacture- Third Embodiment

The third embodiment of this invention provides an article 336 (Figs. 19-21) similar in principle to the articles 36 and 236 of the first and second embodiments except

that the third embodiment uses single, synthetic crystals 350 of cubic boron nitride (CBN). The article includes a backing member or carrier 338 for the crystals which has a mounting surface 340 and a back surface 342.

Cubic boron nitride, like diamond, is in the cubic class of crystals, but, unlike diamond, has the sphalerite structure. The CBN crystal 350 (Fig. 22) is thus a regular polyhedron like diamond but, unlike diamond, has a tetrahedral shape. Individual crystals of CBN of good quality are commercially available, with planar triangular faces 352 meeting in sharp edges 354 and corners 356, and have dimensions of up to about 0.5 mm on an edge. It is important to emphasize that, like the embodiments 36 (Fig. 1) and 236 (Fig.11) of this invention utilizing diamond crystals, the CBN used for the third embodiment is in the form of single or individual crystals and not the CBN grains used in the prior art as abrasive grains or grit that are predominately crushed aggregates of intergrown, randomly-oriented crystals. Like the other embodiments, use of single, substantially uniform crystals allows predetermination of the crystallographic directions, manipulation of the crystals, and resultant orientation into the desired positions.

As is known, the tetrahedral crystal, as 350, has several planes and axes of symmetry. One such axis is referred to in Fig. 23 by the reference letter p and is useful in describing and claiming the present invention. The axis p passes through the center of one edge of the crystal, through its center and through the center of the edge opposite to the first edge, and is perpendicular to both such edges.

No careful work is known that has correlated the variation of abrasion-resistance of the CBN crystals, as 350 (Fig. 22), with crystallographic direction. The similarity, however, between the internal atomic configurations of CBN and diamond leads to the conclusion that the most abrasive-resistant direction of a CBN crystal is along a line, as 360 (Figs. 19, 22-24), which is perpendicular to an edge, as 354a, of the crystal. This directional line may also be described as tangential to the edge 354a and parallel to the opposite edge 354b, as best illustrated in Fig. 23. It is of course understood that the edge 354a is chosen by way of example only and that there is such a directional line of maximum hardness perpendicular and tangential to each of the edges 354. Miller notations for faces of a CBN crystal are shown in the Figs. 22-24.

The crystals 350 (Figs. 19-21) are mounted in the backing member 338 so that a plane cutting through each crystal and parallel to a pair of its opposite, perpendicularly related edges lies approximately in or close to the mounting surface 340 (Fig. 20) of the

backing member. Such a plane divides the crystal into two portions, so that with such a mounting, one of these portions is embedded in the backing member and the other portion is outside the backing member. In the preferred embodiment illustrated in Figs. 19-21, about sixty percent of each crystal is embedded in the backing member and the remaining forty percent protrudes out of the backing member. The important feature, however, is that the exposed edge 354a of said opposing pair of edges of each crystal is parallel with the corresponding exposed edges of all the other crystals, as is readily seen in Fig. 19, and with the mounting surface 340. Also, these edges 354a of crystals in the same NS row, as 366, are in alignment.

As previously mentioned with regard to the other embodiments, the third embodiment of the invention is not limited to the specific spacing or number of crystals 350 (Fig. 19) or rows, nor to the orthogonally formed rows, nor to the number or concentration of crystals. It is important to the invention, however, that the crystallographic lines 360 of maximum hardness of corresponding edges, as 354a, of all the crystals are in alignment, or are parallel, with each other. Such alignment or parallelism of the crystallographic lines follows from mounting the crystals with the exposed edges 354a in alignment or parallel with each other.

Method of Making the Third Embodiment of the Article

This embodiment of the method is similar to the other two method embodiments except that templates 390 and 392 (Figs. 25 and 28), similar to the templates 280 (Fig. 18) and 260 (Fig. 14), respectively, are constructed to accommodate the tetrahedral, CBN crystals. The article 336 illustrated in Fig. 19 is made using the template 390 in Fig. 25. The template 390 has elongated V-shaped recesses or troughs 394 with end walls 396, and side walls 398 meeting at predetermined angles in bottom corners or edges 400 which are all in a common plane 406 (Fig. 26).

As an example, the entire template 390, only a portion of which is shown in Fig. 25, may be approximately 32 mm x 15 mm x 5 mm in size and be made of high density polyethylene. The recesses 394 may be milled lengthwise of the template to a depth of about 0.5 mm and so that the side walls 398 have an included angle of about 70°32 ′, ±5°.

With the template 390 (Fig. 25) maintained in a horizontal position, crystals 350 of CBN of pre-sorted, substantially uniform size are sprinkled on the template and thus

randomly positioned thereon. By vibrating and slightly tilting the template, the crystals are caused to drop into the recesses 394 with an edge 354a (Fig. 26) of each crystal fitting against the bottom edge 400 of a recess, and thus being tangent to the common plane 406, and with two opposite side faces 352 (Fig. 25) resting against the side walls 398 of the recess and with slightly less than half of each crystal protruding outwardly from the template. Tilting the template toward one end while vibrating and tapping the same also causes excess crystals on the top surface of the template and between the recesses to drop off the template.

Epoxy resin (system three, phase two) is then poured over the template 390 so as to provide a layer 410 (Fig. 26) of about 5 mm depth covering the projecting portions of the crystals 350. The resin is then cured at about 60°C for about two hours, causing the resin to cure and harden and form the backing member 338. The crystals are thus individually fixed in the backing member in their oriented positions in the template. The backing member and its attached crystals are then removed from the template thus resulting in article 336 (Fig. 27) wherein all of the exposed edges 354a of the crystals are parallel to each other (Fig. 19), thereby causing the crystallographic directional lines 370 of maximum hardness to be either aligned or parallel to each other and lying in the common plane of the work surface 420 (Figs. 20, 21 and 27) defined by the edges 354a. It will be understood that the coplanar relation of the edges 354a results from the bottom edges 400 of the recesses 394 lying in a common plane 406 (Fig. 26).

It will now be understood how the template 392 (Fig. 28) having spaced V-shaped recesses or pockets 426 is used to create an article, not shown, with crystals 350 temporarily placed in the pockets, individually fixed in a backing member, not shown, and then removed, to produce such an article very similar to article 236 (Fig. 10), but with CBN crystals instead of diamond crystals.

The recesses, trough or grooves 394 and 426 (Figs 25 and 28) that act as receptors of the crystals 350 to align the crystals can be chosen to be of a length slightly longer than the length of an edge of a CBN crystal, in the case of the recesses of Fig. 28, or any multiple of this length in the case of the recesses of Fig. 25. Thus, the pattern and density of the crystals can be adjusted to make optimum use of the CBN crystals for workpiece treatment.

By now it will be understood that the template, as 120, 260, 280, 390, or 392, used in the present invention is not limited to the particular recess or well configurations

shown, but more broadly, the template is understood to have a receptor area shaped to accommodate and align the crystals 50 or 350, such receptor area including either a plurality of recesses or pockets or wells, as 124 or 264 or 426, or one or more troughs, as 282 or 426 or 394.

In all the embodiments of this invention, it will be understood that bonding agents other than epoxy resin or other plastic formulations may be used, as are well known in the art. Briefly, with the templates 120, 260, 280, 390, or 392 made of graphite, a powdered infiltration metal or a powdered infiltrator alloy with abrasion-resistant particles, such as tungsten carbide, can first cover the crystals 50 or 350. The assembly can then be heated to fuse the metal and create the backing member 38, 238 or 338, fixing the crystals in their oriented positions. Also, metal, such as nickel, can be electrodeposited over the crystals in the template to serve as the backing member by a well known process. Still further, any of the templates may be made of a refractory material not bondable to fired ceramic bodies, such as graphite or silicon carbide. An unfired plastic ceramic could then be layered over the crystals in the template and subsequently heated to a temperature suitable to sinter the ceramic body, whereby a vitreous backing member embeds the crystals in their oriented positions.

Figs. 29 and 30 show one of the articles, as 336, constituting part of a tool 500 which moves relatively to a workpiece 510 along a linear path 520. It will be noted that the edges 354a contact the workpiece together since they are tangential to a common plane or work surface 420. Also, the crystals all move across the workpiece perpendicularly of the edges 354a or, in other words, along the common lines 360 (Fig. 30) of directional hardness of all of the crystals. Each individual crystal engages the workpiece so that its predetermined line of maximum hardness 360 is aligned with the path 520 of movement of the crystal. Therefore, a maximum amount of abrasive action is exerted by the crystals.

Figs. 31 and 32 illustrate the principles of the present invention for use in a tool 600 which surfaces a workpiece 610, shown in phantom outline in Fig. 31, along a rotary path 602. The tool comprises a sleeve 604 having an annular end 606, and a plurality of crystals, as 50, mounted on the end so that the sharp edges, as 70a, are oriented radially of the sleeve. In this manner, the crystals engage the workpiece so their individual lines 248 of high hardness are aligned with the rotary path 602 of the crystals. Although the drawing shows groups of crystals mounted at each quadrant at the end of the sleeve, the

crystals can be spaced or mounted in a continuous formation about the circumference. The important point is that the crystals are mounted so that each crystal contacts the workpiece with its line of high hardness aligned with the path of movement of the crystal.

Article of Manufacture- Fourth Embodiment

The fourth embodiment is useful as a bearing, heat sink or semiconductor. This embodiment provides an assembly 650 (Figs. 33 and 34) of synthetic single crystals 50 (or 60, although only the numeral 50 will be used in the following description) of diamond secured together in a formation by a binder 658 which forms a backing member. The crystals are oriented so as to provide the assembly with enhanced physical properties similar to what has been previously described. Full advantage of these properties cannot be realized with an individual crystal because of its minute size.

The assembly 650 of the synthetic single diamond crystals 50 shown in Figs. 33 and 34 as approximately twice actual size. In order to explain the principles of this invention as incorporated in the fourth embodiment, however, it is necessary to use illustrations considerably more enlarged from actual size than even Figs. 33 and 34. Such an enlarged assembly is indicated in Fig. 35 by reference numeral 660 and may be regarded as merely a segment of the assembly of Fig. 33.

The crystals 50 are placed in the assembly or formation 660 (Fig. 35) in an integrated, tightly packed mosaic pattern. The crystals are in side-by-side and edge-to-edge relationship with adjacent side faces 64 of adjacent crystals in mating congruent contact so as to eliminate or at least greatly reduce any gaps between the crystals and to restrict intrusion of contamination or foreign material. In the assembly, all the top faces 64 of the crystals are in a common plane which thus creates a top, outwardly directed surface 662 of the assembly, and all of the bottom faces 64 of the crystals are coplanar and define a bottom, outwardly directed surface 664.

The crystals 50 are integrated or bonded together in the formation 660 by one or more of several bonding techniques, as subsequently described in greater detail. One of these bonding techniques is an adhesive coating 666 over either the top surface 662, as shown in Fig. 36, or over the bottom surface, not shown.

Of greatest significance, the crystals 50 (Fig. 35), by virtue of their substantially same size and predominately cubic shape and by virtue of their described assembly 660, are oriented with their crystallographic directions of maximum abrasive resistance either

aligned with, or parallel to, each other. Alignment occurs because the crystallographic directions 90, 90 ′ of each crystal (Fig. 5) are aligned with the corresponding directions 90, 90 ′ of all the other crystals lying in a row along one of the principal diagonals 670 (Fig. 35) of the assembly. Likewise, the crystallographic directions 92, 92 ′ (Fig. 5) of the crystals lying in a row along the other principle diagonal 672 (Fig. 35) of the assembly are aligned. Parallelism occurs because these directions, as 90, 90 ′, are parallel to such directions of the crystals in other shorter, diagonal rows, one of which is indicated by line 674 in Fig. 35.

Furthermore, the directions of minimum abrasive resistance 94, 94 ′ (Fig. 5) are aligned and parallel to each other in a similar manner and as represented by line 676 in Fig. 35, and this line is at forty-five degrees separation from the lines of maximum resistance 670, 672.

In its basic form, the assembly or formation 650 (Fig. 33), or 660 (Fig.35), comprises only one layer of crystals 50 and may be of any practical surface area, that is, any practical number of crystals, limited only by the assembly space and the particular use or application of the assembly. By way of example only, the assembly in Fig. 33 includes two-hundred twenty-five crystals with an actual size of approximately fifteen millimeters by fifteen millimeters square and slightly in excess of one millimeter thick allowing for the thickness of the binder 658. In contrast, the assembly of Fig. 35 includes sixty-four crystals and would measure about 8 by 8 by 1 mm in actual size.

The perimeter or outside edge of the assembly 650 need not be rectangular and may have other regular or irregular configurations since the principles of the invention still apply along the diagonals of the assembly as governed by the cubic crystal faces 64 (Fig. 35) within the margins of the assembly. Again, reference to top and bottom surfaces 662 and 664 does not imply use of the assembly in any particular orientation but is for convenience in describing the assembly of the crystals 50. If desired for some applications, multiple assemblies, not shown, may be bonded together in edge-to-edge coplanar relation to form a much larger surface area. Also, multiple assemblies may be bonded together in stacked, layered relation, also not shown. In any case, the crystals are assembled so that their crystallographic directions are oriented in the same direction, in accordance with the principles of this invention. Multiple layers also occur upon chemical vapor deposition, as subsequently described.

Method of Making the Fourth Embodiment of the Article

In general, the method of making the fourth embodiment may be divided into two parts for descriptive purposes, namely, initially assembling the crystals 50 so as to form the assembly 650, and secondly, binding the crystals in the assembly. Figs 37 illustrates the steps of assembling the crystals, and Figs. 38 and 39 illustrate two embodiments of binding the crystals in the assembly.

The initial part of the method, namely, placing the diamond crystals 50 in an assembly 660a is thus described by reference to Fig. 37. One of the first tasks is to select the crystals to be used. Synthetic single diamond crystals of subtantially cubic shape, or of cubo-octahedral shape where the cubic faces predominate, are chosen. Also, the crystals used should be of substantially the same size. Currently, crystals are available up to about 1 mm on an edge, but as synthetic growing techniques improve, larger crystal sizes may become available. If not already accomplished, and as discussed above, the supply acquired should be sized to insure that the crystals used are of substantially the same size, preferably from 0.75 mm to 1 mm or larger if available. As previously noted, only perfectly cubic crystals 50 are shown in Fig. 37, but the method described is equally applicable to the cubo-octahedral crystals 60 with predominately cubic faces 82.

Synthetic, single diamond crystals 50 are dropped (Fig. 37) one at a time or in limited numbers into a tray or receptacle 680 having a planar bottom surface 682 and side walls 684 defining a corner 686 of the tray which has the shape of a corner of a cube. The tray is tilted toward the corner and is gently shaken, vibrated or tapped in the plane of the bottom surface. When the crystals land on the bottom surface 682, they attain a stable position on one of their faces 64. Stability occurs because of the cubic shape of each crystal; the angle of tilt of the tray; the mass of the crystal; and the material of the tray, more particularly the bottom surface 682. Then, because of the tilt and vibration of the tray, the crystals slide toward the corner. The angle of tilt of the tray and the vibrating action are adjusted to achieve this stabilization and sliding action. In the described embodiments, the tray is preferably made of high density polyethelene, PTFE, graphite, a refractory, or other material which has a coefficient of friction to promote the described stabilty and sliding action of the diamond crystals.

As the crystals 50 slide into the corner 686 of the tray 680 (Fig. 37), they align themselves with the side walls 684 of the tray or with the side faces 64 of crystals that are already in oriented positions in the corner and thereby build up the assembly 660a of

crystals in a layer, one crystal thick. Use of needle point tweezers, not shown but commonly available, may be used to reposition any errant crystals. The side faces of adjacent crystals are in congruent contact with each other, and the top faces of all the crystals in the assembly form the common planar surface 662. This results in all the crystals being oriented in the same crystallographic direction, as explained above in describing the assembly 660 in Fig. 35.

After the crystals 50 are positioned in the assembly 660a (Fig. 37), they are bound together in accordance with the second part of the method, now described with reference to the two embodiments shown in Figs. 38 and 39. In describing these embodiments, all of the crystals are shown as cubo-octahedral crystals 60 with predominately cubic faces 82, but it is understood that in actual use, the crystals may be a mixture of cubic crystals 50 and such cubo-octahedral crystals 60. Only cubo-octahedral crystals are shown in Figs. 38 and 39 because of illustrative convenience and because it facilitates description of the binding and grinding steps.

With reference first to Fig. 38a through 38d, the steps are described for binding crystals 50 in an assembly 660b which has utility for abrasion resistance in bearings and heat sink purposes. It is noted that Figs. 38 and 39 are schematic views involving only a few crystals and are intended primarily to show the principles of the method. Cubo-octahedral synthetic single diamond crystals 60 (Fig. 38a) with large cubic faces 82 and relatively small octahedral facets 84 and approximately one millimeter in size are contained and oriented in a tray 680b, for example in the manner discussed with reference to Fig. 37. The crystals in the tray are then covered with a metal infiltration powder 690, such as Macrofil, a product available from Kennametal Inc. of Latrobe, Pennsylvania, USA that is capable of wetting the crystals upon heating. The powder is then heated to melting temperature to fuse the metal to the surface of the crystals and to draw it by capillary action into interstices between the top corners or octahedral facets 84 of the crystals. It is to be understood that the tray is made of a heat-resistant material, such as graphite, which is not wetted by the metal. The molten metal is then allowed to cool and solidify to form a binder coating 692 (Fig. 38b), whereupon the crystal assembly is removed from the tray (Fig. 38c). Finally, the bottom surface 664b of the assembly is ground to remove the octahedral facets and to produce a smooth coplanar surface.

The embodiment of the method described and illustrated in Figs. 37 and 38a-38d produces the bearing surface 664b which has a maximum abrasive resistant direction along

the aligned diagonals of the crystals 60, as fully described above in discussing Fig. 35. Using the principles of Figs. 37 and 38a-38d, an article, as 650 (Fig. 33), is produced which is useful as a bearing member with an exceptionally high abrasion resistance along the defined direction. It is significant to note, however, that the method also causes, and the article exhibits, a direction of minimum abrasive resistance, and it is along this line that the grinding occurs in achieving the smooth planar surface 664b. Thus, by following the principles of this invention, both maximum and minimum abrasive directions are fully achieved and exploited.

In addition, the article of the fourth embodiment is useful as a heat sink since the cubic faces 82 of the crystals 60 are in intimate contact and allow maximum heat conductivity across the interfaces of the crystals. The metal binder 692 enters essentially only the interstices between the octahedral facets 84 of the crystals and thus does not contaminate the main body of the assembly and interfere with the excellent thermal conductivity of diamond. The bearing surface or heat sink can be enlarged by including more crystals in the assembly 650 or by duplicating the assembly and mounting the assemblies so provided in contiguous edge-to-edge generally coplanar relationship to form a larger assembly of crystals, as will be understood although not shown.

Figs. 39a through 39f are referred to in describing another embodiment of the binding part of the method of the present invention so as to provide an article of manufacture suitable for electronic, heat sink, or abrasion-resistant uses. In Fig. 39a, the crystals 60 are assembled as previously described in a tray or box 680e which is temperature resistant to about 1000° C and chemically resistant to chemical vapor deposition (CVD) of diamond. For this purpose a suitable tray material is refractory cement. A first coat 710 (Fig. 39b) of diamond is deposited by CVD on the upper surface 662d which binds the crystals 60 together in assembly 660e. While the assembly is still in the tray (Fig. 39c), a rigid backing 712, which may be made of plate glass or aluminum, is temporarily cemented, for example by lapidarist's cement such as stick shellac, to the first coat 710 of diamond to hold the assembly 660e rigidly together to allow grinding. Next, the assembly of diamond crystals as held together by the rigid backing is removed from the tray (Fig. 39d), and the lower surface 664e is finished by a grinding tool, by chemical milling, or by laser machining to provide a smooth coplanar surface 664e with any octahedral facets 84 destroyed.

In the next step (Fig. 39e), the backing 712 and the cement used to attach it are removed by dissolution with a solvent, such as alcohol, or by heating to a temperature of approximately 200°C. Many other temporary cements could also be used and dissolved. A second coat 715 (Fig. 39f) of diamond is then deposited by CVD over the planar surface 664e. It is to be understood that the diamond in both the first and second coats 710 and 715 inherits the orientation of the atomic arrangement of the oriented diamond crystals in the assembly 660e so that the final article is an assembly of pure, single crystal diamond, with all of the crystallographic directions oriented in the same direction. The article 660e is thus ideally suited for the semiconductor, heat sink and bearing purposes discussed herein.

In summary of the present invention and its advantages, each of the described embodiments comprises synthetic single crystals of diamond or CBN, as 50, 60 and 350, held in a formation with selected crystallographic directions of the crystals oriented in the same direction. In the first three embodiments, a plurality of single synthetic crystals of diamond or CBN of substantially uniform size and shape are mounted in a backing member, as 38, 238 and 338, so that all the crystals are oriented with corresponding hard-to-abrade directions aligned. With the first and third embodiments in Figs. 1 and 19, the hardest-to-abrade directions are aligned, whereas with the second embodiment of Fig. 10, the next-to-the hardest directions are aligned. In all four embodiments the exposed workpiece-engaging extremities, as 64, 70a, 354a, 64b of the crystals lie in a common plane for simultaneous workpiece engagement even though some of the crystals are of slightly differing sizes. With the second and third embodiments of Figs.10 and 19, sharp edges, as 70 and 354, are presented to a workpiece, and with the variation of the first embodiment (Fig. 7), sharp corners, as 74, are presented. In the embodiments of Figs. 7, 10, 19, therefore, the sharp edges or sharp corners are in a saw-tooth formation which together with the aligned hardness directions produce an especially effective abrading action. It is also to be noted that the spacing between the crystals facilitates removal of abraded material as a workpiece is being processed.

From the foregoing, the following advantages, inter alia, of the first three embodiments will be understood. Since only the hardest-to-abrade directions are presented to a workpiece, the abrasive article: has increased life thus saving abrasive material; abrades faster; requires less frequent replacement of parts; maintains dimensional tolerances longer; minimizes adjustment for wear compensation; reduces dulling and

flatting; and allows variation of abrasive concentration and thus facilitates its optimization. Furthermore, since all of the workpiece-engaging extremities of the crystals lie in a common plane, even though the individual crystals may vary somewhat in length, the crystals engage the workpiece simultaneously and uniformly thereby enabling uniform removal of material from the workpiece and avoiding the problems of grains which stand high and slow the abrasive action. All of the above stated features and advantages have the effect of reducing cost, time and labor and improving abrasive action.

The terms "abrasive" and "abrading" are sometimes used in the art in a very specific sense to mean a very specific type of workpiece treating action. It is to be understood, however, that as used herein, these terms are not limited to such a specific meaning but include cutting, grinding, dressing, lapping, sawing, or otherwise treating or engaging workpieces in the multitude of ways in which a hard surface or tool is used. It is also to be noted that the principles of the invention are more broadly applicable to wear-resistant surfaces which are useful not only as workpiece-treating elements but as bearing elements.

In addition, it will be understood from the foregoing that the fourth embodiment yields the following advantages. The alignment of the hardest-to-abrade direction, that is the cube face diagonal of diamond crystals, gives superior wear surface, as compared to bonded aggregations of randomly oriented diamond crystals, because of the presentation of the one hundred percent hardest directions and the absence of a softer bonding agent. This is an advantage in sliding-surface bearings or thrust bearings especially in applications with abrasive contamination between the wear surfaces. The reduction in wear lengthens the time between bearing replacement or adjustment, retains the dimensional tolerances between bearing surfaces for longer periods, and retains the smoothness of bearing surfaces for longer periods of service. Friction values of the hardest-to-abrade diamond directions on each other are lower than friction values for random diamond directions. The result is less heat generation, lower power consumption, and less stress on the bearing parts.

The high heat conductivity of diamond makes a superior heat sink to conduct heat away from the heat source. The subject invention produces an extended assembly 650 with almost one hundred percent diamond content, and thus a continuous homogeneous content of diamonds without the diluting effect of binders used in binding diamond crystals.

The fourth embodiment produces an extended, voidless assembly 650 of diamond crystals with identical crystallographic directions. Chemical vapor deposition on the assembly results in a thin layer of diamond with one crystallographic direction because of the epitaxial relationship between the chemically-vapor deposited layer and the substrate of oriented diamond crystals. It is important to regognize that the assembly has one crystallographic direction yielding single crystal quality because the contacting adjacent crystals avoids spaces between the crystals which would otherwise produce defects at the growth boundaries.

Following the principles of the fourth embodimen thus makes possible improved exploitation of diamond's semiconductor properties. Chemically-vapor deposited single-crystal assemblies, as 660e, can be made insulating in character by using pure diamond or can be doped with impurities to yield P or N carriers to make diodes, transistors, radiation detectors, or photo conductor devices. The diamond substrate forms an integral heat sink to allow increased electric current capacity to the devices, and diamond's high temperature and chemical immunity permit devices to function in hostile environments.

In attrition grinding of hard materials to reduce particles to smaller sizes, the wear of machine surfaces by the abrasive action of the particles is costly because the parts wear rapidly and must be replaced, and the parts that wear produce particles that contaminate the product being ground. By applying to the wear surfaces, assemblies or layers 650 of aligned diamond crystals that present the hard-to-abrade directions of the crystals to the abrading directions of the particles being ground, machine wear can be drastically reduced thus saving the cost of new wear surfaces and the cost of replacing them. The great reduction of impurities from wear surfaces is often of critical importance in quality control, and the minuscule contamination by diamond wear surfaces is of a highly inert nature.

The present invention takes advantage of the inherent properties of diamonds and particularly synthetic diamond crystals in the manner described, but it is to be understood that the principles of this invention are equally applicable to other materials that have similar or equivalent crystalline properties.

In addition to the terms "assembly" and "formation," the terms "array," "sheet," "mosaic," "block," and "matrix" are used to describe the article of manufacture provided by the present invention. Other terms could be used without affecting the principles

described herein. It is understood that the use of these terms does not imply any particular surface area or size of the various assemblies shown in Figs. 1, 10, 19 or 33.

Furthermore, although preferred embodiments have been shown and described, various modifications and substitutions may be made thereto without departing from the spirit and scope of the invention. Accordingly, it is to understood that the present invention has been described by way of illustration and not limitation.

Claims

1. An article of manufacture comprising synthetic single crystals held in a formation with selected crystallographic directions of the crystals oriented in the same direction.

2. The article of claim 1 wherein the crystals are polyhedral in shape.

3. The article of claim 2 wherein the shapes are selected from the group consisting of cubic, cubo-octahedral and tetrahedral.

4. The article of claim 2 wherein the crystals are of uniform size and shape.

5. The article of claim 4 wherein the crystals are at least about 0.5 mm to 1 mm in size.

6. The article of claim 1 wherein the crystals are selected from the group consisting of diamond and cubic boron nitride.

7. The article of claim 6 wherein the crystals are of uniform size and shape, wherein each of the crystals has face portions and edge portions, wherein one of said portions of each crystal faces outwardly of the formation, wherein said selected crystallographic direction of each crystal lies along a line in contact with its outwardly directed portion, wherein all of said selected crystallographic directions have substantially the same degree of hardness, and wherein said outwardly directed portions thereby exhibit a common crystallographic direction of hardness.

8. The article of claim 7 wherein the crystals are spaced from each other.

9. The article of claim 8 wherein all of the outwardly directed portions project equidistantly outwardly from said formation.

10. The article of claim 8 wherein said outwardly directed portions are faces of the crystals.

11. The article of claim 8 wherein said outwardly directed portions are edges of the crystals.

12. The article of claim 11 wherein said outwardly directed edges are coplanar.

13. The article of claim 11 wherein said outwardly directed edges are at an angle to a common plane and terminate in sharp corners which are in said common plane.

14. The article of claim 7 wherein the crystals are closely packed together with said outwardly directed portions being faces of the crystals and forming a continuous common surface.

15. The article of claim 7 including a binder of plastic or metal holding the crystals in said formation.

16. The article as in any one of claims 7-13 or 15 wherein said outwardly directed portions are abrading portions whereby the article is an abrasive article.

17. The article of claim 14 wherein said continuous common surface is a bearing surface, a heat sink or a semiconductor substrate.

18. The article of claim 7 or 14 wherein the formation is a semiconductor substrate, and wherein a layer of diamond crystals is deposited on said outwardly directed portions by chemical vapor deposition whereby the deposited layer has the same crystallographic direction as the assemblage.

19. The article of Claim 18 wherein the deposited layer is doped with impurities to provide P or N carriers and wherein the formation is an integral heat sink for the doped layer.

20. The article of claim 7 wherein the formation is a layer of said crystals in a common plane.

21. A method for producing an article of oriented crystals comprising the steps of selecting synthetic single crystals of substantially uniform size and of polyhedral shape and wherein each of said crystals has at least one portion with a crystallographic direction which is substantially the same in all of the crystals, positioning the crystals in a formation so that all of said crystallographic directions are oriented in the same direction and said portions collectively exhibit a common crystallographic direction of hardness, and securing the crystals together in said formation.

22. The method of claim 21 wherein said selecting step invloves selecting the crystals from the group consisting of diamond and cubic boron nitride.

23. The method of claim 21 or 22 wherein the crystals are positioned in said formation in spaced relation to each other.

24. The method of claim 21 or 22 wherein the crystals are positioned in said formation in contacting, closely packed relation to each other.

25. The method of claims 21 or 22 wherein said one portion of each crystal is an abrasive portion, wherein said positioning step includes introducing the crystals into a template having receptor means shaped to position and align said abrasive portions to collectively exhibit said common crystallographic direction of hardness and wherein said abrasive portion of each crystal protrudes from said template, said method including the further step of vibrating the template to stabilize the crystals in the receptor means and to remove excess crystals, wherein said securing step involves applying a binder to the crystals protruding from the template whereby the crystals are fixed in the positions in which they were aligned in the template and at least partially curing said binder, and including the additional step of removing the crystals and binder from the template.

AMENDED CLAIMS

[received by the International Bureau on 05 February 1996 (05.02.96); original claims 1,5,7,20 amended; new claim 21 added; original claims 21-25 renumbered as claims 22-26 remaining claims unchanged (2 pages)]

1. An article of manufacture comprising a formation of synthetic single crystals each having a predetermined crystallographic direction of hardness, said crystals being held in the formation with said predetermined crystallographic directions oriented in the same direction, said formation being created by physically moving the crystals from disoriented positions into their oriented positions in said formation.

2. The article of claim 1 wherein the crystals are polyhedral in shape.

3. The article of claim 2 wherein the shapes are selected from the group consisting of cubic, cubo-octahedral and tetrahedral.

4. The article of claim 2 wherein the crystals are of uniform size and shape.

5. The article of claim 4 wherein the size of the crystals ranges from about 0.5 mm to about 1 mm or more.

6. The article of claim 1 wherein the crystals are selected from the group consisting of diamond and cubic boron nitride.

7. The article of claim 6 wherein the crystals are of uniform size and shape, wherein each of the crystals has face portions and edge portions, wherein one of said portions of each crystal faces outwardly of the formation, wherein said predetermined crystallographic direction of each crystal lies along a line in contact with its outwardly directed portion, wherein said crystals have substantially the same degree of hardness along their respective predetermined crystallographic directions, and wherein said outwardly directed portions thereby exhibit a common direction of hardness.

8. The article of claim 7 wherein the crystals are spaced from each other.

9. The article of claim 8 wherein all of the outwardly directed portions project equidistantly outwardly from said formation.

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20. The article of claim 7 wherein the formation is a coplanar layer of said crystals.

21. The article of Claim 1 wherein the formation is a matrix of rows and columns of crystals, each of said rows and columns being completely filled with crystals, said crystal formation having a common crystallographic direction of hardness.

22. A method for producing an article of oriented crystals comprising the steps of selecting synthetic single crystals of substantially uniform size and of polyhedral shape and wherein each of said crystals has at least one portion with a crystallographic direction which is substantially the same in all of the crystals, positioning the crystals in a formation so that all of said crystallographic directions are oriented in the same direction and said portions collectively exhibit a common crystallographic direction of hardness, and securing the crystals together in said formation.

23. The method of claim 22 wherein said selecting step involves selecting the crystals from the group consisting of diamond and cubic boron nitride.

24. The method of claim 22 or 23 wherein the crystals are positioned in said formation in spaced relation to each other.

25. The method of claim 22 or 23 wherein the crystals are positioned in said formation in contacting, closely packed relation to each other.

26. The method of claims 22 or 23 wherein said one portion of each crystal is an abrasive portion, wherein said positioning step includes introducing the crystals into a template having receptor means shaped to position and align said abrasive portions to collectively exhibit said common crystallographic direction of hardness and wherein said abrasive portion of each crystal protrudes from said template, said method including the further step of vibrating the template to stabilize the crystals in the receptor means and to remove excess crystals, wherein said securing step involves applying a binder to the crystals protruding from the template whereby the crystals are fixed in the positions in which they were aligned in the template and at least partially curing said binder, and including the additional step of removing the crystals and binder from the template.

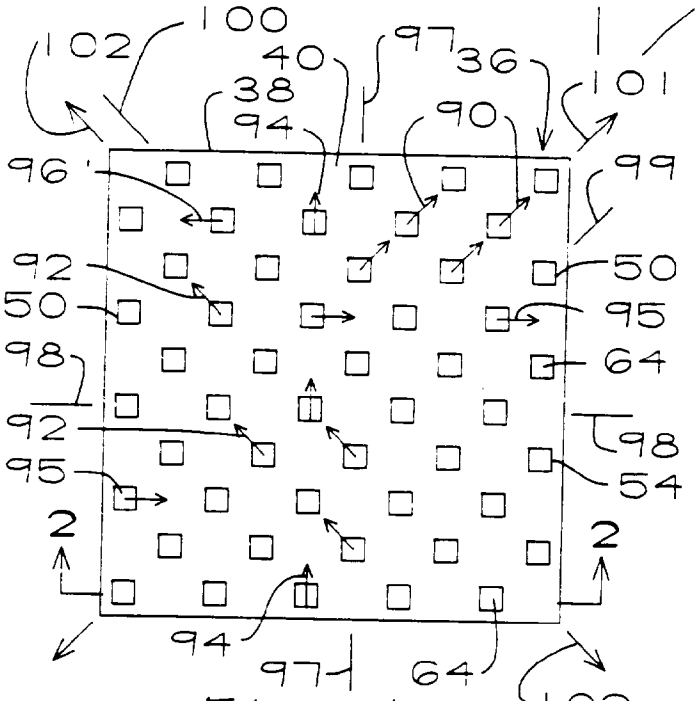


Fig. 1

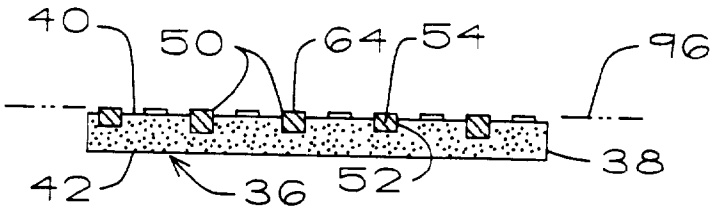


Fig. 2

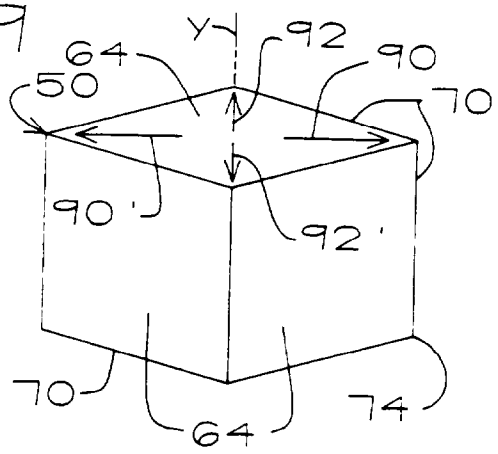


Fig. 3
PRIOR ART

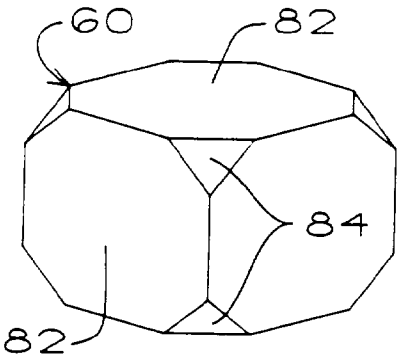


Fig. 4
PRIOR ART

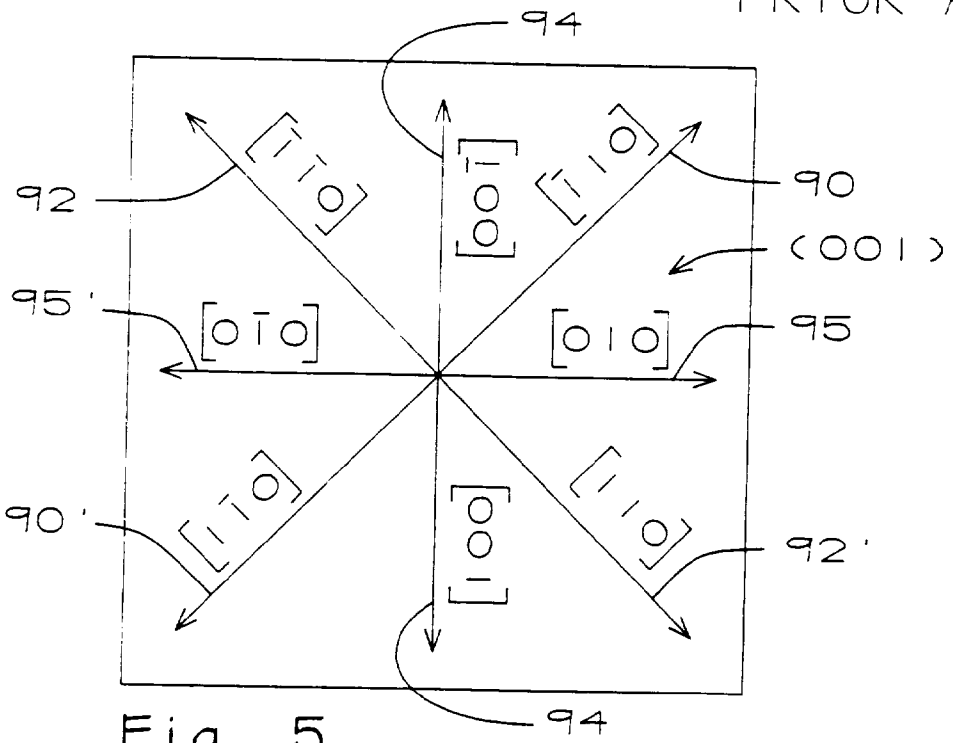


Fig. 5
PRIOR ART

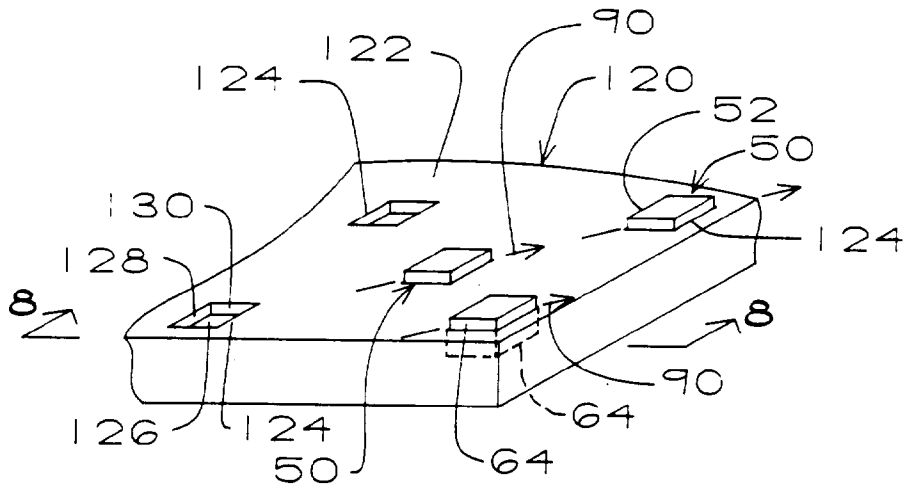


Fig. 6

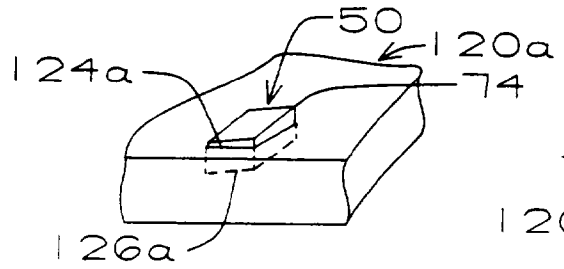


Fig. 7

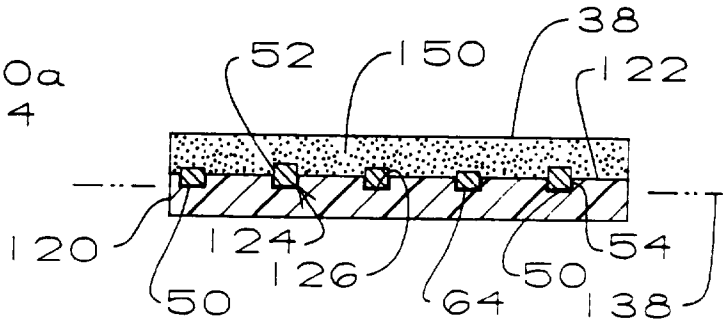


Fig. 8

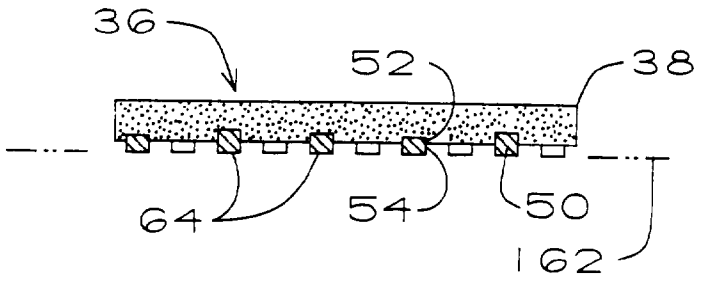


Fig. 9

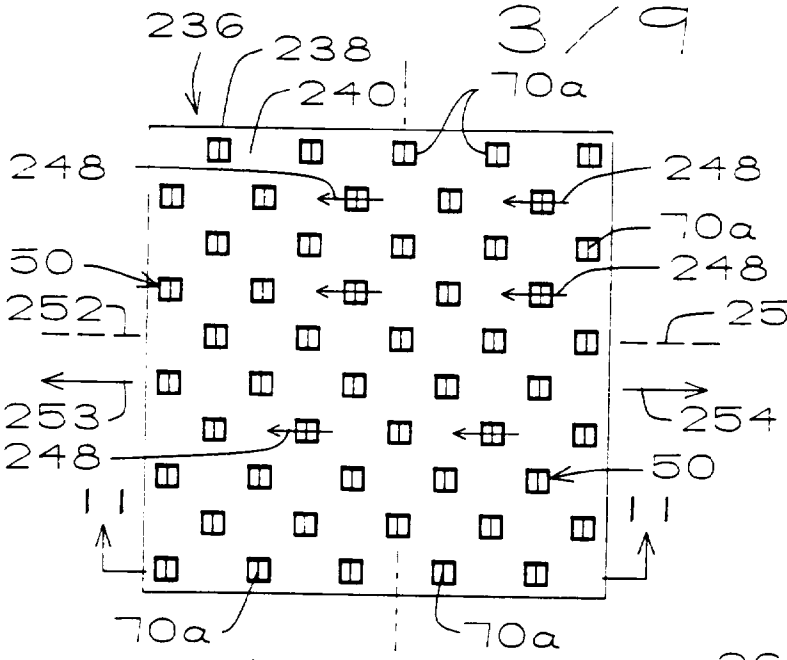


Fig. 10

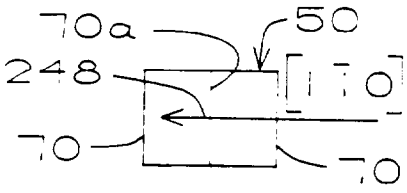


Fig. 12

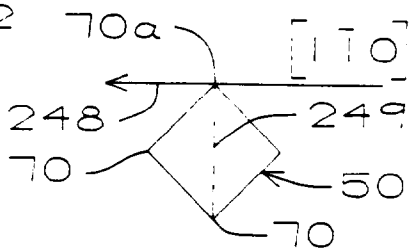


Fig. 13

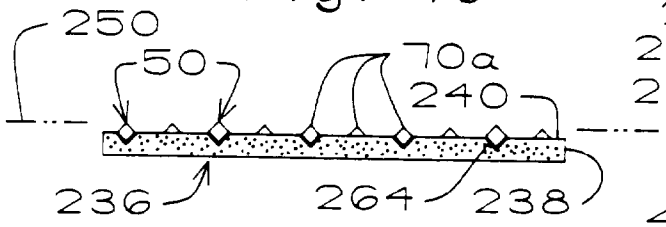


Fig. 11

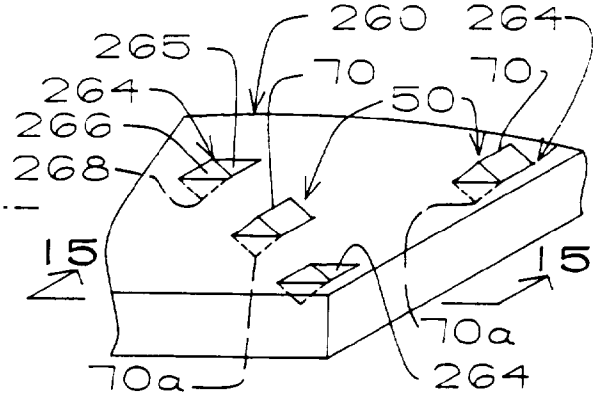


Fig. 14

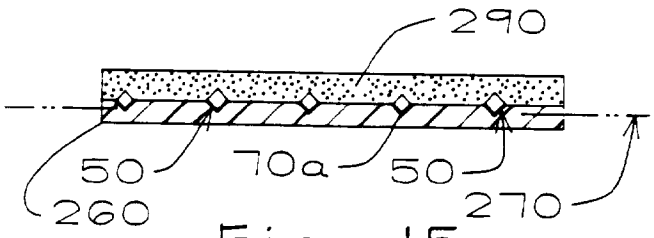


Fig. 15

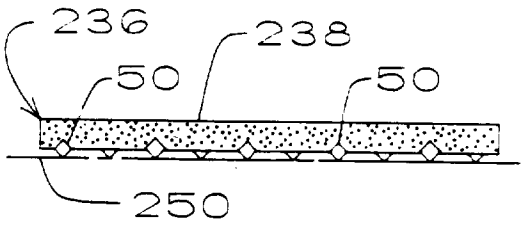


Fig. 16

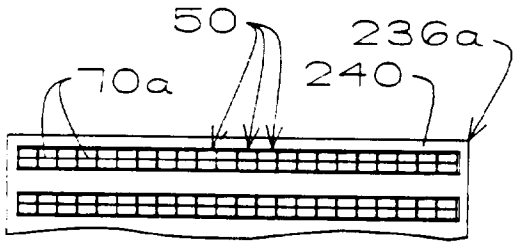


Fig. 17

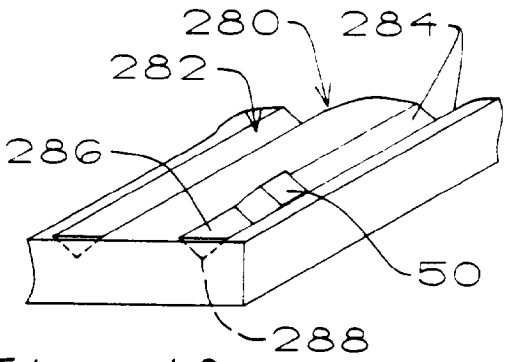


Fig. 18

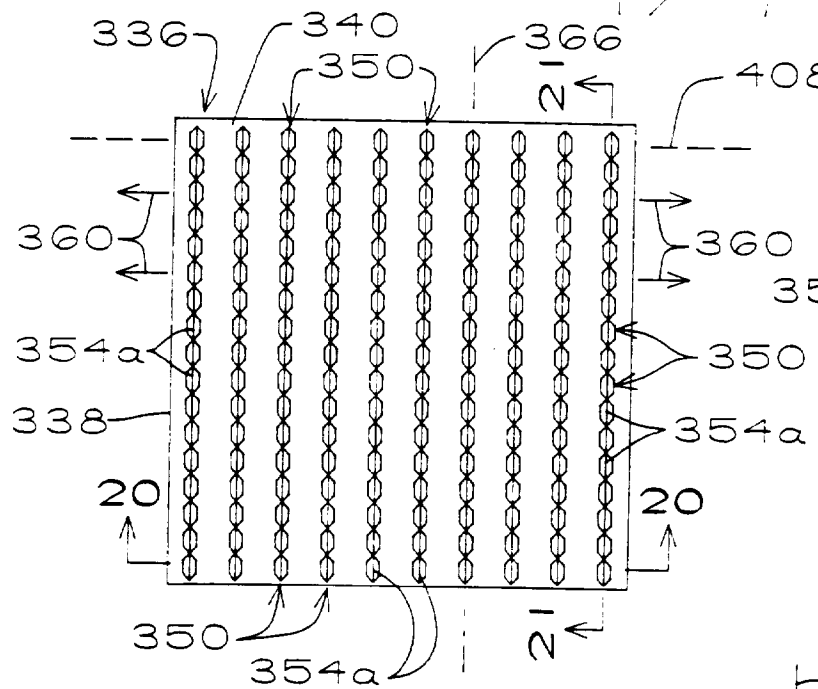


Fig. 19

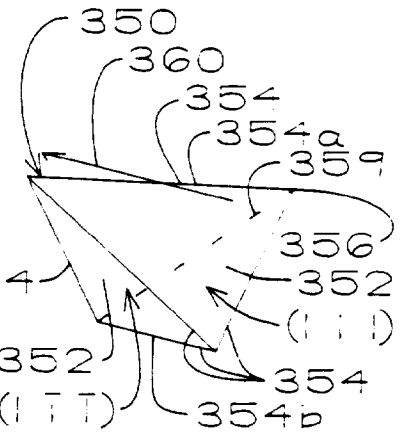


Fig. 22

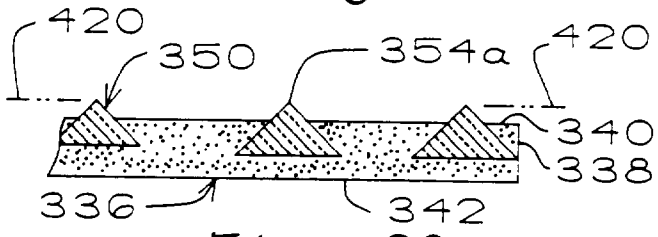


Fig. 20

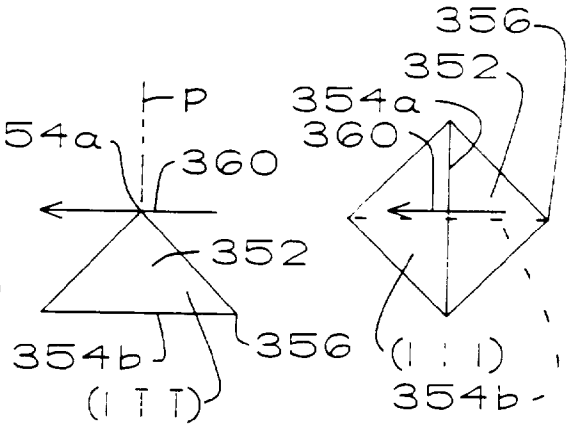


Fig. 23 Fig. 24

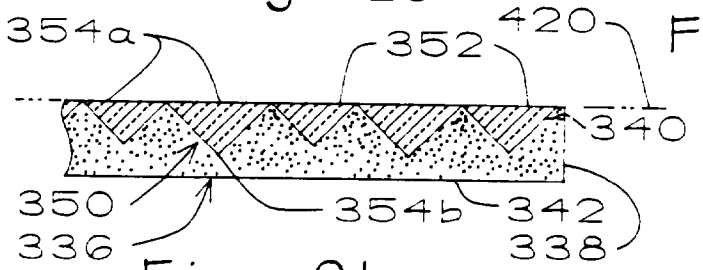


Fig. 21

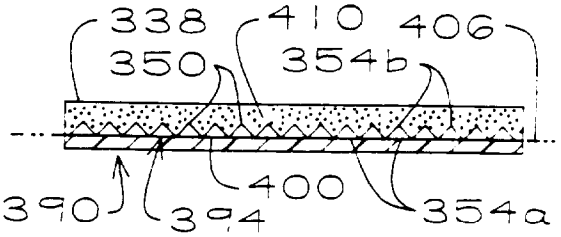


Fig. 26

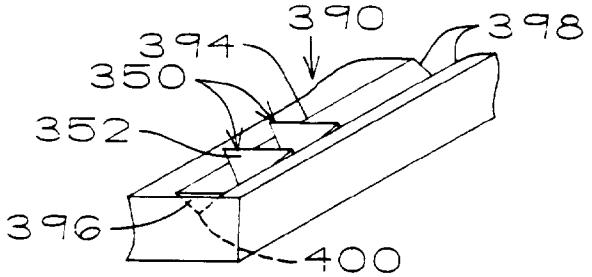


Fig. 25

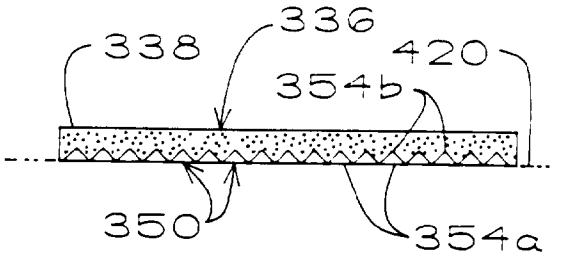


Fig. 27

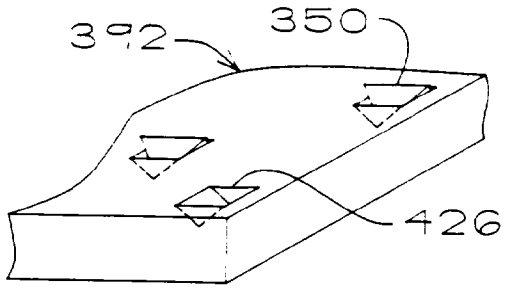


Fig. 28

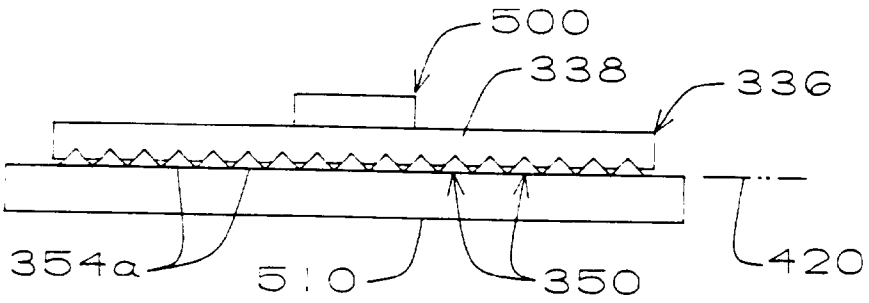


Fig. 29

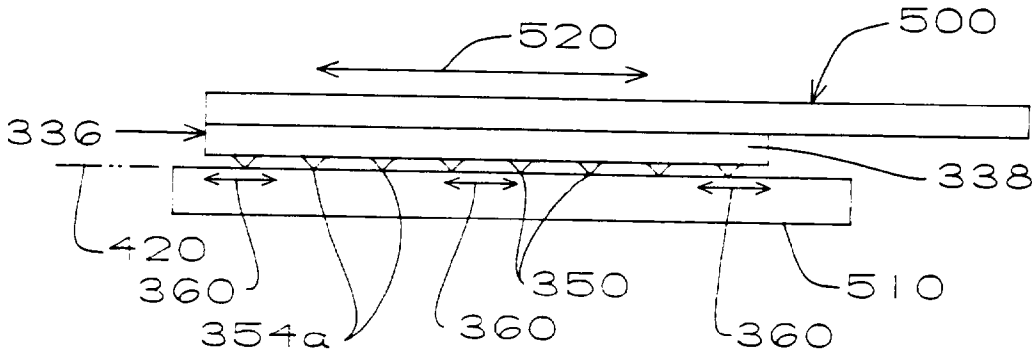


Fig. 30

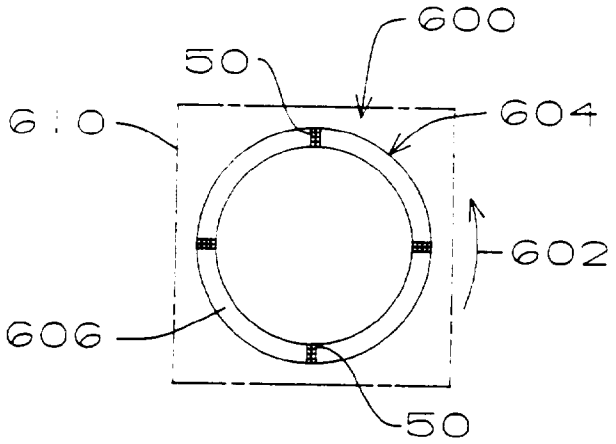


Fig. 31

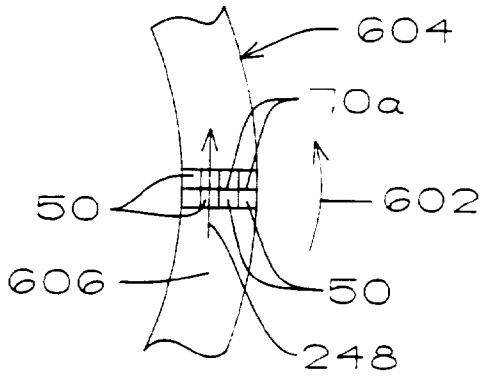


Fig. 32

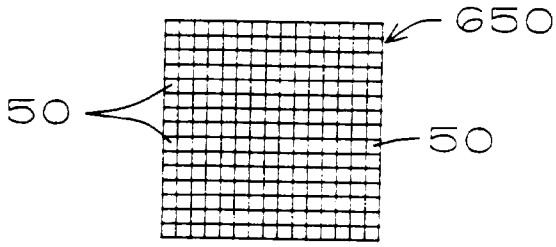


Fig. 33

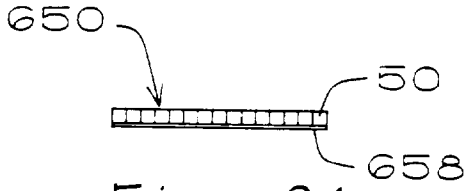


Fig. 34

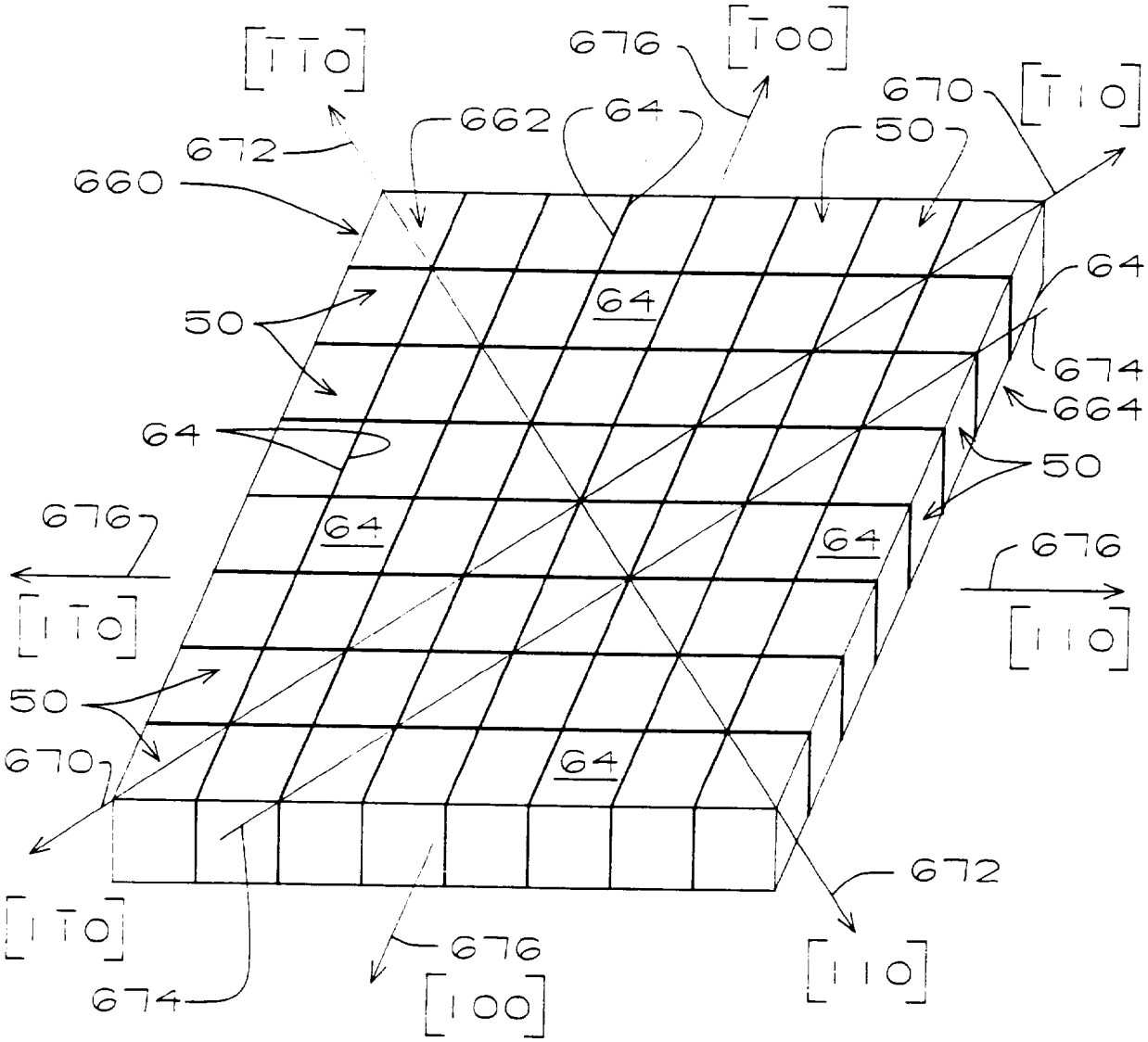


Fig. 35

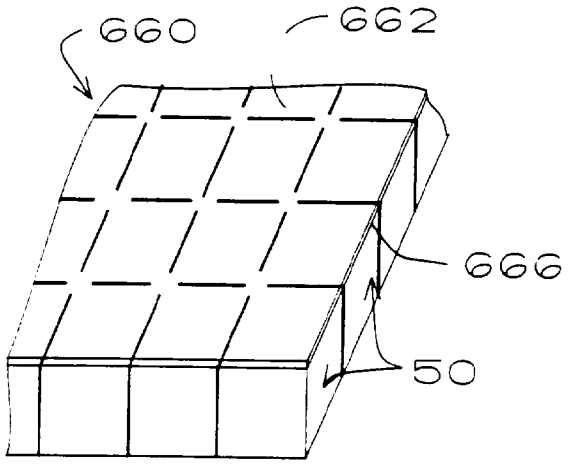


Fig. 36

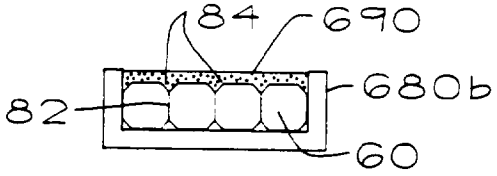


Fig 38a

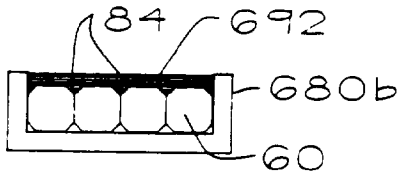


Fig 38b

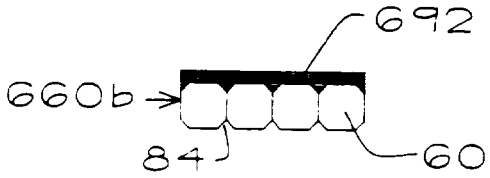


Fig 38c

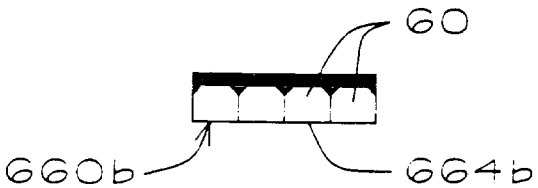


Fig 38d

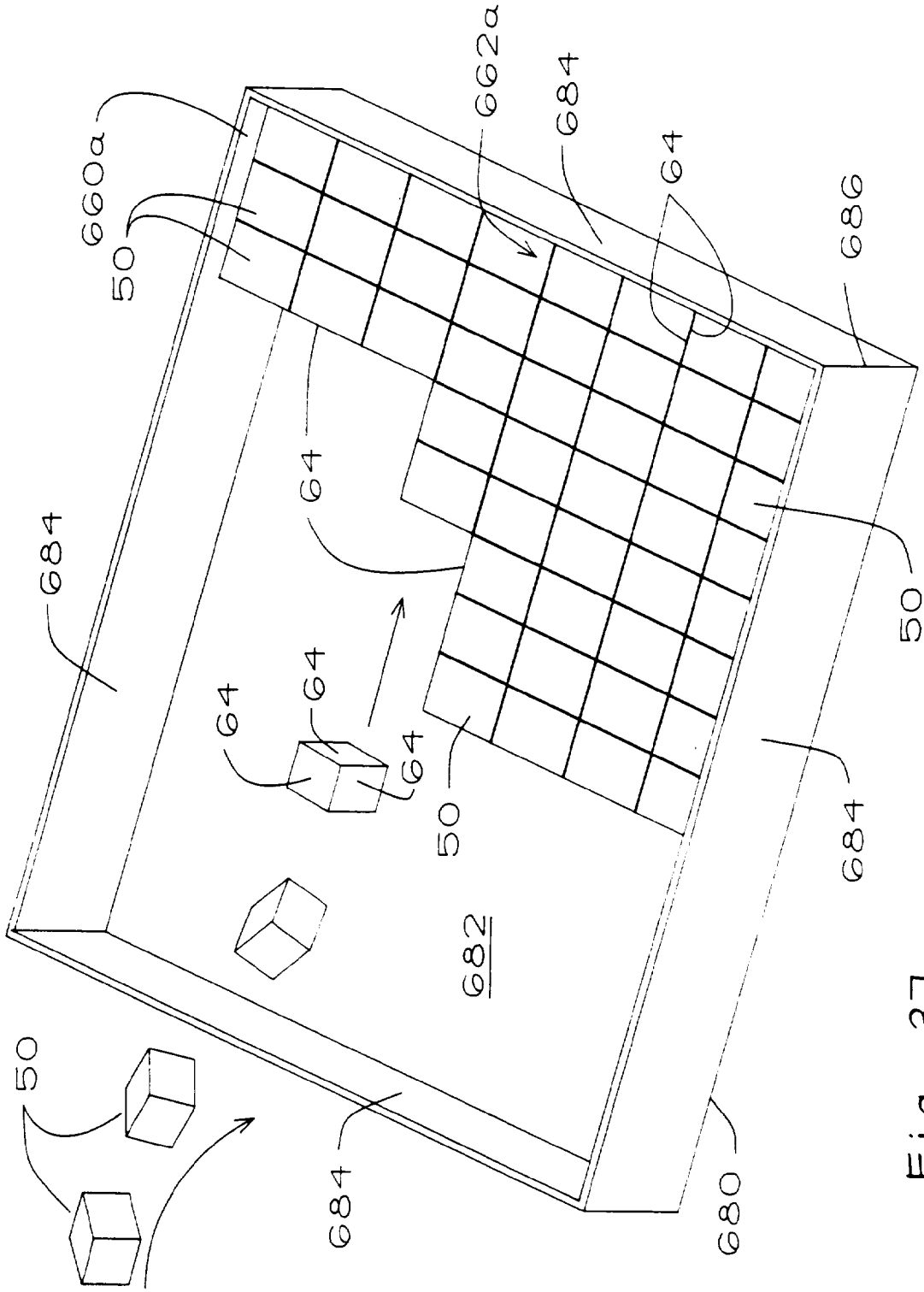


Fig. 37

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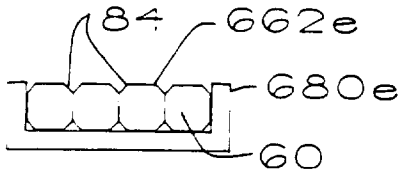


Fig 39a

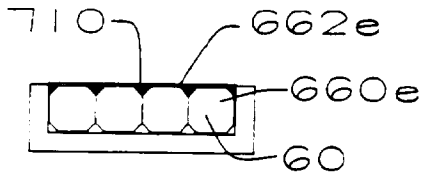


Fig 39b

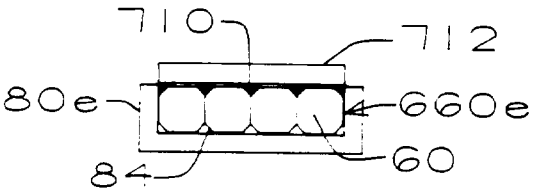


Fig 39c

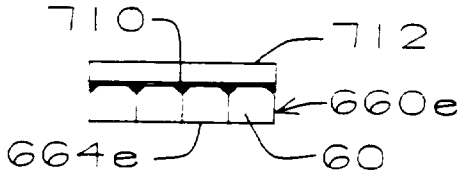


Fig 39d

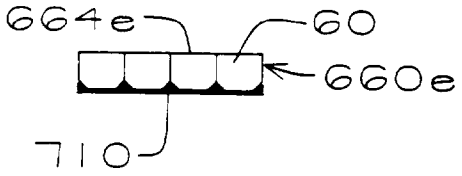


Fig 39e

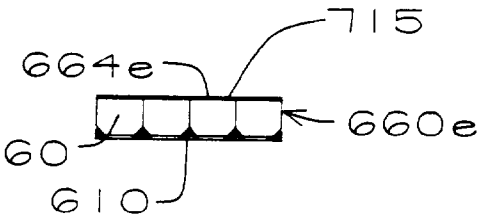


Fig 39f

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/10195

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :Please See Extra Sheet.
US CL :428/141, 143, 217, 323, 408; 51/295, 307; 257/64, 77, 627, 628; 117/84, 95, 101
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 428/141, 143, 217, 323, 408; 51/295, 307; 257/64, 77, 627, 628; 117/84, 95, 101, 902, 924

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

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

APS: diamond, orientation, heat sink, abrasive.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	WO, A, 92/01827 (MASSACHUSETTS INSTITUTE OF TECHNOLOGY) 06 February 1992, see entire document.	1-4, 6-7, 14, 17-22, 24
Y	Applied Physical Letters, Volume 58, Number 22, issued 03 June 1991, Geis et al, "Large-area Mosaic diamond films approaching single-crystal quality", pages 2485-2487, see pages 2485-2487.	1-4, 6-7, 14, 17-18, 20-22, 24
Y	US, A, 3,895,313 (SEITZ) 15 July 1975, see Figure 8; columns 3-4; column 7, line 63 - column 8, line 60.	1-4, 6-7, 14, 17, 20-22, 24
Y, P	US, A, 5,371,383 (MIYATA ET AL) 06 December 1994, see column 2, lines 34-68; column 4, lines 38-45; column 5, lines 20-23.	1-4, 6-7, 14, 17-22, 24

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

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Date of the actual completion of the international search 27 OCTOBER 1995	Date of mailing of the international search report 07 DEC 1995
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer VIVIAN CHEN Telephone No. (703) 308-2351

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/10195

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	US, A, 4,925,457 (DEKOK ET AL) 15 May 1990, see entire document.	2, 6-13, 15-16, 22-23, 25
Y	US, A, 5,107,626 (MUCCI) 28 April 1992, see Figure 1; column 1, line 60 to column 2, line 50.	1-4, 6-13, 15-16
Y	US, A, 5,304,223 (PIEPER ET AL) 19 April 1994, see column 2.	1-4, 6-13, 15-16
Y	US, A, 5,152,917 (PIEPER ET AL) 06 October 1992, see column 2.	1-4, 6-13, 15-16
A	US, A, 5,296,207 (LUX) 22 March 1994, see entire document.	17

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US95/10195

A. CLASSIFICATION OF SUBJECT MATTER:
IPC (6):

B32B 5/16; B24D 3/00, 3/02; C09C 1/68; C09K 3/14; C30B 23/00, 25/00, 28/12, 29/04, 31/00; H01L 29/04, 31/0312, 31/036

PCT WORLD INTELLECTUAL PROPERTY ORGANIZATION
International Bureau

INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B24D 3/28, 18/00, 5/00

A1

(11) International Publication Number: **WO 98/10897**

(43) International Publication Date: 19 March 1998 (19.03.98)

(21) International Application Number: PCT/US97/15724

(22) International Filing Date: 5 September 1997 (05.09.97)

(30) Priority Data:
08/711,636 10 September 1996 (10.09.96) US

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(74) Agents: GORDON, David, P.; 65 Woods End Road, Stamford, CT 06905 (US) et al.

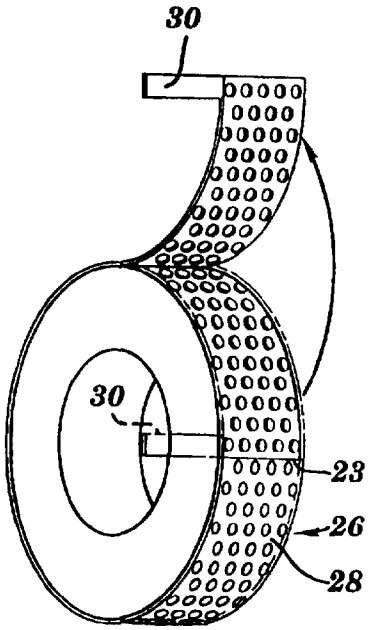
(81) Designated States: AU, BR, CA, CN, JP, KR, MX, RU, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: GRINDING WHEEL

(57) Abstract

A molded bonded abrasive grinding wheel adapted for relatively rough grinding operations is provided with a plurality of protuberances spaced in a predetermined pattern along the peripheral surface thereof and extending substantially orthogonally therefrom to define a textured grinding face. The protuberances are molded integrally with the grinding wheel and are perfomed by placing a perforated, or textured annular insert in a grinding wheel mold during molding wherein the insert is molded in-situ about the peripheral surface of the grinding wheel. The insert is removed from the peripheral surface after molding or during grinding to expose the protuberances defined by the perforations of the insert.



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GRINDING WHEEL

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to grinding wheels and more particularly, to a grinding wheel molded with a textured grinding face to facilitate use in rough grinding or conditioning operations.

2. Background Information

The grinding wheel art is highly developed and includes a wide range of wheel constructions and wheel fabrication processes adapted to optimize specific grinding operations and/or applications. One specific operation to which consideration has been given is known as conditioning. Conditioning is generally the removal of surface defects from ingots, blooms, billets and slabs of steel prior to further processing. Types of defects include cracks, folds, scale, scabs, seams, cinder patches and burned steel. Conditioning operations are generally characterized as "rough grinding" operations and utilize relatively large contact pressures between the wheel and the workpiece. Typically, grinding wheels optimized for these conditioning operations, commonly referred to as conditioning wheels, are fabricated from relatively heavy duty abrasive particulate, such as aluminum oxide, alumina zirconia, silicon carbide, or combinations thereof, of relatively large size (usually corresponding to an industry standard "grit size" of 4 through 46). Moreover, the particulate utilized for these wheels tends to be relatively hard or durable to provide resistance to the aforementioned relatively high grinding pressures. This particulate is generally maintained in a three-dimensional matrix of organic bonds, such as those provided by, for example, resinoid or phenolic resin bond material. Examples of conventional conditioning wheels are known as "BZZ Conditioning

Wheels" available from Norton Company of Worcester, Massachusetts.

As discussed hereinabove, the durability of the abrasive used in conditioning wheels serves to resist the relatively high pressures associated with the conditioning operation. The rough grinding face provided by the relatively large grit size, moreover, serves to effectively reduce the surface area of contact between the wheel and the workpiece to provide a relatively high pressure per unit area of contact therebetween. In this manner, contact pressure exerted between the exposed cutting edges of the abrasive and the workpiece is relatively high to facilitate the rough grinding or conditioning operation, while minimizing undesirable effects of excessive wheel pressure, such as uneven wheel wear or wheel breakage, as will be discussed hereinafter.

Conditioning wheels, like most other types of grinding wheels, are generally fabricated by hot or cold pressed molding operations. Disadvantageously, however, this fabrication method tends to produce wheels that emerge from the mold having substantially smooth peripheral grinding faces in which relatively few, if any, of the cutting edges of the abrasive are exposed. Thus, in the event such a smooth surface were brought into contact with a workpiece in a conditioning application, the increased contact area provided thereby would tend to reduce the contact pressure per unit area. To compensate for this condition, additional wheel pressure would generally be required to provide sufficient contact pressure between the wheel and workpiece to char or break the bonds of the grinding face and expose the cutting edges of the abrasive. Disadvantageously, however, this increased wheel pressure tends to generate non-uniform bond attrition which may lead to the wheel breaking or alternatively, becoming out of round and out of balance causing vibration during operation.

To overcome these disadvantages, most conventional conditioning wheels are subjected to an additional post-mold

operation commonly referred to as "dressing." Dressing generally includes applying a sharp implement, such as crush dressing, shot facing, or conical cutter, to the smooth face of the wheel during wheel rotation to remove the outer layer of bond material therefrom. This serves to expose the relatively course texture defined by the abrasive particulate to facilitate conditioning operations. Once the abrasive particulate has been exposed, the grinding wheel will wear away during subsequent grinding operations in a conventional manner, thus continually exposing new abrasive particulate in the bond matrix.

Although this dressing operation may serve to ameliorate the problem generated by the molding process, it is not without disadvantages. In particular, this additional operation contributes disadvantageously to the manufacturing cost, as well as to the length of time or lead time required to manufacture the wheel.

Thus, a need exists for an improved grinding wheel which overcomes the disadvantages of the prior art.

SUMMARY OF THE INVENTION

According to an embodiment of this invention, a molded grinding wheel includes bonded abrasive particulate, a substantially curved peripheral surface and a plurality of surface irregularities spaced in a predetermined pattern along the substantially curved peripheral surface to define a textured grinding face.

According to a second aspect of the present invention, an insert is adapted for use in conjunction with a grinding wheel mold having a mold cavity defined by at least one curved surface. The insert includes at least one liner sized and shaped for disposition in superimposed and concentric relation with the at least one curved surface of the grinding wheel mold. The at least one liner has a plurality of discontinuities disposed

therein and is adapted for being selectively molded in-situ with a grinding wheel in the grinding wheel mold, and removed from the grinding wheel, wherein the plurality of discontinuities define surface irregularities in a peripheral surface of the grinding wheel.

In a third aspect of the present invention, a method of forming a grinding wheel includes the steps of molding the grinding wheel to form a substantially curved peripheral surface and disposing a plurality of surface irregularities in a predetermined pattern along the substantially curved peripheral surface to define a textured grinding face.

In a fourth aspect of the present invention, a grinding wheel comprises a plurality of protuberances disposed on a peripheral surface thereof by providing at least one liner having a plurality of recesses disposed therein, molding the at least one liner in-situ about the peripheral surface and removing the at least one liner from the peripheral surface after molding.

The above and other features and advantages of this invention will be more readily apparent from a reading of the following detailed description of various aspects of the invention taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a perspective view of a grinding wheel of the subject invention;

FIG. 2 is a cross-section taken along 2-2 of FIG. 1;

FIG. 3 is a perspective view of a component utilized to fabricate the grinding wheel of FIG. 1; and

FIG. 4 is a perspective view, with portions in phantom, of

the grinding wheel of FIG. 1, during a step in the fabrication thereof.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Briefly described, as shown in FIG. 1, a molded, bonded abrasive grinding wheel 10 adapted for relatively rough grinding operations is provided with a plurality of surface irregularities, such as protuberances 20, spaced in a predetermined pattern along the peripheral surface thereof and extending substantially orthogonally or radially therefrom, to define a textured grinding face 18. Protuberances 20 are molded integrally with the grinding wheel and are formed by placing an annular insert 22 having a plurality of discontinuities, such as perforations 24, in a grinding wheel mold during molding of the wheel wherein the insert is molded in-situ about the peripheral surface of the grinding wheel. The insert is removed from the peripheral surface after molding to expose protuberances 20 defined by perforations 24.

For definitional purposes, throughout this disclosure, the term "axial" when used in connection with an element described herein, shall refer to a direction substantially parallel to the axis of a circular dimension thereof. The term "orthogonal" when used in connection with an element described herein, shall refer to a direction substantially perpendicular to a tangent of a curved surface at a point of intersection of the element with the curved surface.

Referring now to the drawings in detail, as shown in FIG. 1, grinding wheel 10 of the present invention is of conventional, generally disc-shaped construction, having a generally cylindrical inner surface or bore 12, planar side surfaces 14 and 16 (FIG. 2) and a substantially cylindrical outer surface or grinding face 18. The dimensions of the grinding wheel, including diameters of inner surface 12 and outer surface 18, as shown at a and b, respectively, as well as the thickness of the

wheel as shown at t (FIG. 2), are predetermined in a conventional manner, based in part on the particular grinding application for which wheel 10 is to be employed. The grinding wheel may be fabricated from a conventional bonded abrasive material such as, for example, the type mentioned hereinabove.

In a preferred embodiment, grinding wheel 10 is a "conditioning wheel" as generally described hereinabove. Outer surface 18 has a diameter preferably within a range of from approximately 14 inches (in) to 36 in, or approximately 35 centimeters (cm) to 91 cm. Thickness t (FIG. 2) is preferably within a range of from approximately 1.5 in to 6 in, or approximately 3 cm to 15 cm. Grinding wheel 10 also preferably comprises abrasive particulate having a grit size within a range of 4 to 46, or an average diameter within a range of .25 in (.65 cm) to .02 in (.05 cm). The abrasive is preferably maintained within hot or cold pressed phenolic resin or resinoid bonds.

As shown in FIGS. 1 and 2, outer surface 18 is provided with a series of surface irregularities such as protuberances 20 which, as shown, extend orthogonally or radially outwardly therefrom. Protuberances 20 are spaced at predetermined intervals from one another about outer surface 18 and serve to provide the outer surface with a relatively rough or "knobby" texture as shown.

Referring now to FIG. 3, a mold liner, insert or annulus 22 is provided to facilitate molding of protuberances 20. Mold band liner 22 comprises a generally cylindrical web of predetermined diameter d and width w sized to nominally define outer surface 18 of wheel 10 as will be discussed hereinafter. The liner is preferably provided with at least one axially extending scribe or cut 23, as shown in phantom, to facilitate removal of the insert from wheel 10 as will also be discussed hereinafter. Discontinuities such as apertures or perforations 24 are spaced at predetermined intervals throughout liner 22. The perforations serve to define protuberances 20 in a manner to be discussed in greater detail hereinafter. Liner 22 is adapted to slidingly

interfit in a superimposed and concentric manner with an outermost cylindrical surface of the cavity of a conventional grinding wheel mold (not shown). In this manner, liner 22 serves as a template for outer surface 18, including integral protuberances 20, of a grinding wheel 10 molded therein, as will be discussed in greater detail hereinafter with respect to the operation and fabrication of the present invention.

Liner 22 is preferably fabricated from a material capable of resisting deformation due to heat and pressure generated during hot pressed molding operations commonly employed to fabricate grinding wheels. In addition, the material is preferably relatively flexible to facilitate removal from wheel 10, as will be discussed hereinafter. In a preferred embodiment, the liner is thus fabricated from a relatively light gauge steel or aluminum, or from a paper product such as cardboard or chipboard.

In an alternate embodiment (not shown), the liner may comprise an inflatable bladder fabricated from a suitable material such as a heat resistant polymer. Such a bladder may include a plurality of discrete inflatable portions disposed on the generally cylindrical surface of the mold cavity as discussed hereinabove. It may thus be inflated during molding to define the textured grinding face 18 of the wheel and subsequently deflated to facilitate removal of the wheel from the mold in the manner to be discussed hereinafter.

A preferred embodiment of the invention having been fully described, the following is a description of the fabrication and operation thereof.

As discussed hereinabove, liner 22 is placed in concentric and superimposed orientation with the outermost cylindrical surface of the cavity of a conventional grinding wheel mold (not shown). A grinding wheel 10 is then molded in a generally conventional manner. Briefly described, a grinding wheel mixture, such as the above-described abrasive particulate and phenolic resin mixture, is deposited into the mold and

subsequently either hot or cold pressed. A post bake operation may be provided, in which the wheel is maintained for a predetermined period at typical elevated cure temperatures. During these molding operations, the grinding wheel mixture will enter and fill apertures 24 of liner 22, to effectively form a grinding wheel 10 having liner 22 molded in-situ with the peripheral surface thereof.

Once the molding process is complete, grinding wheel 10 and liner 22 are preferably removed from the mold as a single unitary wheel/liner assembly 26, in which liner 22 is disposed in concentric, superimposed relation with the wheel, as shown partially in phantom, in FIG. 4. As also shown, when so disposed, wheel 10 and liner 22 cooperate to provide assembly 26 with a substantially smooth, cylindrical outer surface 28 which serves to facilitate removal of wheel/liner assembly 26 from the mold without disadvantageously damaging either the wheel or the mold. In this regard, cylindrical outer surface 28 enables removal of wheel/liner assembly 26 simply by sliding the wheel/liner assembly in an axial direction out of the mold.

One skilled in the art will recognize that a molded wheel having an irregular or textured circumferential grinding face wholly defined by a wall of the mold cavity generally would not be removable from the mold simply by axial movement. Rather, irregularities in the grinding face, such as protuberances of the type described hereinabove, would tend to engage the corresponding recesses within the mold cavity and thus prevent such axial movement relative to the mold. Such a wheel would not be removable from the mold without damaging the mold and/or wheel. To avoid this problem, a segmented mold with muiltiple discrete sections may be used to mold wheels of the invention without using a perforated liner. Other mold types may be used. Such molds must be adapted to allow removal of the textured side walls of the mold without disturbing the grinding face of the wheel.

Once removed from the mold, liner 22 is removed from wheel 10. This may be accomplished by suitably engaging the liner proximate scribe or cut 23, such as at a tab 30, and peeling the liner away from outer surface 18 of wheel 10 as shown in FIG. 4 and continuing until the liner is completely removed from the wheel.

Once the liner has been so removed, grinding wheel 10 may then be utilized in grinding operations without further dressing operations. Indeed, the textured grinding face defined by the surface irregularities or protuberances 20 serves to effectively lower the area of contact between the wheel and workpiece. This lower contact area serves to increase the contact pressure per unit area between the wheel and workpiece to facilitate charring or breaking the bonds of the grinding face to expose the cutting edges of the abrasive as discussed hereinabove. Once cutting edges are exposed, the grinding wheel will wear away during subsequent grinding operations in a conventional manner, thus continually exposing new abrasive particulate in the bond matrix as also discussed hereinabove.

In an alternate embodiment, the liner may be fabricated from a cardboard or chipboard material as discussed hereinabove, either with or without tab 30. This material is advantageously flexible to facilitate fabrication and insertion into the cavity of the wheel mold, while it also tends to become relatively brittle when subjected to the elevated temperatures of typical post-bake operations. Accordingly, such a liner 22 may be left in-situ, in concentric orientation about wheel 10 until the wheel is used for grinding, whereupon the grinding operation itself will tend to disintegrate the liner to remove it from wheel 10. Such a cardboard or chipboard liner may thus advantageously enable elimination of the aforementioned liner removal step to further reduce manufacturing costs of wheel 10 of the subject invention.

In a further alternative embodiment, the inflatable bladder liner discussed hereinabove may be utilized to provide the

textured face. In this embodiment, the step of removing the liner from the wheel may be effected simply by deflating the bladder. Moreover, the bladder may be fastened to the mold wherein deflation may be accomplished while the wheel is disposed within the mold to facilitate removal of the wheel from the mold.

The use of liner 22 thus enables a grinding wheel to be molded with an irregular outer surface to eliminate the necessity of subsequent "dressing" operations of the type mentioned hereinabove, while enabling use of substantially conventional and relatively inexpensive molds and molding techniques. Elimination of these operations advantageously serves to reduce the manufacturing cost of grinding wheels such as "conditioning wheels." Moreover, elimination of the need for dressing serves to substantially reduce the length of time or lead time required to manufacture such grinding wheels. This reduced lead time may advantageously serve to reduce inventory costs for both the wheel manufacturer and wheel purchasers. The reduced lead time also tends to enable the wheel manufacturer to provide improved service to customers, by enabling orders such as for custom or particularly large numbers of wheels to be filled relatively quickly.

The discontinuities of insert 22 and the surface irregularities of wheel 10 have been shown and described herein as generally concave recesses 24 and generally convex protuberances 20, respectively. However, it should be recognized by those skilled in the art that the discontinuities of insert 22 may comprise generally convex protuberances of the type shown and described hereinabove with respect to wheel 10, and the surface irregularities of wheel 10 may comprise generally concave recesses of the type shown and described hereinabove with respect to insert 22, without departing from the spirit and scope of the present invention.

Moreover, those skilled in the art should recognize that the discontinuities of insert 22 may be of any configuration, such as a series of troughs, striations or other convex or concave

structures sufficient to provide a grinding wheel with a substantially textured grinding face, without departing from the spirit and scope of the present invention.

Although the present invention has been described herein with respect to a grinding wheel having a substantially cylindrical grinding face, the invention may be practiced with grinding wheels having a grinding face of any other substantially curved geometry, including but not limited to substantially frusto-conical, dome shaped, bowl shaped, or other concave or convex geometries, without departing from the spirit and scope of the present invention.

Although the present invention is described herein with respect to conditioning wheels, it should be understood by one skilled in the art that any type of grinding wheel may be provided with a textured grinding face as set forth herein without departing from the spirit and scope of the present invention.

The foregoing description is intended primarily for purposes of illustration. Although the invention has been shown and described with respect to an exemplary embodiment thereof, it should be understood by those skilled in the art that the foregoing and various other changes, omissions, and additions in the form and detail thereof may be made therein without departing from the spirit and scope of the invention.

Having thus described the invention, what is claimed is:

CLAIMS

1. A molded grinding wheel adapted for rough grinding operations comprising:

bonded abrasive particulate;

a substantially curved peripheral surface; and

a plurality of surface irregularities spaced in a predetermined pattern along said substantially curved peripheral surface to define a textured grinding face.

2. The grinding wheel as set forth in claim 1, wherein said plurality of surface irregularities comprise protuberances extending substantially orthogonally from said substantially curved peripheral surface.

3. The grinding wheel as set forth in claim 1, wherein said grinding wheel comprises abrasive particulate dispersed in a phenolic resin bond material.

4. The grinding wheel as set forth in claim 1, wherein said plurality of surface irregularities are formed by selectively placing at least one insert in-situ about said substantially curved peripheral surface, in a grinding wheel mold having a cavity defined by at least one curved surface wherein said at least one insert is disposed within the cavity during molding of said grinding wheel, and removing said at least one insert from said substantially curved peripheral surface following molding.

5. The grinding wheel as set forth in claim 4, wherein said at least one insert comprises an annulus having a plurality of perforations.

6. An insert adapted for use in conjunction with a grinding wheel mold, the grinding wheel mold having a mold cavity defined by at least one curved surface, said insert comprising:

at least one liner sized and shaped for disposition in substantially superimposed and concentric relation with the at

least one curved surface;

said at least one liner having a plurality of discontinuities disposed therein;

said at least one liner adapted for being selectively molded in-situ with a grinding wheel in the grinding wheel mold and removed from the grinding wheel, wherein said plurality of discontinuities define surface irregularities in a peripheral surface of the grinding wheel.

7. The insert as set forth in claim 6, wherein said at least one liner is adapted for being removed from the mold unitarily with the grinding wheel.

8. A method of forming a grinding wheel adapted for rough grinding operations comprising the steps of:

molding abrasive particulate dispersed in a bond material to form a substantially curved peripheral surface; and

disposing a plurality of surface irregularities in a predetermined pattern along the substantially curved peripheral surface to define a textured grinding face.

9. The method as set forth in claim 8, wherein said step of disposing a plurality of surface irregularities further comprises molding the surface irregularities integrally with the grinding wheel.

10. The method as set forth in claim 9, wherein said plurality of surface irregularities comprises a plurality of protuberances.

11. The method as set forth in claim 9, wherein said step of disposing a plurality of surface irregularities further comprises the steps of selectively:

placing at least one insert for molding in-situ about the substantially curved peripheral surface; disposing the at least one insert about an inner curved surface of a grinding wheel mold during molding of the grinding wheel, and

removing the at least one insert from the substantially curved peripheral surface following molding.

12. The method as set forth in claim 11, wherein said at least one insert comprises a perforated annulus.

13. A grinding wheel comprising:

a plurality of regularly spaced surface irregularities disposed on a peripheral surface thereof by providing a at least one liner having a plurality of recesses disposed therein, molding the at least one liner in-situ about the peripheral surface and removing the at least one liner from the peripheral surface after molding.

14. The grinding wheel of claim 13, wherein said at least one liner is removed from the mold unitarily with the grinding wheel.

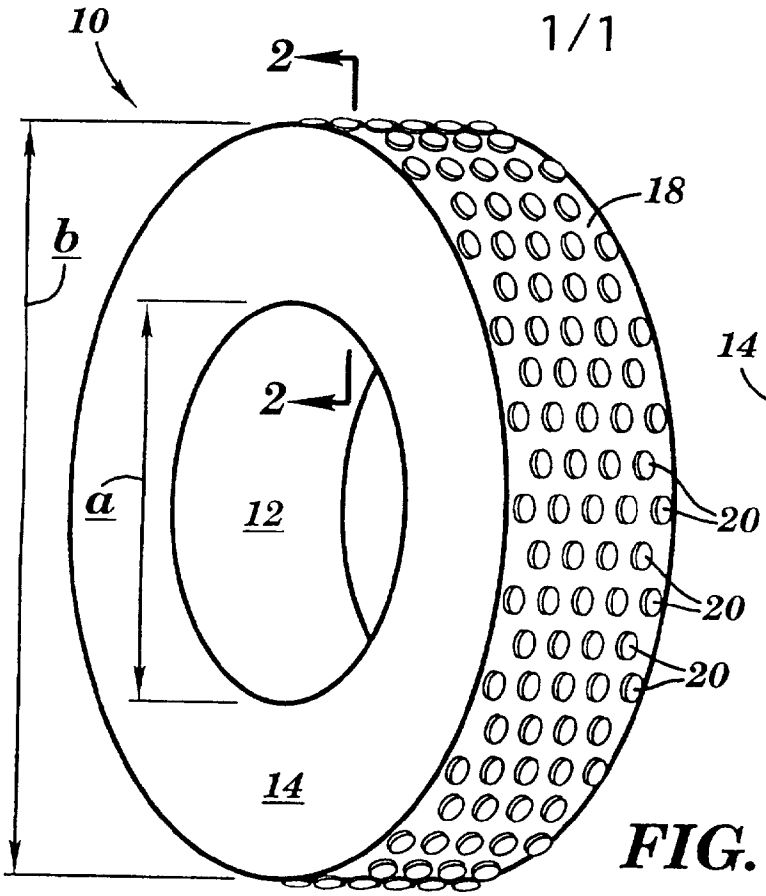


FIG. 1

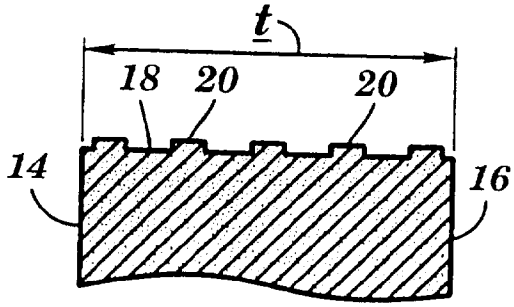


FIG. 2

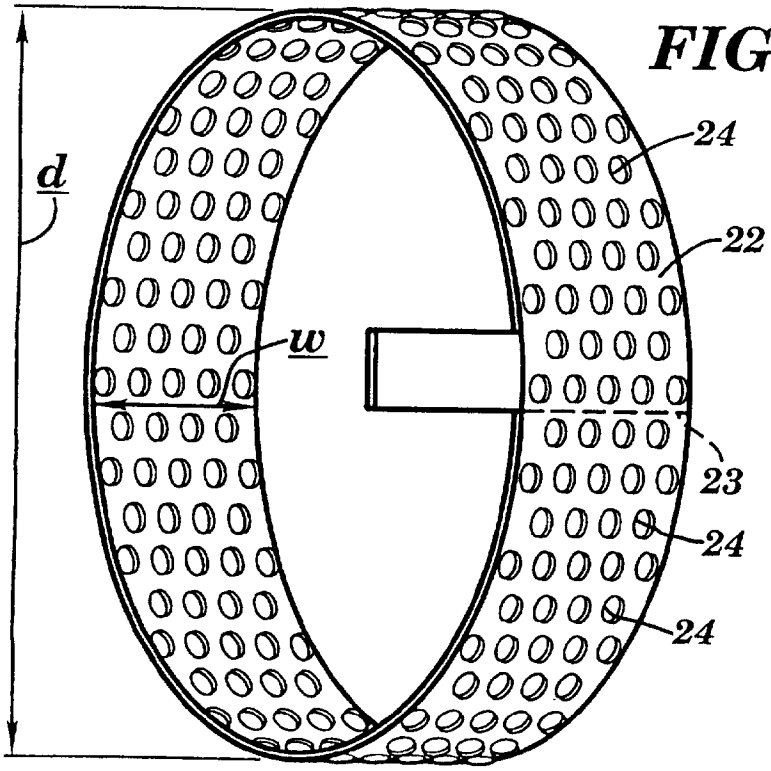


FIG. 3

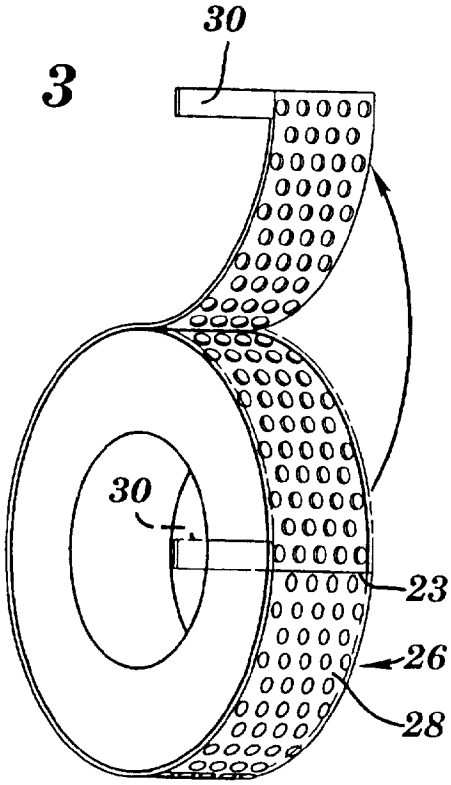


FIG. 4

INTERNATIONAL SEARCH REPORT

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

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24D3/28 B24D18/00 B24D5/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24D B24B C09K

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

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

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

[X] Patent family members are listed in annex.

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21 November 1997	28/11/1997

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

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C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B24D | A2

(11) International Publication Number: **WO 98/45091**

(43) International Publication Date: 15 October 1998 (15.10.98)

(21) International Application Number: PCT/US98/05988

(22) International Filing Date: 26 March 1998 (26.03.98)

(30) Priority Data:
08/835,117 4 April 1997 (04.04.97) US

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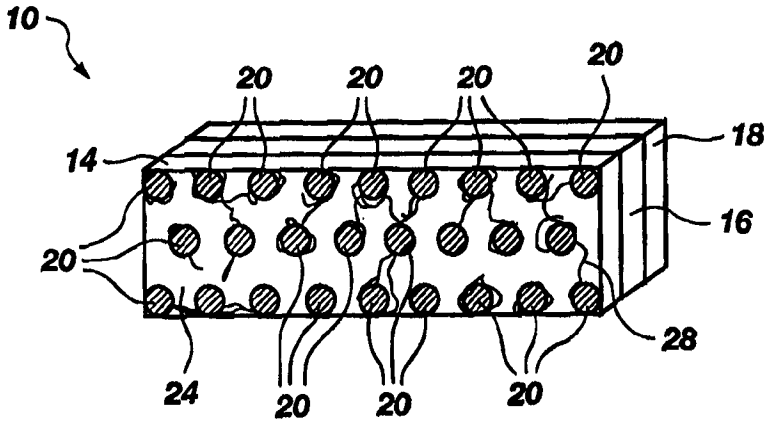
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: BRAZED DIAMOND TOOLS BY INFILTRATION

(57) Abstract

The present invention describes a diamond tool with diamond bonded chemically by a braze that contains either Cr, Mn, SI, or Al or mixtures or alloys thereof. The diamond tool is made by infiltrating the braze into a matrix metal that contains diamond in either form of grits or polycrystalline bodies.



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BRAZED DIAMOND TOOLS BY INFILTRATION

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to tools having diamond particles formed thereon/therein, wherein the diamond particles are chemically bonded to matrix support material used to hold the diamond in place. More specifically, the diamond grit is bonded chemically in a matrix powder by a braze that can wet diamond. These tools are manufactured by the infiltration of the molten braze into a preform of matrix that contains diamond particles, thereby securing the diamond in place by a chemical bond.

2. State of the Art

Abrasive tools have long been used in numerous applications, including cutting, drilling, sawing, grinding, lapping and polishing materials. Because diamond is the hardest abrasive material, it is widely used as a superabrasive on saws, drills, and other devices which utilize the abrasive to cut, form or polish other hard materials. The total value of such tools consumed is believed to be over 5 billion U.S. dollars per year. More than half of the value of these tools is consumed in sawing applications such as cutting stones, concretes, asphalts, etc.

Diamond coated tools are particularly indispensable for applications where other tools lack the hardness and durability to be practical substitutes. For example, in the stone industry,

where rocks are cut, drilled, and sawed, diamond tools are about the only type which are sufficiently hard and durable to make the cutting, etc., economical. If diamond tools were not used, many such industries would be economically infeasible. Likewise, in the precision grinding industry, diamond tools, due to their superior wear resistance, are uniquely capable of developing the tight tolerances required, while simultaneously withstanding wear sufficiently to be practical.

Despite the prevailing use of diamond tools, these tools have suffered from several significant limitations which have placed unnecessary limits on the useful life of the tools. One such drawback is that the diamond grit is not attached to the matrix support material in a sufficiently strong attachment to maximize useful life of the cutting, drilling, polishing, etc., body. In fact, in most cases diamond grit is merely mechanically embedded in the matrix support material. As a result, diamond grit is often knocked out or pulled out prematurely during use. Moreover, the grit may receive inadequate mechanical support from the loosely bonded matrix under work conditions. Hence, the diamond particles could be shattered by the impact of the tool against the work piece to which the abrasive, etc., is applied.

It has been estimated that in a typical diamond tool, less than about one tenth of the grit is actually consumed in the intended application - i.e. during actual cutting, drilling, polishing, etc. The remainder of the diamond grit is either wasted by being leftover when the tool's useful life has expired, or is wasted by being pulled-out or broken during use due to poor attachment and inadequate support. Most of these diamond losses could be avoided if the diamond particles can be properly

positioned in and firmly attached to the surrounding matrix.

Furthermore, to ensure that the diamond grit is mechanically held sufficiently to remain in place, it must be buried deep in the matrix to prevent it falling out or being knocked free of the tool body during use. As a result, the protrusion of the diamond particle above the tool surface is insufficient. The low grit protrusion limits the cutting height for breaking the material to be cut. These limitations, in turn, limit the cutting speed of the cutting tool. If the diamond grit could be held more securely in the matrix, it could protrude higher from the matrix. The greater cutting depth would allow increased cutting speed and a greater useful life for the product. Moreover, due to the lower friction of the workpiece and tool matrix, the power required for cutting, drilling, etc., may also be reduced.

In order to anchor diamond grit firmly in the matrix, it is highly desirable for the matrix to form a carbide around the surface of the diamond. The chemical bond so formed is much stronger than the traditional mechanical attachment. The carbide may be formed by reacting diamond with a suitable carbide former such as a transition metal. Some examples of carbide forming transition metals are: titanium (Ti), vanadium (V), chromium (Cr), zirconium (Zr), molybdenum (Mo), and tungsten (W).

The formation of a carbide requires that the carbide former be deposited around the diamond and that the two subsequently be caused to react to form a carbide. Moreover, the non-reacted carbide former must also be consolidated by sintering or other means. All these steps require treatment at high temperatures. However, diamond may be degraded when exposed to a temperature above 1,000° C. The

degradation is due to either the reaction with the matrix material or the development of microcracks around metal inclusions inside the crystal. These inclusions are trapped catalysts used to synthesize the diamond.

Most carbide formers are refractory metals so they may not be consolidated below a temperature of about 1,200° C. Hence, refractory carbide formers are not suitable as the main constituent of the matrix support material.

There are, however, some carbide formers that may have a lower sintering temperature, such as manganese (Mn), iron (Fe), silicon (Si), and aluminum (Al). However, these carbide formers may have other undesirable properties that prohibit them from being used as the primary constituent of the matrix support material. For example, both manganese and iron are used as catalysts for synthesizing diamond at high pressure (above 50 Kb). Hence, they can catalyze diamond back to graphite during the sintering of the matrix powder at a lower pressure. The back conversion is the main cause of diamond degradation at high temperature.

Aluminum, on the other hand, has a low melting point (660° C), thus, making it easy to work with for securing the diamond particles. However, the melting point of aluminum can be approached when a diamond grit is cutting aggressively. Hence, aluminum may become too soft to support the diamond grit during the cutting operation. Moreover, aluminum tends to form the carbide Al_4C_3 at the interface with diamond. This carbide is easily hydrolyzed so it may be disintegrated when exposed to coolant. Hence, aluminum typically is not a suitable carbide former to bond diamond in a matrix.

To avoid the high temperature of sintering, carbide formers, such as tungsten, are often diluted

as minor constituents in the matrix that is made primarily, for example, of either cobalt or bronze. During the sintering process, there is a minimal amount, if any, of liquid phase formed. The diffusion of carbide former through a solid medium toward diamond is very slow. As a result, the formation of carbide on the surface of diamond is negligible. Therefore, by adding a carbide former as a minor matrix constituent, the improvement of diamond attachment is marginal at the best.

In order to ensure the formation of a carbide on the surface of diamond, the carbide former may be coated onto the diamond before mixing with the matrix powder. In this way, the carbide former, although it may be a minor ingredient in the matrix, can be concentrated around diamond to form the desired bonding.

The coating of diamond may be applied chemically or physically. In the former case, the coated metal is formed by a chemical reaction, generally at a relatively high temperature. For example, by mixing diamond with a carbide former such as titanium or chromium, and heated the mixture under a vacuum or in a protective atmosphere, a thin layer of the carbide former may be deposited onto the diamond. The thickness of the coating may be increased by increasing temperature. The deposition rate may also be accelerated by adding a suitable gas (e.g., HCl vapor) that assists the transport of the metal. For example, Chen and Sung (U.S. Patent No. 5,024,680) describes such a coating process.

Alternatively, the coating may be performed in a molten salt. For example, U.S. Patent No. 2,746,888 describes a method of coating a thin layer of titanium over diamond in a molten salt of chlorides.

A commonly used chemical method for coating diamond is chemical vapor deposition (CVD). In this

case, the deposited metal is produced by the reaction of gases at a high temperature. Thus, U.S. Patent No. 3,520,667 describes a technique to deposit a thin layer of silicon (Si) onto the surface of diamond. The temperature of this deposition is high enough so silicon carbide is formed instantaneously at the interface.

In order to prevent diamond from possible degradation by exposure to high temperatures, coating is produced at the lowest temperature possible. However, coating often becomes too thin when deposited at a low temperature. For example, the coating produced by a typical chemical method is about one micrometer thick. There are some commercial diamond grits that contain such thin coatings. For example, General Electric Company offers a saw grit that may be coated with a thin coating of either titanium or chromium.

However, when the thin coating is exposed to a high temperature, such as that which may be encountered during the sintering process, it can be easily oxidized in the atmosphere, or dissolved into the matrix metal. Thus, although a significant benefit is claimed for such commercially coated products, e.g., a one-third improvement in tool life, the ability for the thin coating to survive the manufacturing process is debatable.

In order to protect the thin metal coating, multiple layers of coating may be applied. Thus, U.S. Patent Nos. 5,232,469 and 5,250,086 described a second layer made of nickel, or another non-carbide former. The second layer may be deposited by an electroless process that is performed at a lower temperature. For more layers, Chen and Sung (U.S. Patent Nos. 5,024,680 or 5,062,865) describe a diamond grit with three layers of coating. In this case, the inner most layer is made of chromium, and it is overlaid by a secondary

metal layer such as titanium. The double layers are further wrapped in a third overcoat of a material such as tungsten. However, such a complicated coating system may be too costly to be economically feasible in the production of many cutting, drilling or polishing tools.

Alternatively, a chemical coating may be deposited relatively thick by a CVD method. For example, Sung, et al. (U.S. Patent Nos. 4,943,488 or 5,116,568) describes a fluidized bed system that can coat diamond with tungsten of a few tens of micrometers. But again, such a coating is expensive, and its application has not been widely used.

In contrast to chemical methods, a physical method may be inexpensive. Moreover, it may deposit a thick metal coating onto diamond at a very low temperature. For example, the author evaluated "Metal Coating of Saw Diamond Grit by Fluidized Bed" (see p267-273 of Fabrication and Characterization of Advanced Materials, edited by S. W. Kim and S. J. Park of The Materials Research Society of Korea 1995). The coating system is based on the method as described in U.S. Patent No. 4,770,907 (a similar concept is disclosed in U.S. Patent 5,143,523 or European Patent No. 0 533 443 A1). However, such a method, like many other similar processes, often produces coatings with different thickness. Moreover, only very fine (<5 micrometers) metal powders can be coated effectively onto the surface of diamond. Hence, although physical methods may be used to coat a diamond grit with an alloy that contains a carbide former, their benefits are limited.

When diamond is coated mechanically by a metal powder, as described in the above example, the powder is held loosely by an organic binder (e.g., PVA, or PEG). Such a coating may be easily rubbed off during the subsequent treatments, e.g., mixing or pressing.

Although heat treatment may increase the mechanical strength of the coating, it may not consolidate the coating to the full density. A porous coating lacks the mechanical strength necessary to support a diamond grit that is impacted repeatedly during the cutting operation.

Carbide formers may also be diluted in an alloy. If the alloy can melt below 1100° C, it may be used to braze the diamond without causing much degradation of the latter. Many diamond brazes are known in the art. Most are based on Group Ib solvents (copper, silver and gold) that contain one or more carbide formers, e.g., gold-tantalum (Au-Ta), or silver-copper-titanium (Ag-Cu-Ti). These brazes, however, are typically too expensive for commercial use. Moreover, they are soft and unsuitable as ingredients for the matrix support material of diamond tools.

There are some high temperature filler metals that may be used to braze diamond. Such brazes may be hard enough to hold a diamond grit in place during cutting. For example, U.S. Patent Nos. 3,894,673 and 4,018,576 describe diamond tools made by brazing a hard facing alloy that contains nickel-chromium (Ni-Cr) as the major constituent. However, these brazed diamond tools, although useful, are generally limited as surface set tools that contains only one layer of diamond. Such tools may not last when they are used to cut highly abrasive materials, e.g., granite. Moreover, the braze in these tools, in addition to holding the diamond, must also serve as the hard facing. The compromise of these dual-functions may not always be possible as the optimal wear resistance of the tool surface may need to be adjusted for specific applications.

Alternatively, a diamond bonding alloy may be used to infiltrate a high concentration (i.e greater than 40 % by volume) of diamond particles. Thus, Chen

and Sung (U.S. Patent Nos. 5,030,276 or 5,096,465) describe such a product and the process of making the same. However, the infiltration is very difficult due to the high concentration of diamond. Moreover, such products have limited applications, such as a drill bit. They are not applicable for most applications that require a lower concentration (i.e., less than 40 % by volume) of diamond, such as saw blades and grinding wheels.

The hard facing alloys may also be used as the matrix support material. For example, U.S. patent 4,378,975 describes a method to coat diamond with a very thin layer of chromium, and subsequently palletizing the coated grit with a nickel-chromium alloy. The palletized particles are then consolidated by sintering the alloy. However, as the consolidation process is taking place primarily in a solid phase, the bonding of matrix and diamond may not be sufficient.

In addition to sintering, infiltration is also a common technique for making diamond tools, in particular for drill bits and other specialty diamond tools that contain a large (i.e. greater than U.S. mesh 30/40) diamond grit. For example, U.S. Patent No. 4,668,522 describes a process to infiltrate a rotary drill bit with a copper alloy at a temperature lower than 850° C (preferably 750° C). Most commonly used infiltrants for these tools are copper based alloys. These infiltrants must flow and penetrate the small pores in the matrix powder. In order to avoid the diamond degradation at high temperature, the melting point of the infiltrant must be low. Hence, the infiltrant often contains a low melting point constituent, such as zinc (Zn). In addition to lowering the melting point of the infiltrant, the low melting point constituent also reduces the viscosity so the infiltrant can flow with ease. However, as

most carbide formers tend to increase the melting point of the infiltrant, they are excluded from most infiltrants. As a result, these infiltrants cannot improve the bonding of diamond.

Some infiltrants do contain a carbide former that may facilitate the bonding of diamond. U.S. Patent No. 5,000,273 describes an abrasive tool that is produced by infiltrating a matrix powder with an alloy that contains the major constituents of copper, manganese and zinc. However, as discussed above, zinc is added to increase the fluidity of the infiltrant, and it may not be suitable for making certain products that is produced under different environments. For example, if infiltration is performed under a vacuum, zinc may be vaporized. As a result the remaining alloy may become too viscous to infiltrate completely the matrix powder.

Thus, there is a need for an improved method of infiltrating the matrix powder to bond the diamond thereto. Such a method should be able to be accomplished at a sufficiently low temperature to avoid potential damage to the diamond. Additionally, such a method should be designed to improve the bonding of the diamond to the matrix support material.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an improved method for forming tools having diamond particles disposed therein/thereon.

It is another object of the present invention to provide such a method wherein the diamond particles are disposed in a matrix support material, and then the matrix support material infiltrated with a braze to bond the diamond particles to the matrix support materials.

It is yet another object of the present invention to provide such a method wherein the brazing occurs at

sufficiently low temperatures to prevent thermal damage to the diamond particles.

It is still another object of the present invention to provide such a method wherein the matrix support material is specifically selected to provide numerous pores through which the brazing material may flow and thereby facilitate chemical bonding of the diamond and matrix support material.

It is still yet another object of the present invention to provide such a method wherein the diamond particles are disposed in the matrix support material in some predetermined pattern, to thereby lengthen the useful life of the tool to which the diamond and matrix support material are attached.

The above and other objects of the invention are realized in specific illustrated embodiments of a novel method for forming brazed diamond tools, and for tools made by the novel method. The method includes forming a sheet of matrix support material, and then disposing a plurality of diamond particles in the matrix support material. Preferably, the amount of diamond particles to matrix support material is preferably less than 50 percent by volume, and most preferably less than 40 percent by volume. The diamond impregnated sheet is then infiltrated by a braze which is capable of wetting the diamond, so as to form a chemical bond with the diamond. The braze also bonds to the matrix support material, thereby creating a chemical bond connecting the diamond to the matrix support material, rather than relying on a simple mechanical attachment in accordance with the prior art. Although the technique is most suitable for making saw blades, its applications can extend to all diamond tools.

In accordance with one aspect of the present invention, the matrix support material may be made of common metal powder. Examples of such metal powder

are cobalt, nickel, iron, bronze or their alloys or mixtures (e.g., tungsten or its carbide). After formation of the matrix support material is then infiltrated by a diamond braze, such as Nicrobraz L. M. (made by Wall Colmonoy Company), either under a vacuum, typically about 10^{-5} torr, or in an inert atmosphere (e.g., argon (Ar) or nitrogen (N_2)) or a reducing atmosphere (e.g., hydrogen (H_2)). The braze, thus, facilitates bonding between the diamond particles and the matrix support material.

In accordance with another aspect of the present invention, the matrix support material is formed by coarse metal powder (i.e. greater 400 mesh U.S. or 34 microns). While conventional methods require the density of the green body be as high as possible so subsequent sintering can proceed rapidly, it has been found in accordance with the present invention, that it is preferable to use a precursor with a lower packing density to allow the easy flow of the diamond braze. In some situations, the porosity of the precursor body may be intentionally increased by using irregularly shaped matrix particles. This preference is again contrary to the conventional wisdom that requires the particles be as spherical as possible so the packing density can be increased.

In accordance with yet another aspect of the present invention, the diamond particles are placed in a predetermined pattern within the matrix support material, and the diamond impregnated matrix support material is then impregnated with the diamond braze to promote chemical bonding of the diamond material. The predetermined pattern may be substantially planar, i.e. the diamond placement may be controlled by the use of a template, or may be substantially vertical, with channels being formed in the matrix support material to receive diamond particles, which are then infiltrated with the diamond braze.

In accordance with still yet another aspect of the present invention, the matrix support material may contain minor ingredients to enhance certain properties. For example, hard materials such as tungsten, tungsten carbide and silicon carbine may be added to increase wear resistance. Soft materials, such as molybdenum sulfide, copper, and silver, may also be added as solid lubricants.

The supportive material may be prepared by a conventional method. For example, the powder may be mixed with diamond grit thoroughly. An organic binder (e.g., PVA or PVB) may be added to hold the mixture. The mixture is then cold pressed to form the desirable shape (e.g., a saw blade). The precursor is then ready to be infiltrated by a suitable diamond braze.

As discussed, a fine matrix powder used for conventional tools may hinder the infiltration of the diamond braze. Moreover, it would react excessively with the braze so the melting temperature of the braze is raised. As a result, the infiltration may not be complete.

Alternatively, the mixture may be processed following the teaching of applicant's other, copending patent application (U.S. Patent Application, Serial No. 08/832,852 (identified as attorney docket no. T5100), filed April 4, 1997). For example, the powder blend of the supportive material may be cold rolled to form a sheet. The sheet can then be punched out with a desirable shape (e.g., a saw segment) (See Fig. 1). Several such punched segments may be assembled to form the precursor (see Fig. 2,3,4) for infiltration. As described in the pending patent application, by assembling substantially two-dimensional segments to form a three-dimensional body, the distribution of diamond grit in a tool can be positively controlled. Thus, diamond concentration in different parts of the same tool may be adjusted (see FIGS. 1A through 4).

Such a control of diamond distribution is highly desirable to improve the wear characteristics of the tool. For example, the sides of a diamond saw blade are often worn faster then the center, so it is advantageous to add more diamond grit on to the sides (see FIG. 1B).

Current applications require the matrix support material to serve dual functions: to provide the mechanical support of the tool, and to hold the diamond grit in the matrix. These two functions often demand contradictory properties. For example, as the mechanical support, the matrix support material must be strong and wear resistant (e.g., cobalt, or bronze mixed with tungsten carbide). However, the material with good mechanical support is often ineffective to adhere the inert diamond. On the other hand, a braze alloy (e.g., silver-copper-titanum alloys) may hold diamond firm, but are too soft to provide the mechanical support for the tool body. Thus it is desirable to separate these two functions of the matrix support material by using a composite material. In this case, the framework of the composite material is optimized for mechanical support, yet the filler material is designed to hold the diamond.

The composite material may be made by using coated diamond as discussed above. In this case, a diamond braze may be used to coat the diamond grit first and the coated grit is subsequently mixed in the matrix powder. However, the coating incurs an additional cost. Moreover, most diamond brazes are not in a powder form. Even if they were, it is very difficult to coat these brazes uniformly onto the diamond grit. As a result, coated diamond grit is seldom used today in making diamond tools.

The present invention makes the composite matrix support material by infiltrating a diamond braze into a supporting material that contains diamond grit. The

braze includes carbide formers such as chromium, manganese, silicon and aluminum, while avoiding volatile metals such as zinc, lead and tin.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings in which:

FIG. 1A shows a segment from a superabrasive tool formed by a plurality of linear, longitudinal layers disposed adjacent one another to form a three-dimensional superabrasive member;

FIG. 1B shows a cross-sectional view of one typical configuration of the tool segment shown in FIG. 1A, wherein a layer formed by a matrix support material and a relatively large superabrasive is sandwiched between two layers of matrix support materials which have smaller grit and higher concentration of the abrasive;

FIG. 2A shows a segment from a superabrasive tool formed by a plurality of arcuate, longitudinal layers which are attached to one another to form a three-dimensional superabrasive member;

FIG. 2B shows a cross-sectional view of a plurality of layers matrix support material as may be used with the segment shown in FIG. 2A;

FIG. 3 shows another possible layout of a segment of a cutting tool with transverse layers configured with a denser concentration of abrasive material disposed at a forward, cutting end of the three-dimensional superabrasive member;

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution

toward the upper surface of a tool with horizontal layers;

FIGs. 5A through 5D show one possible method for forming layers with controlled superabrasive distribution within the layer;

FIGs. 6A through 6C show an alternate method for forming one or more layers with controlled superabrasive distribution;

FIG. 7A shows a side view of a matrix support material formed in accordance with one aspect of the present invention, wherein a plurality of slots are formed in the matrix support material;

FIG. 7B shows a side view of the matrix support material of FIG. 7A, wherein a plurality of diamond particles are disposed in the slots and brazed to bond with the matrix support material and thereby form a plurality of abrasive fins in the matrix support material; and

FIG. 8 shows a perspective view of the matrix support material similar to that shown in FIGs. 7A and 7b, but with a plurality of abrasive needle structures.

DETAILED DESCRIPTION

Reference will now be made to the drawings in which the various elements of the present invention will be given numeral designations and in which the invention will be discussed so as to enable one skilled in the art to make and use the invention. It is to be understood that the following description is only exemplary of the principles of the present invention, and should not be viewed as narrowing the pending claims.

Referring to FIG. 1A, there is shown a perspective view of a segment, generally indicated at 10, formed by a plurality of layers, 14, 16 and 18. Each of the layers 14, 16 and 18 is formed by matrix

support material 24 impregnated with diamond particles, indicated by the circles 20, and has been infiltrated with a braze 28 selected to bond to the diamond particles and the matrix support material. Preferably, the diamond particles 20 constitute less than 50 percent by volume of the matrix support material - diamond mixture, and more preferably less than 40 percent by volume. Keeping the amount of diamond particles to the minimum helps to minimize cost while optimizing the useful life of the product.

Preferably, the diamond braze contains at least 3% by weight of a member selected from the group consisting of chromium, manganese, silicon and aluminum, and alloys and mixtures thereof. Additionally, the diamond braze should have a liquidus temperature of less than 1,100° C to avoid damage to the diamond during the brazing process.

As discussed in U.S. Patent No. _____ (U.S. Patent Application, Serial No. 08/832,852 (Attorney Docket No. T5100)), which is expressly incorporated herein, forming the segment 10 in a plurality of thin layers provides remarkably improved control over the distribution of the diamond particles 20. By controlling the distribution of the diamond particles 20 within each layer and then combining layers, a three-dimensional segment can be formed in which distribution of the diamond particles is controlled in each dimension. This, in turn, enables the formation of segments which are particularly adapted to the likely use of the segment, be it for polishing, cutting, grinding, etc. By tailoring the distribution and concentration of the superabrasive particles within the segment 10, more precise control is given over performance of the tool under actual working conditions.

The present invention further improves the above technique by infiltrating the matrix support material

24 with a braze 28 which is selected to chemically bond to the diamond particles and to the matrix support material. Thus, while the placement of the diamond particles shown in FIG. 1A is a marked improvement over the prior art, an additional increase in the segment's 10 useful life is obtained by utilizing a braze to form a chemical bond, rather than merely relying on mechanical retention of the diamond particles.

Likewise, the selective placement of differing sizes of diamond particles can used to form a cutting segment formed to resist premature wear to the sides of the segment, thereby extending the cutting segment's useful life. Referring specifically to FIG. 1B, there is shown a cross-sectional view of the cutting segment 10 of FIG. 1A. Unlike the cutting segments of the prior art, the cutting segment 10 is formed of three layers, 14, 16 and 18 respectively. The middle layer 16 has a plurality of superabrasive particles 20a which are of a first size (e.g. 40/50 mesh) and a first concentration. The outer layers 14 and 18, in contrast, have a plurality of superabrasive particles 20b, which are of a second size (e.g. 50/60 mesh) smaller than the first size, and in a second concentration greater than that present in the middle layer 16. The smaller, more densely distributed superabrasive particles 20b provide the outer layers 14 and 18 with a greater resistance to wear as they cut through concrete, rock, asphalt, etc. Because the outer layers 14 and 18 are more resistant to wear, the cutting segment 10 resists formation of a convex outer surface, as has traditionally occurred with cutting elements. By maintaining a more planar cutting surface, the cutting segment is able to maintain a straight cutting path so it can cut more efficiently with a longer useful life.

Furthermore, an additional increase in useful life is obtained by infiltrating the matrix support material 24 with a braze 28 formed from chromium, manganese, silicon, and/or aluminum, or an alloy or mixture thereof. While a wide variety of quantities of these materials may be used, it has been found that it is preferable if the chromium, manganese, silicon or aluminum or alloy or mixture in the diamond braze constitutes at least 3 percent of the braze by weight (and more preferably 5 percent). The braze 28 fills the pores in the matrix support material 24, which is typically powder selected from the group including iron, cobalt, nickel or alloys or mixtures thereof.

Another advantage to the use of multiple layers of matrix with diamond or some other superabrasive particle disposed therein is that the layers are easily formed into other desirable shapes for the cutting, drilling, grinding, etc., segment. For example, FIG. 2A shows a perspective view of a segment, generally indicate at 30, of a superabrasive tool formed by a plurality of arcuate, longitudinal layers which are attached to one another to form a three-dimensional superabrasive member which has been infiltrated with the braze 28 to thereby hold the diamond within the member. The segment 30 is formed from first, second and third layers, 34, 36 and 38, which are each arcuate. When the three are joined together, an arcuate segment 30 is created. Such a segment, of course, may be used on cutting tools which are non linear, e.g. a circular saw blade, and on other types of tools for which a nonlinear superabrasive segment is desired. Because the layers 34, 36 and 38 are initially formed independent of one another, they are much easier to conform to a desired shape, and are able to do so while the brazed diamond particles 20 disposed therein are held in their predetermined positions.

Referring now to FIG. 2B, there is shown a cross-sectional view of a plurality of the layers 34, 36 and 38 of the segment 30. Of course, the configuration of the diamond particles may be used with the segment shown in FIG. 1A or that shown in FIG. 2A. Unlike the embodiment of FIG. 1B, the layers are each provided with the same size and concentration of the diamond particles 20. However, because the spacing is substantially uniform, there is no underspacing or overspacing between the superabrasive particles, and the segment 30 wears more evenly than the segments of the prior art with randomly spaced particles. The more even wear prevents premature failure of the segment 30, and thus extends the life of the tool while keeping the amount of superabrasive used to a minimum. Furthermore, the braze 28 which bonds to the diamond particles and the matrix 24 further strengthens each layer and prevents loss of the diamond particles 20.

FIG. 3 shows another possible embodiment of a segment 50 made in accordance with the teachings of the present invention. The layered structure in a diamond segment may also be assembled transversely or horizontally, and the braze 28 may be applied to every layer, or to select layers as shown in FIG. 3. Thus, the segment 50 in FIG. 3 is formed from a plurality of transverse layers. A first plurality of the layers (i.e. the first four layers), indicated at 56, are provided with a first concentration of diamond particles 20 which are brazed to bond to the matrix support material 24. A second plurality of layers (i.e. the remaining 9 layers), indicated at 58, are provided with a second concentration, less than the first concentration and are also brazed to bond to the matrix support material 24.

Many cutting tools are configured such that the cutting segment 50 is provided with a lead edge which

performs a majority of the cutting and which receives most of the impact force when contacting the surface to be cut. For example, a circular saw blade will usually have a plurality of teeth or segments, each tooth having a leading edge which takes the force of the cutting. Because the leading edge preforms a significant portion of the cutting, it is much more susceptible to wear than are rearward portions of the tooth. When formed in accordance with the prior art, the teeth, however, often had relatively consistent concentrations of abrasive disposed thereon. Over time the leading edge wears significantly, but the other portions coated with diamond particles are subjected to minimal wear. Eventually, the abrasive is worn off the leading edge, while significant amounts remain on the other portions of each tooth. Thus, a considerable amount of superabrasive is wasted when the blade is discarded. The embodiment of FIG. 3 is specifically configured to overcome such concerns. The layers 56 and 58 are configured to provide substantially even wear across the cutting segment 50 by placing a larger percentage of the diamond particles 20 near the leading edge, than on the rear portions. Additionally, brazing the diamond particles 20 in layers 56 and 58 further extends tool life.

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution toward the upper surface of a tool with horizontal layers. As with the embodiment of FIG. 3, the controlled distribution of the diamond particles 20 forms an improved abrasive segment 70, while at the same time decreasing the cost of abrasive tools by decreasing the unnecessary consumption of diamond particles. Additionally, brazing may be used on some of the layers, while being omitted from other layers, to thereby customize the abrasive segment 70.

With routine experimentation and the teachings of the method of the present invention, those skilled in the art will be able to customize cutting, drilling, grinding, polishing and other types of abrasive segments which are specifically formed to maximize their abrasive ability (i.e. cutting, drilling, grinding, etc.) over an extended useful life, while simultaneously decreasing the amount of superabrasive which is used to form the tool.

Referring now to FIGs. 5A through 5D, there is shown one method for forming layers in accordance with the principles of the present invention. The first step of the method is to form a sheet 100 of matrix support material 104 which will be bonded to the superabrasive particles 20. The sheet 100 of matrix support material 104 can be formed from conventional powders such as cobalt, nickel, iron, copper or bronze. Additionally, for reasons which are discussed in detail below, it is highly advantageous to use coarse powders, such as those above 34 microns in diameter. While the use of course powders is inconsistent with the prior art teachings that it is desirable to use the finest powder available, considerable benefits may be achieved by combining course powder and braze to secure diamond particles in place.

There are many ways that a matrix powder can be made into the sheets 100. For example, the powder can first be mixed with a suitable binder (typically organic) and a solvent that can dissolve the binder. This mixture is then blended to form a slurry with a proper viscosity. In order to prevent the powder from agglomeration during the processing, a suitable wetting agent (e.g., menhaden oil, phosphate ester) may also be added. The slurry can then be poured onto a plastic tape and pulled underneath a blade or leveling device. By adjusting the gap between the

blade and the tape, the slurry can be cast into a plate with the right thickness. The tape casting method is a well known method for making thin sheets out of powdered materials and it works well with the method of the present invention.

Alternatively, the powder can be mixed with a suitable binder and its solvent to form a deformable cake. The cake can then be extruded through a die with a slit opening. The gap in the opening determines the thickness of the extruded plate. Alternatively, the material can also be drawn between two rollers with adjustable gap to form sheets with the right thickness.

It is desirable to make the sheets pliable for subsequent treatments (e.g., bending over the tool substrate). Therefore, a suitable organic plasticizer can also be added to provide the desired characteristics.

The use of organic agents for powder (metal, plastics, or ceramics) processing is documented in many text books and it is well known by those skilled in the art. Typical binders include polyvinyl alcohol (PVA), polyvinyl butyral (PVB), polyethylene glycol (PEG), pariffin, phenolic resin, wax emulsions, and acrylic resins. Typical binder solvents include methanol, ethanol, acetone, trichlorethylene, toluene, etc. Typical plasticizers are polyethylene glycol, diethyl oxalate, triethylene glycol dihydroabietate, glycerin, octyl phthalate. The organic agents so introduced are to facilitate the fabrication of metal layers. They must be removed before the consolidation of metal powders. The binder removal process (e.g., by heating in a furnace with atmospheric control) is also well known to those skilled in the art.

Once the sheet 100 of matrix support material 104 is formed, a template 110 is laid on the top of the sheet. The template 110 contains apertures 114 that

are larger than one abrasive particle 20, but smaller than two abrasive particles, thereby allowing a single particle of the abrasive to be disposed at each specific location.

The thickness of the template is preferably between 1/3 to 2/3 of the height of the average abrasive particle 20. However, other thicknesses may be used if appropriate accommodations are made for seating the abrasive particles in the desired locations.

After the template 110 is properly positioned, a layer of abrasive particles 20 is then spread over the template so that each aperture 114 receives an abrasive particle. Those particles not falling into the apertures 114 in the template 110 are removed by tilting the substrate, sweeping the template with a broom, or some other methods.

As shown in FIG. 5B, a generally flat surface 120, such as a steel plate, is then laid over the particles 20 which rest in the apertures 114 in the template 110. The flat surface 120 presses the abrasive particles 20 at least partially into the pliable sheet 100 of matrix support material 104 to seat the particles.

After removing the template 110, the flat surface 120 is used again to press the abrasive particles 120 firmly into the sheet 100 of matrix support material 104 as shown in FIG. 5C. While the flat surface 120 is preferable, those skilled in the art will appreciate that there may be occasions when it is desirable to have some of the abrasive particles 20 extend outwardly from the sheet 100 of matrix support material more that other abrasive particles. In such situations, a contoured or otherwise shaped surface could be used to seat some of the abrasive particles 20 deeper into the sheet 100 of matrix support material 104, than other particles.

If desired, the process shown in FIGs. 5A through 5C can be repeated on the other side of the sheet 100 of matrix support material 104 (as shown in FIG. 5D), to form an impregnated layer having diamond particles 20 distributed throughout the layer in some predetermined, desired pattern. The process is typically repeated several times to obtain multiple thin layers or sheets 100 which are impregnated with the diamond particles 20. Of course, each sheet 100 need not have the same distribution pattern for the diamond particles 20, nor need the concentration of the abrasive particles be the same in each sheet.

The abrasive impregnated sheets 100 are then infiltrated with a braze which is formed with chromium, manganese, silicon, aluminum or alloys or mixtures thereof. While prior art brazes typically includes metals which were designed to facilitate flow of the braze material, such as zinc, lead and tin, it has been found in accordance with the present invention that such materials actually impair the brazing process. The materials are generally more volatile, and have a tendency to contaminate the vacuum or inert atmosphere used in infiltration. While very small amounts of the volatile metals will not significantly interfere with brazing, amounts over about 1 or 2 percent can be undesirable. As used herein, substantially free of volatile metals, or substantially free of zinc, etc. is used to characterize such a situation in which the volatile metal is present in sufficiently small amounts as to not provide any impediment to the process of vacuum infiltration.

It is important that the infiltration temperature be kept lower than the melting point of the matrix powder so the tool body can maintain the shape during the infiltration of the diamond braze. Moreover, the brazing temperature must also be low enough to not

cause diamond to degrade. In addition to control the brazing temperature, the brazing time should also be kept short so the braze will not react excessively with diamond and the matrix powder. In the former case, diamond may also be degraded. In the later case, the alloying with the matrix powder may raise the melting point of the diamond braze. As a result, the diamond braze may solidify gradually and eventually stop to flow.

The environment for infiltration also may be controlled to provide superior performance. For example, if the braze material contains a strong getter of oxygen or nitrogen, such as titanium, a high degree of vacuum (e.g., 10^{-6} torr maximum) must be maintained during the infiltration of the braze. On the other hand, if the braze material contains a less sensitive getter, such as chromium and manganese, a lower degree of vacuum (e.g., 10^{-5} torr minimum) or a hydrogen atmosphere may be adequate for the infiltration.

After the infiltration, the produced part (e.g., a saw segment) may be trimmed (e.g., by grinding) to the finished dimension. It can then be mounted (e.g., by brazing) onto a tool body (e.g., a round steel blade) to make a finished product.

As discussed above, this invention uses a diamond braze as the infiltrant that penetrates the matrix powder of a diamond tool. Most diamond brazes can wet easily common matrix powders with major constituents of cobalt, nickel, iron, copper or bronze, so the infiltration may proceed smoothly.

In contrast to a sintering process that eliminates pores in the matrix powder by consolidation, the infiltration allows the diamond braze to fill up these pores. Sintering is achieved by diffusion of atoms mainly along surfaces. In order to facilitate the sintering process the matrix powder

must have large surface areas. Hence, in sintering, it is preferable to use fine powders. The fine powder can allow the sintering to proceed at a lower temperature.

The most widely used matrix powder for making diamond tools (e.g., saw segments) is cobalt powder. The standard sizes of cobalt powder for making conventional diamond tools are less than 2 micrometers. In the last decade, the diamond tool manufacturers have demanded finer and finer matrix powders. The commercial suppliers (e.g., Eurotungsten Co.) are therefore, moving toward making ultrafine (one micrometer), and even ultra-ultrafine (submicron) powders. With such a trend, the sintering temperature is continuously decreasing. A lower sintering temperature can not only reduce the degradation of diamond, it also reduces the cost of manufacturing. For example, the electrical power consumption for heating is lower. Moreover, the oxidation loss of graphite mold is also minimized.

The present invention, however, uses a diamond braze to fill up the pores of the matrix powder. Hence, contrary to a conventional sintering process, coarse-sized powders, i.e. greater than 400 U.S. mesh or 34 microns, are preferred. Moreover, while conventional methods require the packing density be as high as possible so sintering can proceed rapidly, the present invention prefers to use a precursor with a lower packing density to allow the easy flow of the diamond braze. In fact, sometimes, the porosity of the precursor body may be intentionally increased by using irregularly shaped matrix particles. This preference, again, is contrary to the conventional wisdom that requires the particles be as spherical as possible so the packing density can be increased.

As discussed, a fine matrix powder used for conventional tools may hinder the infiltration of the

diamond braze. Moreover, it would react excessively with the braze so the melting temperature of the braze is raised. As a result, the infiltration may not be complete.

The use of a coarse matrix powder has other benefits. For example, a coarse powder can mix better with different compositions. Hence, the diamond grit may distribute more uniformly in the matrix. Moreover, a coarse powder has a smaller surface area, and hence, a lower frictional force for infiltration. Therefore, it can flow easier in the mold. Of course, a coarse matrix powder is also much less expensive, so the production cost may be reduced.

It is important to note that this invention utilizes the matrix merely as the network for holding the diamond grit in place. Hence, the matrix may not have to be made of powder. For example, the matrix body may be made of a piece of steel with openings that contain diamond grits of PCD bodies, such as that which is discussed below with respect to FIGs. 7A and 7B.

The most critical part of this invention is in the selection of a diamond braze. Although there are numerous kinds of diamond brazes, only those that meet the following requirements are applicable. Firstly, the infiltration temperature of the braze must not be so high as to cause significant diamond degradation. The temperature limit is, in general, about 1100° C. The infiltration temperature can be 50° C above the liquidus of the braze. A course matrix powder and a shorter infiltration path requires a lower excess temperature beyond the melting point of the braze.

The diamond braze must wet the diamond and chemically bond with the diamond. As discussed above, a carbide former dissolved in a suitable solvent alloy can meet this requirement. However, the reactivity of the carbide former must be balanced between diamond

and oxygen or other gases such as nitrogen or hydrogen. It is a dilemma that a strong carbide former, such as titanium or zirconium that bonds diamond well are also gas scavengers. They would react quickly with harmful gases in the ambient atmosphere before forming the carbide with diamond.

Most diamond tools are manufactured in a graphite mold often in air or in an inert gas. The minute amount of oxygen or moisture in the atmosphere may oxidize the carbide former so the latter may not bond to diamond. This is true even if the brazing is performed in a vacuum or in a hydrogen atmosphere, unless the vacuum is kept lower than 10^{-6} torr, or the dew point of the gas is kept below - 60° C. Such a stringent requirement of vacuum or dew point often adds unnecessary cost to manufacturing.

On the other hand, if the reactivity is low, such as that of cobalt or nickel, the metal can be processed in graphite mold without being oxidized. However, it cannot bond to diamond either. Hence, there is a compromise for the carbide former between its ability to bond with diamond and its tendency to be oxidized.

In accordance with the present invention, it has been found that the preferred carbide former for the diamond braze is either chromium, manganese, silicon, aluminum or their alloys. The preferred total content of such carbide former is at least 3 percent, and more preferably at least 5 percent by weight. Examples of these brazes are NICROBRAZ LM (Ni-CR-B-Si-Fe), manufactured by Wall Colmonoy Company (U.S.A.), with a melting range of 970-1000° C, and 21/80 (Cu-Mn-Ni), manufactured by Degussa (Germany), with a melting range of 970-990° C. Other possible brazes include: Cu-Mn alloy near the eutectic composition (about 25 wt% Mn) with a melting point of about 880° C; Ni-Si alloy near the eutectic composition (about 50 wt% Si)

with a melting point of about 970° C; Cu-Si alloy near the eutectic composition (about 30 wt% Si) with a melting point of about 810° C; Al-Si alloy near the eutectic composition (about 15 wt% Si) with a melting point of about 600° C.

The above examples of infiltratable diamond brazes cover a wide range of mechanical properties and infiltration temperatures (e.g. about 50° C above the liquidus). The alloys of them may also be used for further adjustments of infiltration temperature and mechanical properties. The selection of diamond braze depends on the intended application. In general, more severe applications, such as sawing granite, concrete, or asphalt) would require a stronger diamond grit that may tolerate a higher temperature of brazing. Brazes which melt at higher temperatures are, in general, more wear resistant. On the other hand, less demanding applications, such as sawing limestone or marble, require lower strength diamond grit. Such a diamond is degraded easily at high temperature so it must be brazed at a lower temperature. Brazes of this type are typically less wear resistant.

The sheets 100 may be first assembled to form the precursor of the tool segment and then infiltrated with diamond braze, or they can be infiltrated by the braze and later assembled to form the tool segment or the entire tool body where appropriate. While the method described in FIGs. 5A through 5D is preferred for many applications, there are instances where it is desirable to have the abrasive particles 20 extend outwardly from the sheet 100 of matrix support material. For example, some tools may only have one layer of abrasive. This can be accomplished simply by leaving the template 110 in place when performing the steps shown in FIG. 5A and 5B, and not further

pressing the particles 20 into the matrix support material once the template has been removed.

In the alternative, FIGs. 6A through 6C show a side view of an alternate to the method discussed in FIGs. 5A through 5D. The sheet 130 of matrix support material in FIGs. 6A through 6C is formed to be of a lesser thickness than the cross-sectional thickness or diameter or the superabrasive particles 20. When the particles or pressed into the sheet 130, the thickness of the sheet forces the particles 20 to protrude from the matrix support material 134. The sheet 130 is then infiltrated with diamond braze in the manner discussed above.

While the use of the diamond braze 28 has been discussed with respect to the patterned distribution of diamond particles, it is equally applicable to the random distribution of diamond particles in a matrix support material. Once the diamonds have been placed in the matrix support material, a diamond braze comprising chromium, manganese, aluminum or silicon, and being substantially free of volatile metals, is melted and poured onto the matrix support material. The liquidous braze infiltrates the matrix support material and bonds the diamond particles to the matrix support material.

In addition to its use with conventional matrix support materials, such as metal powders, the diamond braze also facilitates the use of novel support materials, such as that shown in FIGs. 7A and 7B. Referring specifically to FIG. 7A, there is shown the matrix support material 200 of a saw segment, generally indicated at 210. The matrix support material 200 includes a plurality of slots 214 which are cut in specific intervals.

To form a finished cutting segment, the matrix support material 200 is placed in a mold (e.g. graphite or metal) made of refractory material (e.g.,

graphite). Diamond particles 20 (FIG. 7B) is poured into the slots 214 to fill the open slots. Diamond braze is added on top of these slots. After infiltration, the braze will fill in these slots and bond with the diamond particles 20, and with the matrix support material 200 to form a completed saw segment 210. In this geometry, the diamond particles form blades in the saw segment (FIG. 7B) instead of distributing throughout the matrix body as in the case of a conventional tool. Those skilled in the art will appreciate that such a configuration would be nearly impossible in accordance with the teachings of the prior art, because the matrix support material 200 was required to hold the diamond particles in place mechanically. In contrast, the use of the diamond braze enables the positioning of columns of diamond particles in a slot, hole, etc., because the braze bonds to the diamond and to the support material, the diamonds are secured in place. While the embodiment shown in FIGs. 7A and 7B forms diamond "fins", needle like columns of diamond also can be formed (FIG. 8). Furthermore, the slots, hole, etc, can be formed to provide such columns which are linear, or which curve in any desired direction. Thus, with routine experimentation, those skilled in the art can customize cutting, drilling, polishing, etc., segments which are customized to particular uses. The diamond particles used may be either diamond grit or thermally stable polycrystalline diamond (PCD). The infiltration will not only consolidate the matrix powder, but also bond the diamond firmly, so an integrated diamond tool is formed.

Example 1

40/50 mesh diamond grit (SDA-85+ made by De Beers Company) was mixed with iron powders coarser than 200 U.S. mesh, and an organic binder to form a mixture with diamond concentration of 20 (5% of total volume).

The mixture was cold pressed in a steel mold to form the shape of a saw segment. The precursor was placed in a graphite mold and overlaid with a powder of Nicrobraz LM. The mold was heated under vacuum to about 1,050° C for 20 minutes. The infiltrated braze had bonded diamond and matrix powder together to form a segment. Twenty-four of such segments were manufactured and they were trimmed to desirable tolerances. These segments were brazed onto a 14 inch round steel circular saw blade. The blade was used to cut granite at a faster cutting rate than was possible with conventional diamond saw blades. Additionally, the brazed saw blades had a longer useful life than a conventional diamond saw blade.

A distinct advantage cutting tools of the present invention have over the prior art cutting tools lies in the manner in which the tool may be used. Diamond saws are typically made in the form of a circular blade that cuts the workpiece by rotation in the same direction with each rotation. This one directional movement causes a "tail" to be formed, wherein the matrix material rotationally forward of the diamond particle is worn away, but the matrix material behind the diamond particle is protected by the diamond particle itself. Thus, the matrix material behind the diamond continues to hold the diamond particle in place. If the saw rotation were to be reversed, the diamond particle could easily be knocked free of the matrix.

Round saws, however, can only cut the work piece to a depth of less than one-half the diameter of the saw. In order to cut thicker work pieces, a frame or gang saw is typically used. Because these saws move reciprocally, the diamond particles must be securely held on each side. As a result, tails of diamond matrix cannot be maintained to hold the diamond particles in place. It is for this reason that

reciprocating diamond saws have not been used to saw hard rock such as granite. Rather, they are used to cut only soft materials such as marble.

This invention allows diamond to be held chemically by a braze. Hence, matrix tails are not needed to support the diamond. As a result, tools made according to the present invention can be used on reciprocating saws to cut hard materials. This breakthrough can expand diamond applications to markets which were previously unavailable due to limitations of the prior art.

Thus, there is disclosed an improved method for making diamond saw blades. The above description and examples are intended only to illustrate certain potential uses of this invention. It will be readily understood by those person skilled in the art that the present invention is susceptible of a broad utility and applications. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements will be apparent from or reasonably suggested by the present invention and the forgoing description thereof without departing from the substance for scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to its preferred embodiment, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for purpose of providing a full and enabling disclosure of the invention. The forgoing disclosure is not intended or to e construed to limit the present invention or otherwise to exclude any such other embodiment, adaptations, variations, modifications and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

CLAIMS

What is claimed is:

1. An abrasive tool comprising:

a matrix support material configured for holding diamond particles to be used as abrasives;

a plurality of diamond particles disposed in the matrix support material; and

an alloy infiltrated through the matrix support material and the diamond particles, the alloy being bonded to the diamond particles and the matrix support materials, the alloy comprising a metal alloy that contains 2 to 50 percent of an element selected from the group consisting of chromium, manganese, silicon and aluminum, and being substantially free of zinc.

2. The abrasive tool according to claim 1, wherein the matrix support material contains more than 50 percent by weight of material selected from the group consisting of cobalt, nickel, iron, copper and bronze and mixtures and alloys thereof.

3. The abrasive tool according to claim 1, wherein the matrix support material occupies more volume than the diamond particles.

4. The abrasive tool according to claim 1, wherein the diamond particles are less than 40 percent of the volume of the matrix support material and diamond particles combined.

5. The abrasive tool according to claim 1, wherein the matrix support material is formed of coarse-sized powders greater than 400 U.S. mesh.

6. The abrasive tool according to claim 1, wherein the diamond particles are disposed in the matrix support material in a predetermined pattern.

7. The abrasive tool according to claim 1, wherein the matrix support material is formed by a plurality of diamond impregnated sheets.

8. The abrasive tool according to claim 7, wherein the diamond impregnated sheets are made by rolling, extruding, or tape casting a mixture of metal powder and diamond grits.

9. The abrasive tool according to claim 7, wherein the diamond impregnated sheets are made by mechanically planing diamond grits into the metal sheet.

10. The abrasive tool according to claim 9, wherein the metal sheet is formed by the group consisting of rolling from an ingot and prepared from a metal powder.

11. The abrasive tool according to claim 7, wherein at least one of the diamond impregnated sheets has been infiltrated with the alloy.

12. The abrasive tool according to claim 1, wherein the alloy is substantially free of interfering metals selected from the group consisting of zinc, lead and tin.

13. The abrasive tool of claim 1, wherein the alloy comprises at least 3 percent by weight of a material selected from the group consisting essentially of chromium, manganese, silicon, and aluminum and mixtures and alloys thereof.

14. The abrasive tool according to claim 1 and characterized further in that the alloy is selected from the group consisting essentially of NICROBRAZ LM,

copper-manganese alloy, copper-silicon alloy, and aluminum-silicon alloy.

15. The abrasive tool of claim 1, wherein the alloy has a liquidus temperature of less than 1,100° C.

16. The abrasive tool of claim 1, wherein the matrix support materials has a plurality of slots formed therein, and wherein the diamond particles are disposed within the slots.

17. The abrasive tool of claim 16, wherein the slots are filled with an alloy to bond the diamonds disposed within the slots to the matrix support material defining the slots.

18. The abrasive tool of claim 1, wherein the diamond particles are disposed in columns extending into the matrix support material, and wherein the diamonds are held in place by the alloy.

19. The abrasive tool of claim 18, wherein the column is substantially linear.

20. The abrasive tool of claim 18, wherein the column is curved.

21. The abrasive tool of claim 1, wherein the tool is a circular saw blade.

22. The abrasive tool of claim 1, wherein the tool is a linear saw blade.

23. A method for forming a diamond impregnated tool comprising:

(a) forming a matrix support material configured for holding diamond particles to be used as abrasives;

(b) distributing diamond particles in the matrix supportive material; and

(c) infiltrating the matrix support material with an alloy that contains between 2 and 50 percent of an element selected from the group consisting essentially of chromium, manganese, silicon and aluminum, and being substantially free of zinc.

24. The method according to claim 23, wherein step (a) comprises, more specifically, forming the matrix support material from powder larger than 400 mesh.

25. The method according to claim 23, wherein step (a) comprises, more specifically, forming the matrix support material from irregularly shaped particles.

26. The method according to claim 23, wherein the method comprises, more specifically, distributing the diamond particles in the matrix support material in a predetermined pattern.

27. The method according to claim 23, wherein the method comprises, more specifically, infiltrating the matrix support material with an alloy substantially free of interfering metals selected from the group consisting of zinc, lead and tin.

28. The method according to claim 23, wherein the method comprises, more specifically, forming a plurality of slots in the matrix support material, and distributing diamond particles into the slots.

29. The method according to claim 23, wherein the method further comprises infiltrating the slots with alloy braze to bond the diamond to the matrix support material.

30. The method according to claim 23, wherein the method further comprises subjecting the matrix support material and diamond particles to a vacuum of at least 10^{-3} torr during infiltration.

31. The method according to claim 23, wherein the method comprises, more specifically, infiltrating the matrix support material and diamond particles with an alloy having at least 5 percent by weight of a carbide former selected from the group consisting essentially of chromium, manganese, aluminum and silicon and mixtures and alloys thereof.

32. The method according to claim 23, wherein the alloy is selected from the group consisting of Nicrobraz LM; an alloy including copper and manganese; an alloy including copper and silicon; an alloy including aluminum and silicon and an alloy including nickel and silicon.

33. The abrasive tool according to claim 1, wherein the tool is a wire saw.

34. The abrasive tool according to claim 33, wherein the tool is a diamond wire saw.

35. the abrasive tool according to claim 34, wherein the tool is a diamond wire saw that contains beads fitted over a steel cable.

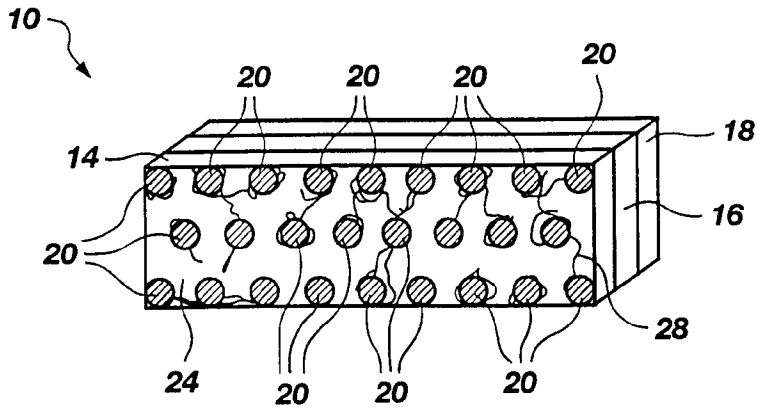


Fig. 1A

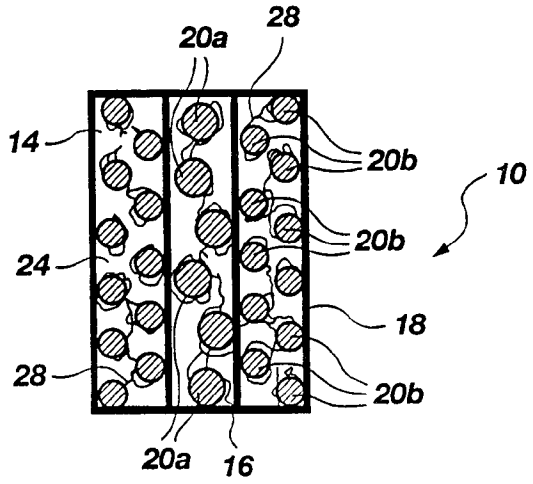


Fig. 1B

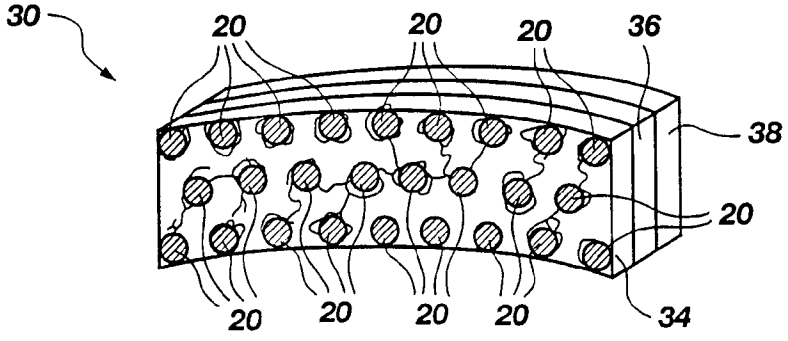


Fig. 2A

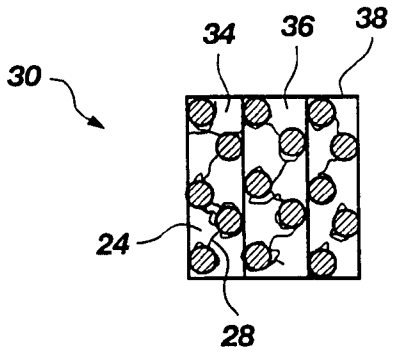


Fig. 2B

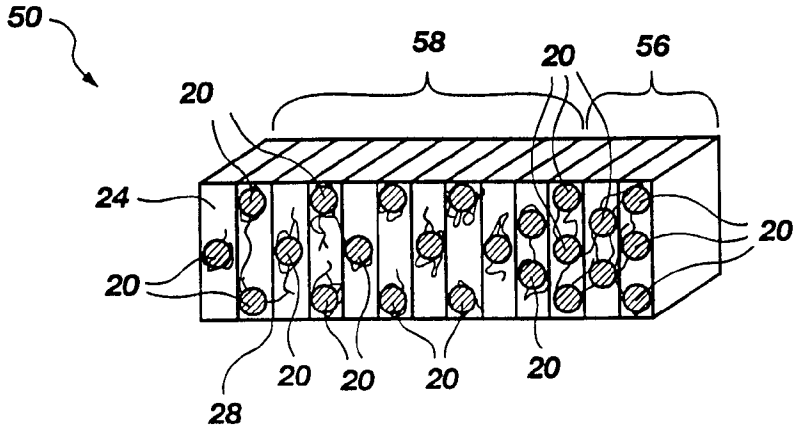


Fig. 3

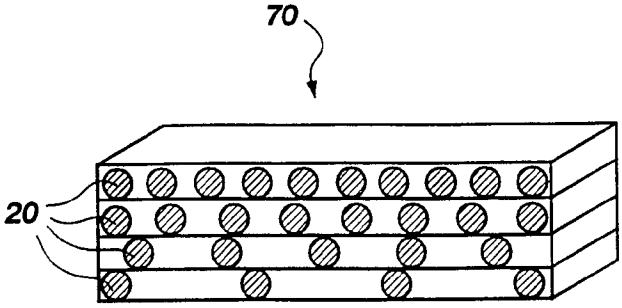


Fig. 4

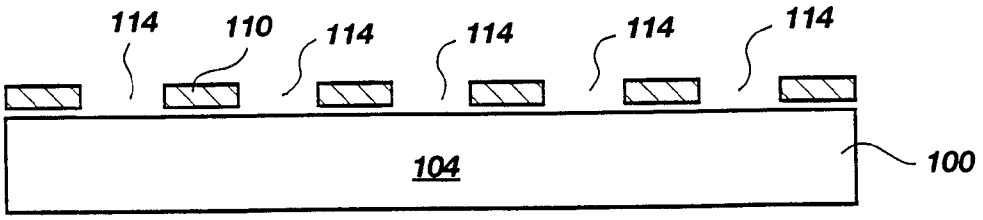


Fig. 5A

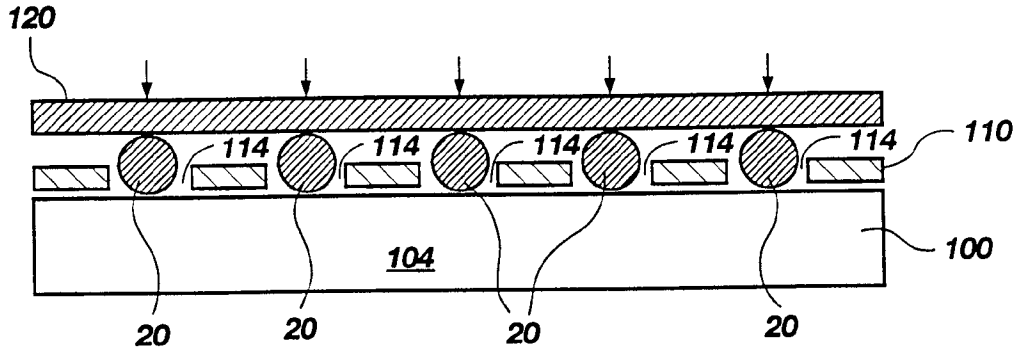


Fig. 5B

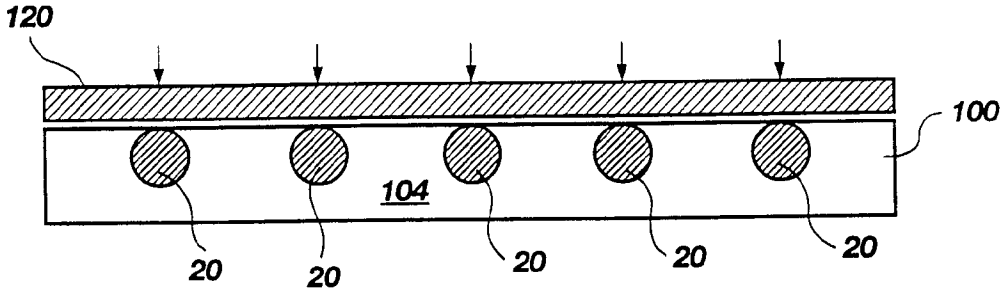


Fig. 5C

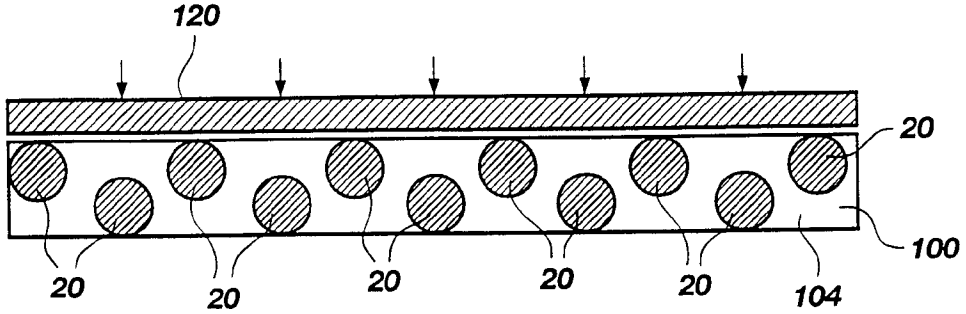


Fig. 5D

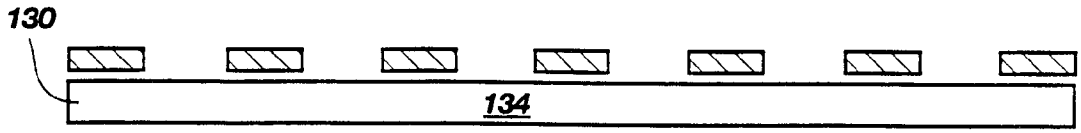


Fig. 6A

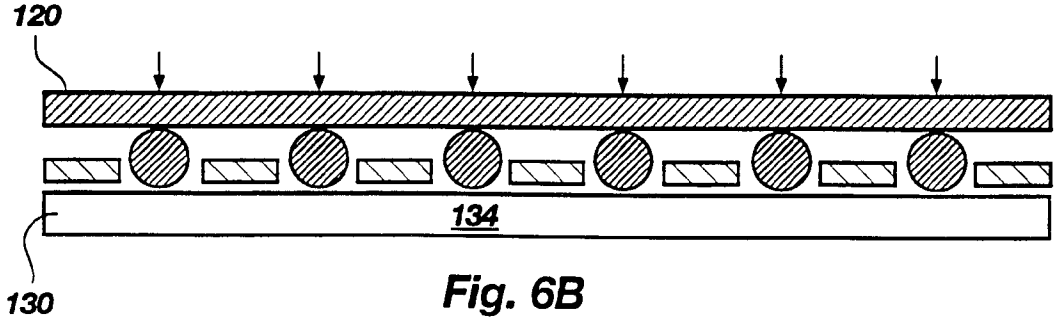


Fig. 6B

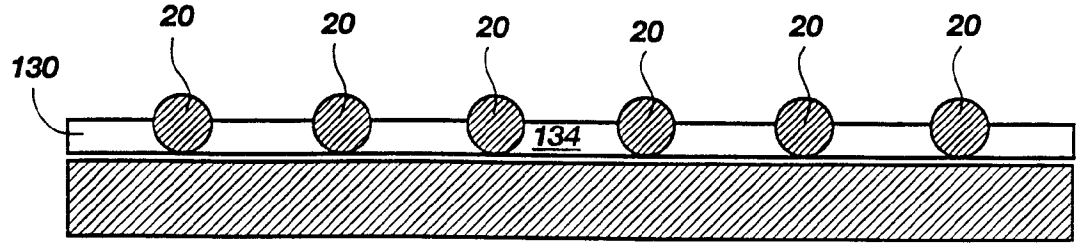


Fig. 6C

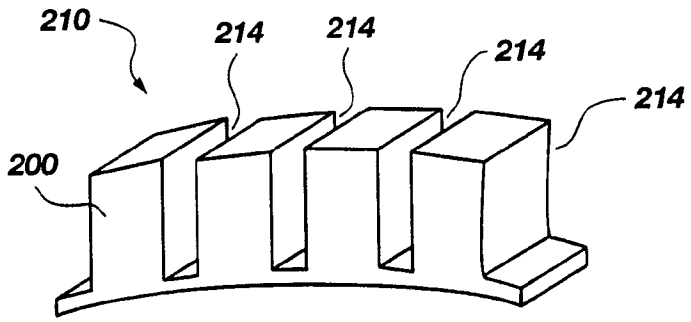


Fig. 7A

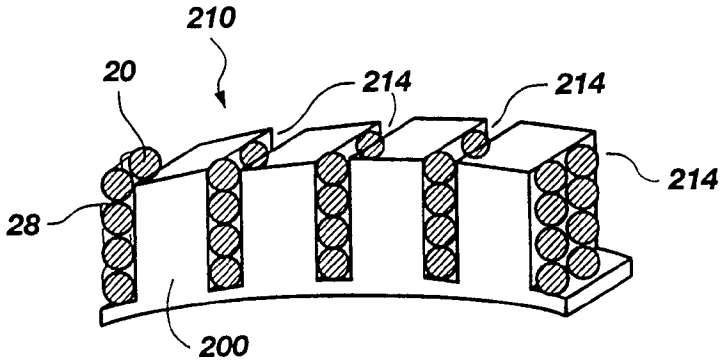


Fig. 7B

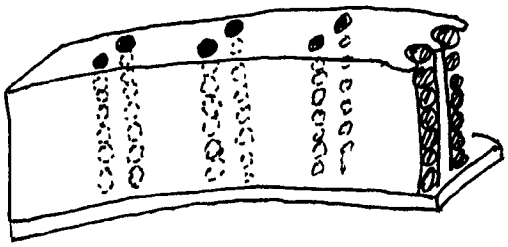


Fig. 8

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B24D 11/00

A1

(11) International Publication Number: **WO 98/45092**

(43) International Publication Date: 15 October 1998 (15.10.98)

(21) International Application Number: PCT/US98/05951

(22) International Filing Date: 26 March 1998 (26.03.98)

(30) Priority Data:
08/832,852 4 April 1997 (04.04.97) US

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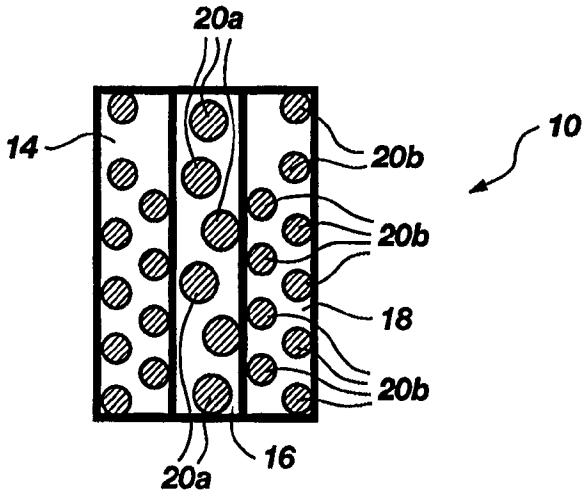
(81) Designated States: AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.

(54) Title: ABRASIVE TOOLS WITH PATTERNED GRIT DISTRIBUTION AND METHOD OF MANUFACTURE

(57) Abstract

An abrasive tool (10) that contains abrasive particles (20) distributed in a predetermined pattern. Such a pattern is produced by fabricating two-dimensional slices (14, 16, 18) and assembling them. Abrasive particles (20) may be incorporated during the process of making these slices, or they may be planted afterwards into these slices which contain matrix powder. The planting may be guided by a template with apertures laid in a specific pattern.



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ABRASIVE TOOLS WITH PATTERNED GRIT DISTRIBUTION AND METHOD OF MANUFACTURE

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to improved abrasive tools used for cutting, grinding and the like. More particularly, the present invention relates to improved abrasive tools wherein abrasive particles are distributed in a predetermined pattern in a matrix powder in order to decrease cost and/or increase the useful life of the tool.

2. State of the Art

Abrasive tools have long been used in numerous applications, including cutting, drilling, sawing, grinding, lapping and polishing materials. Because diamond is the hardest abrasive material and cubic boron nitride is the second hardest, the two materials have been widely used as superabrasives on saws, drills, and other tools which utilize the abrasive to cut, form or polish other hard materials. It is estimated that the total value of superabrasive tools now consumed world wide is over is over 5 billion U.S. dollars per year. More than half of the superabrasive tools are believed to be consumed in sawing and

drilling application such as cutting stones, concretes, asphalts, etc.

Superabrasive tools are particularly indispensable for applications where other tools lack the strength and durability to be practical substitutes. For example, in the stone industry where rocks are cut, drilled, or sawed, diamond tools are the type which are sufficiently hard and durable to make the cutting, etc., economical. If superabrasives were not used, many such industries would be economically infeasible. Likewise, in the precision grinding industry, superabrasive tools, due to their superior wear resistance, are uniquely capable of developing the tight tolerances required, while simultaneously withstanding wear sufficiently to be practical.

Despite the tremendous improvements which diamond and cubic boron nitride have provided for cutting, drilling and grinding tools, there are still several disadvantages which, if overcome, would greatly improve performance of the tools, and/or reduce their cost. For example, the abrasive diamond or cubic boron nitride particles are not distributed uniformly in the matrix that holds them in place. As a result, the abrasive particles are not positioned to maximize efficiency for cutting, drilling, etc., and for production costs of the tools. In some instances, the abrasive particles are disposed too close together.

In other instances, the abrasive particles are disposed to far apart from one another.

In all applications, the separation between abrasive particles determines the work load each particle will perform. Improper spacing of the abrasive particles typically leads to premature failure of the abrasive surface or structure. Thus, if the abrasive particles are too close to one another, some of the particles are redundant. The particles are present, but provide little or no assistance in the cutting, grinding, etc., application. Of course, excess particles add to the expense of the abrasive, due the high cost of diamond and boron nitride. Moreover, these non-performing particles can block the passage of debris, thereby reducing the cutting efficiency. Thus, having abrasive particles disposed too close to one another adds to the cost, while decreasing the cutting efficiency of the tool.

On the other hand, if abrasive particles are separated too far, the work load (e.g., the impact force exerted by the work piece) for each particle becomes excessive. The sparsely distributed particles may be crushed, or even dislodged from the matrix into which they are disposed. The damaged or missing abrasive particles are unable to fully assist in the work load. Thus, the work load is transferred to the surviving abrasive particles. The failure of each

abrasive particle causes a chain reaction which soon renders the tool ineffective to cut, drill, grind, etc.

A typical superabrasive tool, such as a diamond saw blade, is manufactured by mixing diamond particles (e.g., 40/50 U.S. mesh saw grit) with a suitable matrix (bond) powder (e.g., cobalt powder of 1.5 micrometer in size). The mixture is then compressed in a mold to form the right shape (e.g., a saw segment). The "green" form is then consolidated by sintering at a temperature between 700-1200 °C to form a single body with a plurality of abrasive particles disposed therein. Finally, the consolidated body is attached (e.g., by brazing) to a tool body, such a round blade of a saw, to form the final product.

Different applications, however, require different combinations of diamond (or cubic boron nitride) and matrix powder. For example, for drilling and sawing applications, a large sized (anywhere from 20 to 60 U.S. mesh) diamond grit is mixed with a metal powder. The metal powder is typically selected from cobalt, nickel, iron, copper, bronze, alloys thereof, and/or mixtures thereof. For grinding applications, a small sized (anywhere from 60 to 400 U.S. mesh) diamond grit (or cubic boron nitride) is mixed with either metal (typically bronze), ceramic/glass (typically a mixture of oxides of sodium, potassium, silicon, and aluminum) or resin (typically phenolic).

Because diamond or cubic boron nitride is much larger than the matrix powder (300 times in the above example for making saw segments), and it is much lighter than the latter (about 1/3 in density for making saw segments), it is very difficult to mix the two to achieve uniformity. Moreover, even when the mixing is thorough, diamond can still segregate from metal in the subsequent treatments such as pouring the mixture into a mold, or when the mixture is subjected to vibrations. This diamond distribution problem is particularly troublesome for metal matrix tools. Metal matrix tools may account for more than 60% of the total value of all diamond tools. Within metal matrix tools, diamond saws (circular saws, straight blades, wire saws, etc.) comprise about 80% of the value. Thus, finding a method for increasing life of the abrasive material, and/or decreasing the amount of abrasive which is needed is highly desirable. Such has been accomplished by the invention set forth herein. The invention is applicable to all superabrasive tools, and is particularly effective for diamond saws, the largest value category of all diamond tools.

Over the decades, there have been numerous attempts to solve the diamond distribution problem. Unfortunately, none of the attempted methods have proven effective and, as of today, the distribution of diamond particles in diamond tools is still random and

irregular, except for some special cases such as drillers or dressers, where large diamond particles are individually set by hand in the surface to provide a single layer.

One method used in an attempt to make the diamond distribution uniform is to wrap diamond particles with a thick coating of matrix powder. The concentration of diamond particles in each diamond tool is tailored for a particular application. The concentration determines the average distance between diamond particles. For example, the concentration of a typical saw segment is 25 (100 means 25% by volume) or 6.25% by volume. Such a concentration makes the average diamond to diamond distance about 2.5 times of the particle size. Thus, if one coats the diamond to 0.75 times of its diameter and mix the coated particle together, the distribution of diamond would be controlled by the thickness of coating and may become relatively uniform. Additional metal powder may be added as interstitial filler between these coated particles to increase the packing efficiency so the consolidation of the matrix powder in subsequent sintering would be easier.

Although the above described coating method has certain merit, in practice, the uniformity of coating is very difficult to achieve. There are many chemical methods to coat diamond grit and its aggregates (polycrystalline diamond). For example, Chen and Sung

(U.S. Patent Nos. 5,024,680 or 5,062,865) described a CVD method for coating diamond grit using a fluidized bed. Sung et al (U.S. Patent Nos. 4,943,488 or 5,116,568) described another CVD method for coating polycrystalline diamond by fluidized bed. However, most of these methods can only produce thin coatings (e.g. a few micrometers) that do not affect the diamond distribution. Moreover, chemical coating methods typically require treatment at high temperatures (e.g. greater than 900 °C) that may cause damage to diamond. It is well known that synthetic diamond grit tends to form microcracks above this temperature. These microcracks are formed by the back-conversion of diamond to graphite at high temperature. The back-conversion is induced by the catalytic action of metal inclusions that diamond incorporated during its synthesis. CVD treatments cannot readily make thick coatings, and those which are formulated are often cost prohibitive. Thus, CVD treatments are not practical methods to make diamond distribution uniform in the tool.

There are, however, less expensive mechanical methods (e.g., by tumbling diamond particles with metal powder) that can build up a thick coating on diamond grit, typically at a low temperature that would not cause the degradation of diamond. However, it is very difficult to achieve a thick coating with uniform thickness using such methods.

For example, in attempts to practice the invention described in U.S. Patent No. 4,770,907 C.M. Sung performed "Metal Coating of Saw Diamond Grit by Fluidized Bed" (see p 267-273 of Fabrication and Characterization of Advanced Materials, edited by S. W. Kim and S. J. Park of The Materials Research Society of Korea 1995). It was found that the thickness of coated diamond particles varied considerably. Moreover, only extremely fine (i.e. less than 5 micrometers) metal powders can be coated on diamond effectively. Furthermore, the reproducibility of this method is poor. Hence, although such coating may improve the diamond distribution in the tool, its effect is limited.

Furthermore, in mechanical coating, metal powder is held loosely by an organic binder (e.g., PVA, PEG). The coating may be easily rubbed off during the subsequent mixing process, and thereby losing its intended benefit. Although heat treatment may increase the mechanical strength of the coating, nonetheless, it is an additional step with cost.

There is yet another limitation associated with the current methods of coating diamond particles. Many times a diamond tool requires different sizes of diamond grit and/or different diamond concentrations to be disposed at different parts of the same diamond tool. For example, saw segments tend to wear faster on the edge or front than the middle. Therefore,

higher concentrations and smaller diamond grit are preferred in these locations to prevent uneven wear, and thus premature failure of the saw segment. These segments with different concentration/size combinations (known as "sandwich" segments) are difficult to fabricate by mixing coated diamond with metal powder to achieve a controlled distribution of the abrasive particles in the segment. Thus, despite the known advantages of having varied diamond grit sizes and concentration levels, such configurations are seldom used because of the lack of a practical method.

In summary, current arts are incapable of efficiently controlling the uniformity of diamond distribution in the tool. Likewise, the current methods are inadequate to provide effective control of size variations and/or concentration variations on different parts of the same tool. Moreover, even when the distribution is made relatively uniform, current arts cannot tailor the pattern of the distribution to overcome or compensate for typical wear patterns for the abrasive material, when used for a particular purpose. By resolving these problems, the performance of a diamond and other superabrasive tools can be effectively optimized.

It is estimated that less than 10% of abrasives are actually consumed at work. Most of remainder is wasted due to the low efficiency of using these tools.

Among the various causes of this low efficiency, the inability to place every abrasive at the desired location is a major factor. This invention is aimed to make a revolutionary improvement to overcome the deficiency by eliminating random distribution of abrasive particles. The result would be an abrasive tool with every abrasive particle positively planted at desired positions to achieve the maximum utility. Hence, the performance of the abrasive tool can be optimized.

By making the distribution of abrasive particles uniform or tailored to the particular applications of the tool, then the work load can be evenly distributed to each particle. As a result, the abrasive tool will cut faster and its working life be extended a considerable amount of time. Moreover, by eliminating the redundancy, less abrasive may be needed, thereby reducing the cost of the tool manufacture. Additionally, if the distribution can be controlled, abrasive tools utilizing diamond or cubic boron nitride can be configured to provide the most efficient wear profile possible.

The present invention resolves these problems and provides the advantages set forth above by providing a method for forming such tools wherein the abrasive particle distribution can be controlled to provide either uniform grit placement, or to provide grit placement which is tailored to the particular wear

characteristics of the tool. Because the distribution of the diamond particles is controlled, the particles can be disposed in patterns which provide for relatively even wear of the abrasive surface, rather than having portions of the surface wear prematurely. As each particle is more fully utilized, there is no need for redundant particles as a back up. Therefore, the cost of making the abrasive tools can be reduced by decreasing the overall amount of superabrasive which is used. For example, the cost of superabrasives (diamond or cubic boron nitride) is so high that it often accounts for about half of the total manufacturing cost of the tool. By maintaining the performance of a superabrasive tool with a substantially lower concentration used in a controlled distribution, significant cost saving may be realized due to the decreased use of the expensive abrasive.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method for forming superabrasive tools, wherein the distribution of the superabrasive grit is controlled to provide improved cutting, grinding, etc., characteristics without requiring an increase in the amount of superabrasive grit used to form the tool.

It is another object of the invention to provide such a method wherein the distribution of the

superabrasive grit is controlled to promote more even wear of the abrasive surface, and thereby lengthen the useful life of the tool.

It is yet another object of the present invention to provide tools with minimal amount of superabrasive required to perform the task for which the tool is designed, thereby reducing the cost of making the tool.

The above and other objects of the invention are achieved by the use of a novel method of forming the superabrasive surface. While the distribution of the diamond or cubic boron nitride particles has always been viewed as a complex, three dimensional problem, the present invention reduces the distribution of the superabrasive to a substantially two-dimensional process that is easy to manipulate and control, and which can be repeated with a high degree of accuracy. More specifically, the desired distribution of abrasive particles in a matrix body is achieved by assembling layers of matrix material that contain a controlled, preset pattern of abrasive particles. Each layer is formed by distributing the superabrasive grit into a layer of bonding matrix in a predetermined pattern. Each layer which is assembled to form a superabrasive impregnated segment can be of the same distribution pattern and concentration, or the distribution pattern and/or concentration may vary from layer to layer.

In accordance with one aspect of the present invention, each layer is assembled by disposing a layer of matrix material so that it may be used as a precursor. The superabrasive grit is then disposed in the matrix material in a desire pattern. After the diamond particles are planted into the matrix material layer in a predetermined pattern, the process is repeated until a desired number of layers have been formed. These layers are then assembled to form the desired three-dimensional body. Subsequently, the diamond tool is consolidated (e.g., by sintering or infiltration as described above) to form the final product.

By reducing the three-dimensional problem to a two-dimensional solution through the use of the layers, the present invention can not only achieve the desirable diamond distribution pattern in the tool body, but can also provide the flexibility for possible manipulation of diamond concentration at different parts of the same tool body. Thus, for example, diamond particles can be disposed in denser concentrations in some layers than others, and the layers with the greater diamond concentrations can be disposed within the three-dimensional structure created in such a manner to prevent the uneven wear patterns that are typical in many prior art abrasive tools.

In accordance with another aspect of the present invention, each superabrasive layer is created by first forming a thin layer of bonding matrix. A template is then disposed on the bonding matrix. The template has a plurality of apertures formed therein which are sized to receive superabrasive grit of a particular size, with one particle being disposed in each aperture. As the superabrasive grit fills the apertures, it may subjected to pressure or otherwise moved into the bonding matrix. Because of the template, the superabrasive grit which enters the bonding matrix is disposed in a predetermined pattern. A plurality of such superabrasive layers can then be bonded together and attached to the tool by brazing, or some other process, to provide a three-dimensional superabrasive cutting or grinding member on the tool.

In accordance with another aspect of the present invention, the pattern in which the superabrasive grit is disposed may be uniform, or may be calculated to provide superabrasive members with particular cutting abilities. For example, the superabrasive particles may be disposed in varied concentrations to compensate for uneven wear patterns. Thus, the diamond distribution for the cutting edge of a saw may have a greater distribution of diamond particles on the lead edge and sides than on the middle portion which is generally subjected to less wear. Likewise, the sizes of the superabrasive particles can be

controlled to provide a cutting, grinding, etc., surface which is tailored to the particular purpose, such as to prevent chipping of the workpiece.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the invention will become apparent from a consideration of the following detailed description presented in connection with the accompanying drawings in which:

FIG. 1A shows a segment from a superabrasive tool formed by a plurality of linear, longitudinal layers disposed adjacent one another to form a three-dimensional superabrasive member;

FIG. 1B shows a cross-sectional view of one likely configuration of the tool segment shown in FIG. 1A, wherein a layer formed by a matrix material and a relatively large superabrasive is sandwiched between two layers of matrix materials which have smaller grit and higher concentration of the abrasive;

FIG. 2A shows a segment from a superabrasive tool formed by a plurality of arcuate, longitudinal layers which are attached to one another to form a three-dimensional superabrasive member;

FIG. 2B shows a cross-sectional view of a plurality of layers matrix material as may be used with the segment shown in FIG. 2A;

FIG. 3 shows another possible layout of a segment of a cutting tool with transverse layers configured with a denser concentration of abrasive material disposed, e.g., at a forward, cutting end of the three-dimensional superabrasive member;

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution toward, e.g., the upper surface of a tool with horizontal layers;

FIGs. 5A through 5D show one possible method for forming layers with controlled superabrasive distribution within the layer;

FIGs. 6A through 6C show an alternate method for forming one or more layers with controlled superabrasive distribution.

DETAILED DESCRIPTION

Reference will now be made to the drawings in which the various elements of the present invention will be given numeral designations and in which the invention will be discussed so as to enable one skilled in the art to make and use the invention. It is to be understood that the following description is only exemplary of the principles of the present invention, and should not be viewed as narrowing the pending claims.

Referring to FIG. 1A, there is shown a perspective view of a segment, generally indicated at 10, from a superabrasive tool (the remainder of which is not shown). The segment 10 is formed by a plurality of layers, 14, 16 and 18, which are impregnated with superabrasive particles, indicated by the circles 20. The plurality of layers 14, 16 and 18 are disposed adjacent to one another in a linear, longitudinal array so that the layers form the three-dimensional superabrasive segment 10.

As will be discussed in additional detail below, forming the segment 10 in a plurality of thin layers provides remarkably improved control over the distribution of the superabrasive particles. By controlling the distribution of the superabrasive particles within each layer and then combining layers, a three-dimensional segment can be formed in which distribution of the superabrasive particles is controlled in each dimension. This, in turn, enables the formation of segments which are particularly adapted to the likely use of the segment, be it for cutting, sawing, grinding, etc. By tailoring the distribution and concentration of the superabrasive particles within the segment 10, more precise control is given over performance of the tool under actual working conditions.

For example, when using a diamond saw blade to cut a rock (e.g., granite), the two sides of diamond

saw segments are cutting more materials than the center. As a result of the uneven wear, the cross section of the saw segment becomes convex in shape with the center bulging above both sides. This configuration typically slows the cutting rate of the saw blade. Moreover, the protruding profile may also cause the saw blade to deflect sideways in the cut slot. In order to maintain a straight cutting path, it is sometimes desirable to make a "sandwiched diamond segment" to reinforce both sides of the segment with layers impregnated with more superabrasive particles. Such a "sandwich segment" is difficult to manufacture by mixing diamond grit with metal powder by conventional means, but it can be easily accomplished by first planting diamond particles with desirable patterns in layered metal matrix and then assembling these layers together to form the sandwich segment.

In accordance with the present invention, a cutting segment can be formed to resist premature wear to the sides of the segment, thereby extending the cutting segment's useful life. Referring specifically to FIG. 1B, there is shown a cross-sectional view of the cutting segment 10 of FIG. 1A. Unlike the cutting segments of the prior art, the cutting segment 10 is formed of, for example, three layers, 14, 16 and 18 respectively. The middle layer 16 has a plurality of superabrasive particles 20a

which are of a first size (typically 40/50 U.S. mesh) and a first concentration (e.g. 20). The outer layers 14 and 18, in contrast, have a plurality of superabrasive particles 20b, which are of a second size (typically 50/60 mesh), smaller than the first size, and in a second concentration greater than that present in the middle layer 16 (e.g. 23). The smaller, more densely distributed superabrasive particles 20b provide the outer layers 14 and 18 with a greater resistance to wear as they cut through concrete, rock, asphalt, etc. Because the outer layers 14 and 18 are more resistant to wear, the cutting segment 10 resists formation of a convex outer surface, as has traditionally occurred with conventional tools. By maintaining a more planar cutting surface or even a concave profile, the cutting segment can maintain a straighter cutting path with a longer useful life. Moreover, by using a smaller grit on the flank of the saw, the finish of cut surface is more smooth. Furthermore, the chipping of the workpiece can be avoided.

Another advantage to the use of multiple layers of matrix with diamond or cubic boron nitride disposed therein is that the layers are easily formed into other desirable shapes for cutting, drilling, grinding, etc. For example, FIG. 2A shows a perspective view of a saw segment, generally indicate at 30, of a superabrasive tool formed by a plurality

(e.g., 3) of arcuate, longitudinal layers which are attached to one another to form a three-dimensional tool member. In this example, the segment 30 is formed from first, second and third layers, 34, 36 and 38, which are each arcuate. When the three are joined together, an arcuate segment 30 is created. Such a segment, of course, may be used on cutting tools which are non linear (e.g, circular saw blades), and on other types of tools for which a nonlinear superabrasive segment is desired. Because the layers 34, 36 and 38 are initially formed independent of one another, they are much easier to conform to a desired shape, and are able to do so while the superabrasive particles 20 disposed therein are held in their predetermined positions.

Each of the layers is impregnated with a plurality of superabrasive particles 20, typically diamond or cubic boron nitride. Because each layer is formed as a substantially two-dimensional unit (i.e., the matrix will usually be no more than two times the thickness of the diameter of the particles) superior control is provided over placement of the superabrasive particles. As discussed above, the random placement of the prior art often led to ineffective use of superabrasive particles. However, the controlled distribution of the present invention enables either even distribution designed to prevent under or over spacing, or controlled distribution so

that different portions of the segment have different sizes and concentrations which are matched to prevent traditional wear patterns.

Referring now to FIG. 2B, there is shown a cross-sectional view of a plurality of the layers 34, 36 and 38 of the segment 30. Of course, the superabrasive particle as may be used with the segment shown in FIG. 1A or that shown in FIG. 2A. Unlike the embodiment of FIG. 1B, the layers are each provided with the same size and concentration of the superabrasive particles 20. However, because the spacing is substantially uniform, there is no underspacing or overspacing between the superabrasive particles, and the segment 30 wears more evenly than the segments of the prior art with randomly spaced particles. The more even wear prevents premature failure of the segment 30, and thus extends the life of the tool while keeping the amount of superabrasive used to a minimum.

FIG. 3 shows another possible embodiment of a segment 50 made in accordance with the teachings of the present invention. The layered structure in a diamond segment may also be assembled transversely or horizontally. Thus, the segment 50 in FIG. 3 is formed from a plurality of transverse layers. A first plurality of layers, indicated at 56 are provided with a first concentration of superabrasive particles 20 (represented by four layers, that contain superabrasive particles 20 distributed within an

offset pattern). A second plurality of layers, indicated at 58, are provided with a second concentration, less than the first concentration (represented by nine layers with an offset pattern of superabrasive particles 20).

Many cutting tools are configured such that the cutting segment 50 is provided with a lead edge which performs a majority of the cutting and which receives most of the impact force when contacting the workpiece to be cut. For example, a circular saw blade will usually have a plurality of teeth (saw segments), each tooth having a leading edge which takes the force of the cutting. Because the leading edge preforms a significant portion of the cutting, it is much more susceptible to wear than are rotationally trailing portions of the tooth. When formed in accordance with the prior art, the teeth, however, often had similar concentrations of abrasive particles disposed therein. Over time the leading edge wears significantly, but the trailing layers 58 remain with minimal wear. Eventually, the abrasive of the saw tooth is worn off the leading edge, while significant amounts remain on the tail end. Thus, a considerable amount of superabrasive is wasted when the blade is discarded.

The embodiment of FIG. 3 is specifically configured to overcome such concerns. The layers 56 and 58 are configured to provide substantially even wear across the cutting segment 50 by placing a larger

percentage of the superabrasive particles 20 near the leading edge, than on rotationally distal portions. Thus, by the time the leading edge has reached the end of its useful life, the remaining portions of the cutting segment 50 have also been worn out. Such controlled distribution of the superabrasive particles 20 decreases the use of the expensive material and lowers the cost for making the cutting segment 50 without hurting performance. Additionally, by providing more even wear, the cutting segment 50 will often be able to maintain most of its cutting speed until shortly before ending its useful life.

FIG. 4 shows yet another layout of a segment wherein a three-dimensional superabrasive member is formed with progressively denser abrasive distribution toward the upper surface of a tool with horizontal layers. It is often found that the speed of cutting tends to decrease with the wear of the tool. Thus, with a reduced concentration of superabrasive particles, the tool can maintain its current cutting speed at a constant power of the machine. Thus, as with the embodiment of FIG. 3, the controlled distribution of the superabrasive particles 20 forms an improved abrasive segment 70, while at the same time decreasing the cost of abrasive tools by saving those superabrasive particles which are not needed.

With routine experimentation and the teachings of the method of the present invention, those skilled in

the art will be able to customize cutting, drilling, grinding, polishing and other types of abrasive segments which are specifically formed to maximize their performance (i.e. cutting, drilling, grinding, etc.) over an extended useful life, while simultaneously decreasing the amount of expensive superabrasive which is used to form the tool.

Referring now to FIGs. 5A through 5D, there is shown one method for forming layers in accordance with the principles of the present invention. The first step of the method is to form a sheet 100 of matrix material 104 which will be bonded to the superabrasive particles 20. The sheet 100 of matrix material 104 can be formed from conventional metal powders as discussed above, or other bonding agents which have yet to be discovered.

There are many ways that a matrix powder can be made into the sheets 100. For example, the powder can first be mixed with a suitable binder (typically organic) and a solvent that can dissolve the binder. This mixture is then blended to form a slurry with a proper viscosity. In order to prevent the powder from agglomeration during the processing, a suitable wetting agent (e.g., menhaden oil, phosphate ester) may also be added. The slurry can then be poured onto a plastic tape and pulled underneath a blade or leveling device. By adjusting the gap between the blade and the tape, the slurry can be cast into a

sheet with the right thickness. The tape casting method is a well known method for making thin sheets out of powdered materials and it works well with the method of the present invention.

Alternatively, the powder can be mixed with a suitable binder and its solvent to form a deformable cake. The cake can then be extruded through a die with a slit opening. The gap in the opening determines the thickness of the extruded plate. Alternatively, the material can also be drawn between two rollers with adjustable gap to form sheets with the right thickness.

It is desirable to make the sheets pliable for subsequent treatments (e.g., bending over a tool substrate which has a curvature). Therefore, a suitable organic plasticizer may also be added to provide the desired characteristics.

The use of organic agents for powder (metal, plastics, or ceramics) processing is documented in many text books and it is well known by those skilled in the art. Typical binders include polyvinyl alcohol (PVA), polyvinyl butyral (PVB), polyethylene glycol (PEG), paraffin, phenolic resin, wax emulsions, and acrylic resins. Typical binder solvents include methanol, ethanol, acetone, trichlorethylene, toluene, etc. Typical plasticizers are polyethylene glycol, diethyl oxalate, triethylene glycol dihydroabietate, glycerine, octyl phthalate. The organic agents so

introduced are to facilitate the fabrication of metal layers. They must be removed before the consolidation of metal powders. The binder removal process (e.g., by heating in a furnace with atmospheric control) is also well known to those skilled in the art.

Once the sheet 100 of matrix material 104 is formed, a template 110 is laid on the top of the sheet. The template 110 contains apertures 114 that are larger than one abrasive particle 20, but smaller than two abrasive particles, thereby allowing a single particle of the abrasive to be disposed at each specific location.

In this example, the thickness of the template is preferably between 1/3 to 2/3 of the height of the average abrasive particle 20. However, other thicknesses may be used if appropriate accommodations are made for seating the abrasive particles in the desired locations.

After the template 110 is properly positioned, a layer of abrasive particles 20 is then spread over the template so that each aperture 114 receives an abrasive particle. Those particles not falling into the apertures 114 in the template 110 are removed by tilting the substrate, sweeping the template with a broom, or some other similar method.

As shown in FIG. 5B, a generally flat surface 120, such as a steel plate) is then laid over the particles 20 which rest in the apertures 114 in the

template 110. The flat surface 120 presses the abrasive particles 20 at least partially into the pliable sheet 100 of matrix material 104 to seat the particles.

After removing the template 110, the flat surface 120 is used again to press the abrasive particles 120 firmly into the sheet 100 of matrix material 104 as shown in FIG. 5C. While the flat surface 120 is preferable, those skilled in the art will appreciate that there may be occasions when it is desirable to have abrasive particles protruding above the metal sheet 100 with equal height. Alternatively, some of the abrasive particles 20 may be wanted to extend outwardly from the sheet 100 of matrix material more than that of other abrasive particles. In such situations, a contoured or otherwise shaped surface could be used to seat some of the abrasive particles 20 deeper into the sheet 100 of matrix material 104, than other particles.

If desired, the process shown in FIGs. 5A through 5C can be repeated on the other side of the sheet 100 of matrix material 104 (as shown in FIG. 5D), to form an impregnated layer having abrasive particles 20 distributed throughout the layer in some predetermined, desired pattern. The process is typically repeated several times to obtain multiple thin layers or sheets 100 which are impregnated with the abrasive particles 20. Of course, each sheet 100

needs not have the same distribution pattern for the abrasive particles 20, nor does it need the concentration of the abrasive particles be the same.

The abrasive impregnated sheets 100 are next cut to any desired size and shape. The sheets 100 are then assembled to form the tool segment or the entire tool body where appropriate. Typically, the assembly of the sheets 100 is accomplished by a known method such as cold compaction with a press. The "green" body so formed can then be consolidated to form a final tool product by conventional method of sintering or infiltration as described by following the examples.

While the method described in FIGs. 5A through 5D is preferred for many applications, there are instances where it is desirable to have the abrasive particles 20 extend outwardly from the sheet 100 of matrix material. For example, some tools may only have one layer of abrasive. This can be accomplished simply by leaving the template 110 in place when performing the steps shown in FIG. 5A and 5B, and not further pressing the particles 20 into the matrix material once the template has been removed.

In the alternative, FIGs. 6A through 6C show a side view of an alternate to the method discussed in FIGs. 5A through 5D. The sheet 130 of matrix material in FIGs. 6A through 6C is thinner than the height of the superabrasive particles 20. Thus, in this

procedure, when the particles are pressed into the sheet 130, the particles 20 would protrude above the matrix material 134.

Although the present invention is intended for making three-dimensional abrasive tools, the teachings contained in the present application can readily be applied to two-dimensional tools as well. For example, U.S. Patent Nos. 3,894,673 and 4,108,576 describe certain brazed diamond tools that contain a single layer of diamond particles. These particles are brazed onto a tool shank by a chromium containing alloy. Such diamond tools are widely marketed (e.g., by Abrasives Technology of U.S.A.) for cutting and grinding non-ferrous materials (e.g., stones or glass).

However, the distribution of diamond particles on these tools are typically random and non-uniform. The methods illustrated in FIGs. 5A through 6C can readily be applied to such tools to improve the diamond distribution. In this case, the method offers several advantages over the conventional technology as described by these patents. For example, by making diamond particles distributed in a desirable pattern, the load of cutting can be evenly distributed to all diamond particles. As a result, the tool can cut faster with a longer life.

The performance may be further improved by having a braze layer of uniform thickness. This uniformity

can allow a better diamond retention and easier debris removal. Moreover, by fully utilizing each diamond particle for cutting, the concentration of diamond can be reduced. As discussed, diamond cost often accounts for about half of the total manufacturing cost of a diamond tool. Hence, by practicing this invention, manufacturing cost can be reduced substantially.

Also shown in FIG. 6A through 6C is the principle that the spacings of the apertures in the template 130 need not be uniform. Rather, variations in spacing can be provided to facilitate different concentrations on various portions of the sheet 130 of matrix material 134. Likewise, by controlling the size of the apertures 138 and the order in which the diamond particles are placed in the apertures, a single layer could be provided with particles of different sizes.

In addition to being able to improve the performance of the tool and to reduce the cost of the manufacturing, this invention also provides a easier method for making thin bladed tools. For example, the electronic industry requires using larger and larger silicon wafers (now 12 inches in diameter). Hence, thinner saw blades for slicing silicon crystals with lower kurf loss, and thinner dicing wheels for grooving silicon chips with tighter partitions have been in demand.

Prior to the present invention, it has been extremely difficult to make very thin tools that

contain evenly distributed diamond particles. The present invention provides an alternative method for making such tools. For example, it has been discovered that by mixing micron powders of diamond, a blend of metal powders (e.g., bronze and cobalt) and a suitable binder, the material can be rolled to a thickness thinner than 0.1 mm. By firing this thin sheet and mounting it on a tool holder, a thin dicing wheel can be made.

In the alternative to the above, it has been found in accordance with the present invention that some of the advantages of the controlled distribution, multilayered superabrasive configurations described above can be achieved without the use of a template. More specifically, the abrasive particles can also be mixed in with the matrix powder and made as an ingredient of the layered sheet. In this case, the distributions of abrasive particles are still somewhat random. Even so, their distribution is typically more uniform than that in a conventional abrasive body. The segregation of abrasive particles and matrix powders discussed in the background section is less extensive in a substantially two-dimensional sheet than in a three-dimensional body. This is particularly true for sheets made by a deforming process (e.g., by rolling). In this case, abrasive particles are further spread out in the matrix by the shearing action of the rollers.

This invention may also be applicable to other applications not related to making abrasive tools. For example, graphite or metal sheets planted with diamond particles may be used as seeds for diamond growth under high pressure and temperature. Industrial diamonds are typically produced by compressing alternative layers of graphite and metal catalyst (e.g., Fe, Co, or Ni alloy) to high pressure and heated above the melting point of the catalyst. Diamond will then nucleate randomly on the interface of these layers. The quality of the diamond crystal formed often suffers by the impingement of growing crystals that are distributed unevenly. Hence, the yield and cost of diamond synthesis can be substantially improved by making the nuclei distributed uniformly. This invention can provide layers of either graphite or metal catalyst with a pre-determined pattern of diamond seeds. If organic binders are introduced during the fabrication of these layers, they can be removed by heating in a furnace before loading into the press.

Example 1

40/50 mesh diamond grit (SDA-85^{+} made by De Beers Company) were mixed with metal powder to form a mixture with diamond concentration of 20 (5% of total volume). Five different proportion of cobalt (about 1.5 micrometer in size) and bronze (about 20

micrometers in size) were used for the matrix powder. An acrylic binder was added (8% by weight) to the mixture and the charge was blended to form a cake. The cake was then rolled between two stainless steel rollers to form sheets with a thickness of 1 mm. These sheets were cut in the shape of saw segments with a length of 40 mm and width of 15 mm. Three each of such segments were assembled and placed into a typical graphite mold for making conventional diamond saw segments. The assembled segments were pressed and heated by passing electric current through the graphite mold. After sintering for three minutes, the segments were consolidated to a height of 9 mm with less than 1% porosity. Twenty-four segments for each composition were fabricated. They were brazed onto a circular saw of 14 inches in diameter. These five blades were used for cutting granites and found to perform equal or better than those with higher diamond concentrations (e.g. 23) made by conventional methods. Microscopic examination of the worn segment indicated that although diamond particles were not planted into the layered matrix, they were distributed more evenly than segments prepared by the traditional method. The segregation of particles in layered matrix was considerably less than that in a thick body of conventional segments.

Example 2

The same procedures were followed as Example 1, but with 8 thinner layers (0.4 mm) for each segment. The diamond concentration was reduced to 15 and particles were planted according to the illustration as shown in FIGs. 5A through 5D. The diamond distribution was much improved. As a result, the performance of these blades were equal or better than those made by conventional methods with diamond concentration of 20.

Example 3

Iron powders of about 100 mesh were mixed with an S-binder made by Wall Colmonoy Company to form a cake. The cake was then rolled to form sheets of 0.4 mm in thickness. 40/50 mesh SDA-100^{+} diamond grit was planted into these sheets to attain a concentration of 15. These diamond containing sheets were cut in the shape of saw segments with a length of 40 mm and width of 9 mm. Eight of such segments were assembled as a group and placed in a graphite mold. Twenty-four groups were placed horizontally, and another twenty-four groups were placed vertically in the graphite mold. Nicrobraz LM powder (-140 mesh) (made by Wall Colmonoy Company) was added on the top of these segments. These samples were heated in a vacuum furnace (10^{-5} torr) to 1050 °C for 20 minutes for horizontally placed segments, and 30 minutes for

vertically placed segments. The melted LM alloy (Ni-Cr-B-Si with a liquidus point at 1000 °C) infiltrated into these segments and filled the porosity. The excess LM braze on these segments were ground by electrode discharge (EDG). Each of the 24 segments so fabricated were brazed onto a 14 inch (diameter) circular saw blade. These blades were used to cut granite and showed marked improvement over conventional saw blades.

Example 4

Nicrobraz LM powder was mixed with an acrylic binder and rolled to form layers of about 0.25 mm. 40/50 mesh MBS-960 diamond grit manufactured by General Electric Company was planted into these metal layers according to the method as illustrated in Figure 5. These diamond planted metal layers were cut in proper size and wrapped around 2,000 beads (pearls) of wire saw. The beads preferably have a taper angle between 3 and 5 degrees. These beads (10 mm in diameter by 10 mm long) were divided into two groups, one contains 280 crystals (about 0.2 carat) per bead; and the other, 400 crystals (about 0.3 carat). These beads were heated in a vacuum furnace to a temperature of 1,000 °C for 8 minutes. These beads were mounted on several wire saws and used to cut marble, serpentine and granite. The performance of these beads was found to be superior to conventional beads.

The latter beads were typically made by either hot pressing or electroplating. These conventional beads may contain a much higher amount of diamond (up to 1 carat) per bead.

Example 5

The same method as described by Example 4, but applied to other products, e.g., circular saws, thin-wall core bits, and curvature grounder. Each of these products shows superior performance over conventional electro-plated diamond tools having a similar or higher superabrasive concentrations.

The above description and examples are intended only to illustrate certain potential uses of this invention. It will be readily understood by those persons skilled in the art that the present invention is susceptible of a broad utility and applications. Many embodiments and adaptations of the present invention other than those herein described, as well as many variations, modifications and equivalent arrangements will be apparent from or reasonably suggested by the present invention and the forgoing description thereof without departing from the substance for scope of the present invention. Accordingly, while the present invention has been described herein in detail in relation to its preferred embodiment, it is to be understood that this disclosure is only illustrative and exemplary of the present invention and is made merely for the purpose

of providing a full and enabling disclosure of the invention. The forgoing disclosure is not intended to be construed to limit the present invention or otherwise to exclude any such other embodiment, adaptations, variations, modifications and equivalent arrangements, the present invention being limited only by the claims appended hereto and the equivalents thereof.

CLAIMS

What is claimed is:

1. An abrasive tool having an abrasive impregnated segment comprising:

a matrix material configured for bonding abrasive particles; and

a plurality of abrasive particles distributed in the matrix material in a predetermined pattern.

2. The abrasive tool according to claim 1, wherein the plurality of abrasive particles are selected from the group consisting essentially of diamond, cubic boron nitride, alumina and silicon carbide.

3. The abrasive tool according to claim 1, wherein the abrasive impregnated segment is formed by a plurality of matrix material layers, each layer being impregnated with abrasive particles, and wherein the plurality of layers are disposed adjacent one another.

4. The abrasive tool according to claim 3, wherein the abrasive particles in one of the layers are larger than the abrasive particles in at least one of the other layers.

5. The abrasive tool according to claim 4, wherein the plurality of layers includes at least one outer layer and at least one inner layer, and wherein the abrasive particles of the at least one inner layer

are larger than the abrasive particles of the at least one outer layer.

6. The abrasive tool according to claim 5, wherein the abrasive segment is configured with two outer layers and at least one inner layer disposed between the outer layers, wherein each of the outer layers and the at least one inner layer has abrasive particles disposed therein, and wherein the abrasive particles disposed in the at least one inner layer are larger than those disposed in the outer layers.

7. The abrasive tool according to claim 3, wherein at least one of the layers has a greater concentration of abrasive particles than at least one of the other layers.

8. The abrasive tool according to claim 7, wherein the plurality of layers includes at least one outer layer and at least one inner layer, and wherein the at least one outer layer has a greater concentration of abrasive particles than the at least one inner layer.

9. The abrasive tool according to claim 8, wherein the abrasive segment is configured with two outer layers and at least one inner layer disposed between the outer layers, wherein each of the outer layers and the at least one inner layer has abrasive particles disposed therein, and wherein the abrasive particles disposed in the outer layers are disposed in

greater concentration than the abrasive particles in the at least one inner layer.

10. The abrasive tool according to claim 7, wherein the plurality of layers includes at least one first layer having a first concentration of abrasive particles, at least one second layer having a second concentration less than the first concentration, and at least one third layer having a third concentration less than the second concentration.

11. The abrasive tool according to claim 7, wherein the
abrasive impregnated segment has a leading edge configured to initially impact a surface to be cut, wherein the segment is formed by a plurality of layers and wherein the layers adjacent the leading edge having a higher concentration of abrasive particles than layers remote from the leading edge.

12. The abrasive tool according to claim 1, wherein the
abrasive particles are distributed in a uniform pattern throughout the impregnated segment.

13. The abrasive tool according to claim 12, wherein the abrasive particles are uniformly distributed throughout the tool.

14. The abrasive tool according to claim 1, wherein the tool has abrasive particles distributed therethrough, and wherein the tool has an outer

portion having a higher concentration of abrasive particles disposed therein.

15. The abrasive tool according to claim 1, wherein the segment has an impacting surface formed thereon and wherein the abrasive particles are distributed in higher concentration adjacent the impacting surface.

16. The abrasive tool according to claim 1, wherein the segment is formed by a plurality of two-dimensional layers assembled together to form a three-dimensional segment.

17. An abrasive tool comprising a plurality of layers formed from a matrix material for holding abrasive particles, and a plurality of abrasive particles distributed in the layers of matrix material, the layers being attached to one another to form a three-dimensional tool abrasive segment.

18. The abrasive tool of claim 17, wherein at least one of the layers is 1 millimeter thick or less.

19. The abrasive tool of claim 17, wherein the layers have been consolidated together by a method selected from the group consisting of brazing, sintering or infiltration.

20. The abrasive tool of claim 17, wherein the abrasive particles are distributed within the layers in predetermined patterns.

21. The abrasive tool of claim 20, wherein the distribution of the abrasive particles if uniform in at least one of the layers.

22. An abrasive tool comprising at least one layer of matrix material with abrasive particles formed therein, the layer being 1 millimeter or less in thickness and formed by rolling the matrix material and abrasive particles between rollers to improve uniformity in the distribution of the abrasive particles.

23. A method for forming an abrasive tool body, the method comprising:

(a) forming a sheet of matrix material configured for bonding to abrasive particles; and

(b) disposing a plurality of abrasive particles in the sheet of matrix material in a predetermined pattern.

24. The method according to claim 23, wherein the method comprises, more specifically, placing a template with a plurality of apertures formed therein on the sheet of matrix material prior to disposition of the plurality of abrasive particles so that placement of the abrasive particles is controlled by the position of the apertures, thereby selectively limiting placement of the abrasive particles in the sheet of matrix material to the positions of the apertures.

25. The method according to claim 24, wherein the method comprises, more specifically, using a template formed from a sieve.

26. The method according to claim 24, wherein the template is formed by a plate having a plurality of apertures formed therein, the apertures being configured in a predetermined pattern.

27. The method according to claim 26, wherein each aperture has a diameter which is greater than a diameter of the abrasive particles to be positioned thereby, but less than twice the diameter of the abrasive particles.

28. The method according to claim 23, wherein the method comprises, more specifically, forming the sheet of matrix material by tape casting.

29. The method according to claim 23, wherein the method comprises, more specifically, forming the sheet of matrix material by rolling.

30. The method according to claim 23, wherein the method comprises, more specifically, forming the sheet of matrix material by extrusion.

31. The method according to claim 23, wherein the method comprises, more specifically, forming a plurality of layers of matrix material having abrasive particles disposed therein, and attaching the layers together to form a three-dimensional abrasive segment.

32. A method for forming a layer of abrasive impregnated matrix material having improved abrasive distribution, the method comprising:

(a) forming a layer having a mixture of matrix material and abrasive particles; and

(b) rolling the layer of mixture to form a layer no greater than 1 millimeter thick.

33. A method of making layers catalyst for diamond synthesis, the method comprising:

(a) forming at least one layer of a catalyst; and

(b) planting a plurality of diamond particles in the catalyst in a predetermined pattern.

34. The method according to claim 33, therein the method further comprises disposing organic binders in the catalyst prior to planting the plurality of diamond particles, and removing the heating in a furnace before pressing the catalyst and diamond particles.

35. A method of making a source material for diamond synthesis, the method comprising:

(a) providing a layer of graphite; and

(b) planting a plurality of diamond particles in the layer of graphite in a predetermined pattern.

36. The abrasive tool according to claim 1, wherein the abrasive impregnated segment is formed by at least one layer of matrix material.

37. The abrasive tool according to claim 36, wherein the at least one layer of matrix material contains at least one layer of abrasive particles.

38. The abrasive tool according to claim 37, wherein the tool is a wire saw that it at least partially surrounded by the matrix material that contains the abrasive particles.

39. The abrasive tool according to claim 38, wherein the tool is a wire saw that contains diamond beads overcoated with diamond.

40. The abrasive tool according to claim 39, wherein the diamond bead has a taper angle of 3 to 5 degrees.

41. The abrasive tool according to claim 36, wherein the matrix material is consolidated by a method selected from the group consisting of brazing, sintering and infiltration.

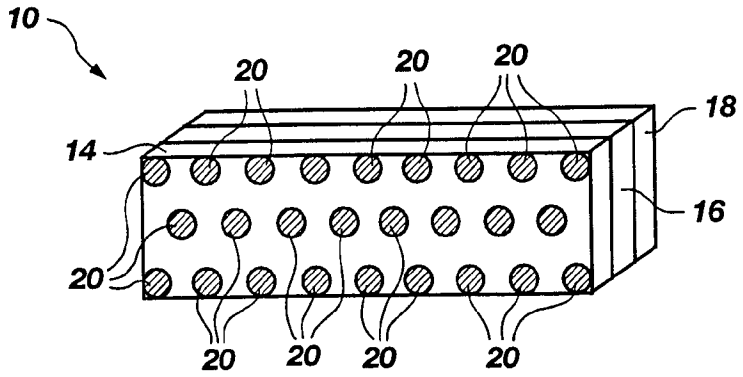


Fig. 1A

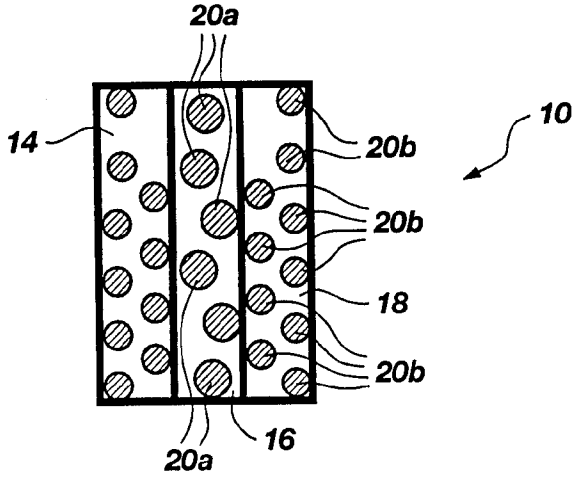


Fig. 1B

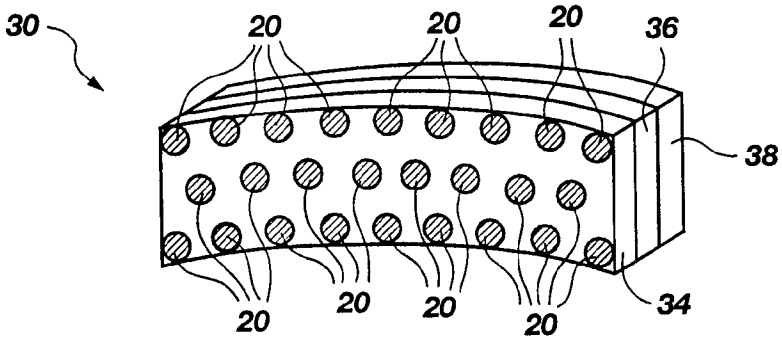


Fig. 2A

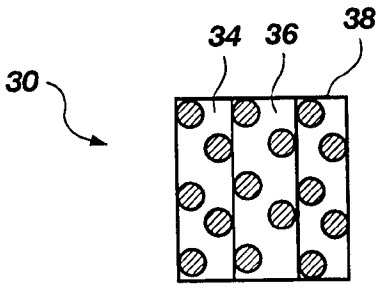


Fig. 2B

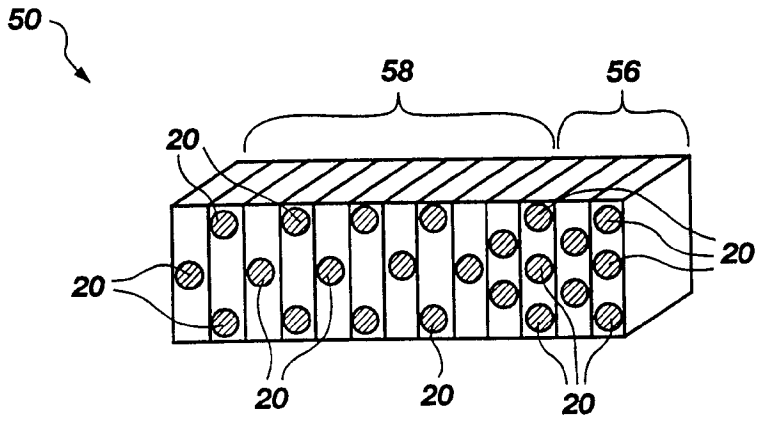


Fig. 3

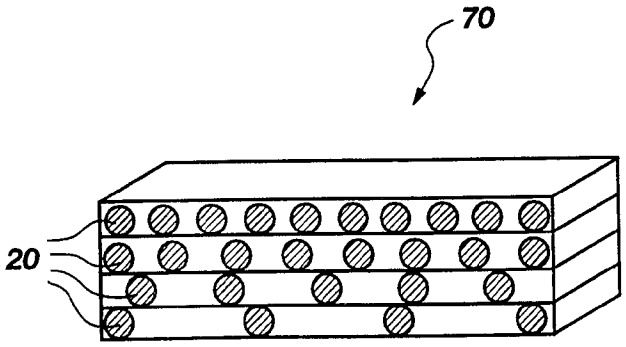


Fig. 4

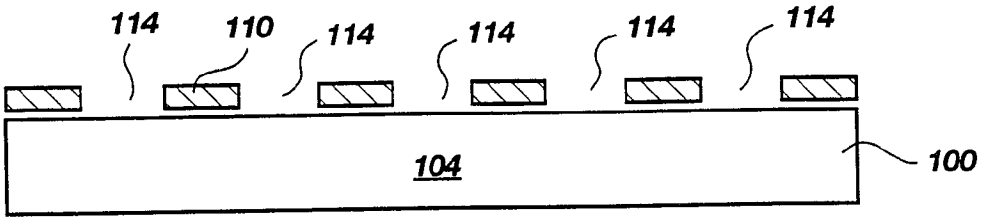


Fig. 5A

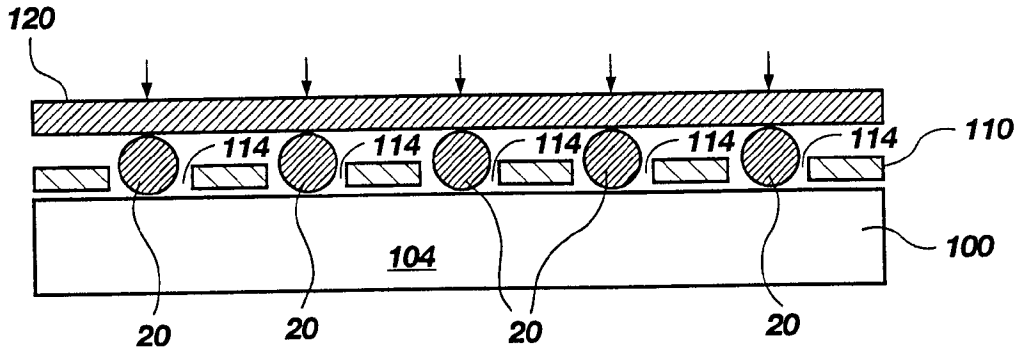


Fig. 5B

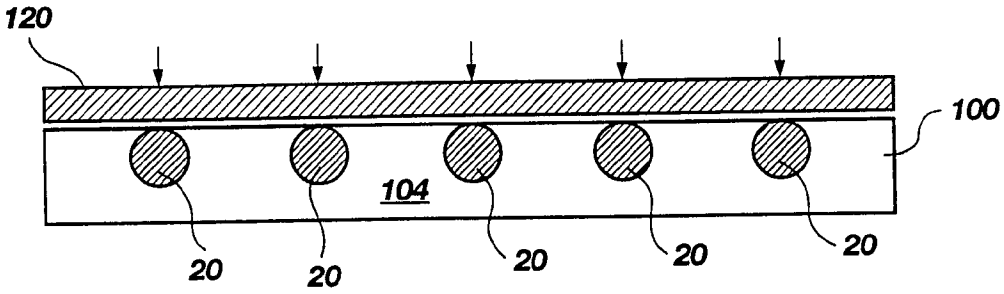


Fig. 5C

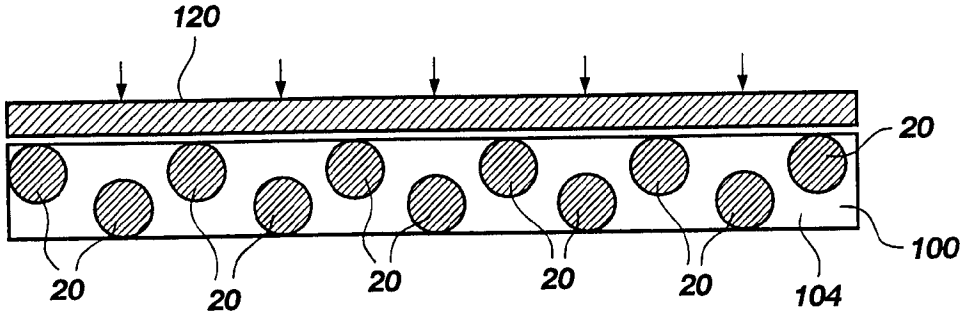


Fig. 5D

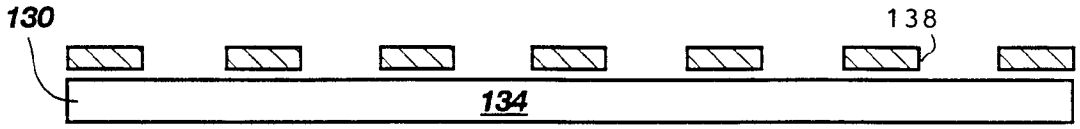


Fig. 6A

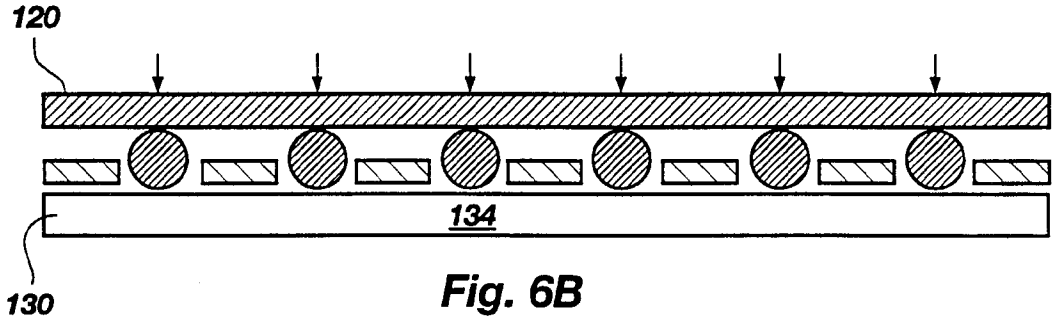


Fig. 6B

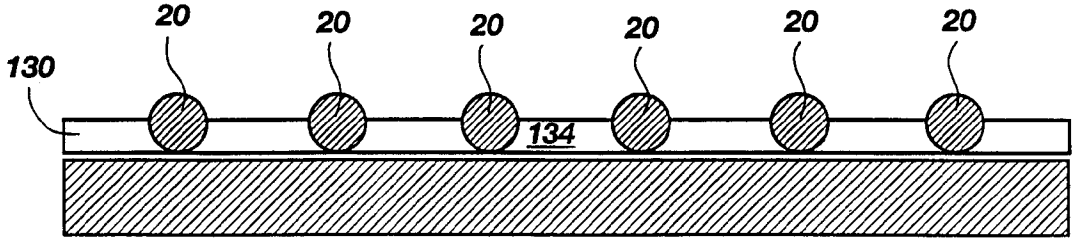


Fig. 6C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/05951

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :B24D 11/00
US CL :451/540

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 451/527,529,533,540; 51/297; 125/16.02,21,22

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US, 2,725,693 A (SMITH) 06 December 1955	1-41
Y	US, 2,952,951 A (SIMPSON) 20 September 1960, see entire document, specifically figure 2	1-41
Y	US, 3,146,560 A (HURST) 01 September 1964, see entire document.	1-41
Y	US 4,712,552 A (PANGBURN) 15 December 1987, see entire document, specifically figures 9 and 10.	1-41
A	US, 4,866,888 A (MURAI et al) 19 September 1989.	1-41
A	US 5,176,155 A (RUDOLPH, JR.) 05 January 1993.	1-41.

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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

Date of the actual completion of the international search 19 JUNE 1998	Date of mailing of the international search report 16 JUL 1998
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230	Authorized officer Sheila Veney for Timothy V. Eley Paralegal Specialist Telephone No. (703) 308-1824 Group ~~3200~~ 3708

Form PCT/ISA/210 (second sheet)(July 1992)★

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) **International Patent Classification** 6 : **B24D 11/00, 18/00**

A1

(11) **International Publication Number:** **WO 98/51448**

(43) **International Publication Date:** 19 November 1998 (19.11.98)

(21) **International Application Number:** PCT/US98/05537

(22) **International Filing Date:** 19 March 1998 (19.03.98)

(30) **Priority Data:**
08/856,501 14 May 1997 (14.05.97) US

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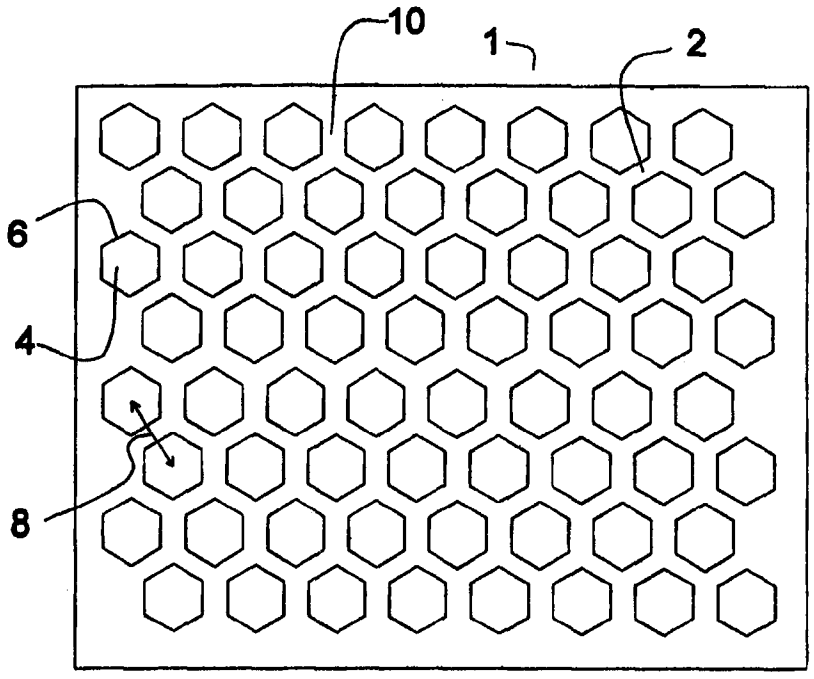
(81) **Designated States:** AU, BR, CA, JP, MX, NZ, European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) **Title:** PATTERNED ABRASIVE TOOLS

(57) **Abstract**

A method of making a metal bonded, abrasive tool uses a perforated stencil to place abrasive parcels in a pattern on the cutting surface of the tool. The stencil is placed against the tool preform so that the perforations define cavities. Metal brazing composition in the form of a paste is packed into the cavities and the stencil is removed to leave discrete parcels of brazing paste tacked to the cutting surface. Abrasive grains are deposited onto the paste particles and fixed in place by firing the preform at brazing conditions. The abrasive grains thus are precisely positioned and spaced apart on the cutting surface by abrasive free channels which are defined by the web of the stencil. The abrasive free channels provide paths to facilitate flow of coolant material and swarf particles at the cutting zone. The method can include initially placing the brazing paste parcels onto a resilient, transfer medium and subsequently transferring the parcels onto the preform cutting surface. This method is particularly useful for depositing an abrasive pattern on a non–planar or highly curved tool surface. In another contemplated variation of the invention, the abrasive grains are premixed with the brazing paste prior to filling the cavities.



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Patterned Abrasive Tools

This invention relates to the manufacture of abrasive tools. More specifically, it relates to making tools with abrasive grains disposed in discrete parcels separated from neighboring parcels on the cutting surface by open channels. The invention further relates to self-sharpening abrasive tools in which the abrasive parcels are formed from multiple, ultrafine abrasive grains embedded therein.

In certain abrasive tools for industrial applications abrasive grains are affixed to a metal preform. The grains are attached to the preform by brazing a metal bonding composition at temperatures above about 600°C.

Removing swarf from the cutting zone during grinding improves performance. Among other things, swarf removal reduces wear of the brazed bonding composition and premature dulling of the abrasive grains. Cooling the work piece is another way abrasive tool users obtain improved grinding performance. Often cooling is accomplished by bathing the work piece in a cool, liquid lubricant. By providing open spaces on the abrasive tool, manufacturers can enhance swarf removal and cooling efficiency. These open spaces provide paths for swarf to leave the cutting zone and conduct coolant to and from the work piece.

A typical method of creating swarf removal and coolant spaces involves cutting grooves or drilling holes through the preform. This technique is widely used in abrasive wheel manufacture. In segmented abrasive tool fabrication, channels can be created by placing gaps between abrasive segments. Normally, such segments are molded from mixtures of abrasive grains and bonding composition and then attached as units to the tool. These methods add to the complexity of the manufacturing operation, are time consuming, and add to product cost.

It is desirable to provide an efficient method of making an abrasive tool with swarf removal and cooling space. Some methods for placing abrasive grains in discrete locations separated by open space on an abrasive tool have been suggested.

U.S. 5,389,119 (Ferronato et al.) discloses a method of making a nonwoven fabric with discrete islands of abrasive bound to a porous fabric layer. The islands are created by

masking portions of a conductive fabric layer and electro-depositing or electroplating a metal structure which contains abrasive material in isolated, unmasked spots.

U.S. 4,826,508 (Schwartz et al.) teaches a method of forming a flexible abrasive member which includes applying a flexible mask of non-electrically conductive material having a multitude of discrete openings therein to one side of a flexible fabric, placing the fabric with the mask applied in a metal deposition bath, and depositing metal directly in the discrete openings in the presence of particulate abrasive material such that the metal adheres directly to the fabric and the abrasive material becomes embedded in the metal deposits.

U.S. 4,047,902 (Wiand) discloses a method of manufacturing a metal-plated abrasive product which entails providing a conductive or metallic backing member, masking off predetermined desired surface portions thereof to leave exposed, spaced-apart portions on the backing, and bonding abrasive grit particles to the exposed portions. The bonding is carried out by a metal plating process.

U.S. 4,863,573 (Moore et al.) teaches a method of making an abrasive article by screen printing a non-conductive mesh with non-electrically conductive ink. The mesh is passed through an electroplating bath while in contact with an electrically conductive cylinder or metal band. A first, nearly complete thickness of metal is electrodeposited onto the non-printed areas of the mesh. Then abrasive particles are deposited on the metal and a second, outer layer of metal is electrodeposited onto the first thickness of metal. The abrasive particles thus are captured by the outer layer of metal and lie at the surface of the metal.

U.S. 4,874,478 (Ishak et al.) provides a method of making an abrasive member comprising attaching a metal film to one surface of a flexible sheet, applying a mask of plating resistant material having a multitude of discrete openings to the exposed surface of the film and depositing metal directly through the openings into the metal film in the presence of particulate abrasive so that the metal adheres to the film and embeds the abrasive in the metal deposits.

Each of the foregoing references relates to manufacture of flexible abrasive fabric or film. Although these abrasive articles might be laminated to supporting substrates to form coated abrasive products, they generally cannot be used by themselves in many industrial grinding applications. Fabric or film-borne abrasive tools will not hold up in aggressive

grinding of construction materials, such as steel and concrete. Additionally, each referenced method employs electro-deposition or electroplating to attach the abrasive to the fabric. Such methods of attachment do not usually provide sufficient thickness of bond material to endure in demanding, industrial grinding applications.

Other approaches to incorporating open space in an abrasive matrix have been disclosed. U.S. 4,882,878 (Benner) describes a grinding wheel having a rigid, continuous abrasive-bearing matrix. The matrix has a plurality of spaced apertures extending into the wheel from the grinding surface. Preferably the matrix is of an organic binding material.

International Patent Application WO 96/26811 (Ferronato) discloses a flexible abrasive member having a backing layer on one side and deposits of abrasive particles and bonding material on the other side. The article further includes a permanent one way mold substantially encircling the deposits and extending along at least part of the height of the deposits. The deposits are placed in holes of the flexible abrasive member.

U.S. 5,152,917 (Pieper et al.) teaches the method of making a structured, coated abrasive article comprising a backing bearing a plurality of abrasive composites having precise shape and disposed in a non-random array. The method includes introducing a slurry of binder precursor and abrasive grains into cavities on the outer surface of a production tool. A backing is placed over the outer surface such that the slurry wets one major surface of the backing to form an intermediate article. The binder precursor is then cured before the intermediate article departs from the outer surface of the production tool. The binder precursor is a quick setting, curable or thermoplastic organic resin.

The prior art does not satisfy the need for a metal preform abrasive tool for aggressive grinding applications in which discretely spaced apart abrasive elements are strongly attached to the preform with a brazeable metal bonding composition. Accordingly, there is provided a process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a cutting surface on the abrasive tool with the stencil whereby the perforations define cavities adjacent the cutting surface;

(C) providing a brazing paste including a metal braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form parcels of brazing paste on the cutting surface, each parcel being separated from neighboring parcels by paste-free channels;

(F) depositing abrasive grains onto the parcels; and

(G) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

In another aspect, the present invention provides a process for making a metal preform abrasive tool in which selectively shaped and spaced apart parcels of brazing paste are first formed on a transfer medium. The brazing paste parcels are then transferred to the cutting surface of a metal preform where abrasive grains are added and brazing is accomplished. This method facilitates the manufacture of oddly-shaped and curved cutting surface abrasive tools. There is thus provided a process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a transfer medium with the stencil whereby the perforations define cavities adjacent the transfer medium;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form a patterned face of parcels of brazing paste on the transfer medium, each parcel being separated from neighboring parcels by paste-free channels;

(F) forcing the patterned face against a cutting surface of the abrasive tool;

(G) peeling the transfer medium away to leave the parcels on the cutting surface;

(H) depositing abrasive grains onto the parcels; and

(I) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a plan view of a mask for creating a stencil useful in the practice of the present invention.

DETAILED DESCRIPTION

The present invention is useful for fabricating abrasive tools in which abrasive grains are metal-bonded onto metal, primarily ferrous metal, preforms. The method can be used with a diverse variety of preform shapes. Representative preforms include flat disks, drill bit cores, abrasive wheel rims, saw blades and many specialty tool bodies, such as spherical, conical, and frustoconical-shaped preforms. The abrasive tools made according to this invention thus will be rugged and suitable for demanding industrial and construction material grinding and cutting applications.

The abrasive grains will be of a substance that is harder than the substance being cut. Very hard abrasive substances generally known as superabrasives, such as diamond, cubic boron nitride and mixtures of them can be used. Among these, diamond is preferred, primarily for cutting nonferrous materials. Many non-superabrasive substances also can be employed. Representative non-superabrasives which can be used in this invention include aluminum oxide, silicon carbide, tungsten carbide, and the like. Aluminum oxide encompasses standard alumina abrasive as well as seeded and unseeded sol-gel microcrystalline alumina, described in greater detail, below.

A preferred non-superabrasive is a microcrystalline alumina. Also preferred are the sol-gel alumina filamentary abrasive particles described in U.S. Pat. Nos. 5,194,072 and 5,201,916, incorporated herein by reference. "Microcrystalline alumina" means sintered sol-gel alumina in which the crystals of alpha alumina are of a basically uniform size which is generally smaller than about 10 μm, and more preferably less than about 5 μm, and most preferably less than about 1 μm in diameter. Crystals are areas of essentially uniform crystallographic orientation separated from contiguous crystals by high angle grain
boundaries.

Sol-gel alumina abrasives are conventionally produced by drying a sol or gel of an alpha alumina precursor which is usually but not essentially, boehmite; forming the dried gel into particles of the desired size and shape; then firing the pieces to a temperature sufficiently high to convert them to the alpha alumina form. Simple sol-gel processes for making grain suitable for use in accordance with the present invention are described, for example, in U.S. Patent Nos. 4,314,827; 4,518,397 and 5,132,789 ; and British Patent Application 2,099,012, the disclosures of which are incorporated herein by reference.

In one form of sol-gel process, the alpha alumina precursor is "seeded" with a material having the same crystal structure as, and lattice parameters as close as possible to, those of alpha alumina itself. The "seed" is added in as finely divided form as possible and is dispersed uniformly throughout the sol or gel. It can be added *ab initio* or it can be formed *in situ*. The function of the seed is to cause the transformation to the alpha form to occur uniformly throughout the precursor at a much lower temperature than is needed in the absence of the seed. This process produces a crystalline structure in which the individual crystals of alpha alumina are very uniform in size and are essentially all sub-micron in diameter. Suitable seeds include alpha alumina itself but also other compounds such as alpha ferric oxide, chromium suboxide, nickel titanate and a plurality of other compounds that have lattice parameters sufficiently similar to those of alpha alumina to be effective to cause the generation of alpha alumina from a precursor at a temperature below that at which the conversion normally occurs in the absence of such seed. Examples of such seeded sol-gel processes are described in U.S. Patent Nos. 4,623,364; 4,744,802; 4,788,167; 4,881,971; 4,954,462; 4,964,883; 5,192,339; 5,215,551; 5,219,806; and 5,453,104, the disclosures of which are incorporated herein by reference, and many others.

Preferably the abrasive grains are attached to the metal preform by a bond containing metal. The bond is formed from a metal braze composition which is thermally treated according to a conventional, high temperature brazing process. Metal braze compositions for uniting abrasive to a metal tool preform are well known. Illustrative metal braze compositions include silver, nickel, zinc, lead, copper, tin and mixtures of these metals alloyed with other metals, such as phosphorous, cadmium, vanadium and the like. Generally minor amounts of additional components can be included in the braze composition to modify the properties of the bond during and after brazing, such as to modify melting temperature, melt viscosity, abrasive surface wetting and bond strength. Copper/tin bronze-based alloys are preferred for bonding abrasives, especially superabrasives to metal. Certain so-called "active metals" or "reactive metals" including titanium, tantalum, chromium,
and zirconium, for example, can be added to the braze composition particularly for bonding diamond. These metals react with the carbon to form carbides and thereby improve the wetting of the braze composition on the superabrasive particle. Hybrid bond

material such as a metal filled resinoid braze composition containing a major fraction of metal can also be used with the present invention.

Brazing is performed at elevated temperatures selected with consideration to numerous system parameters such as solidus-liquidus temperature range of the metal brazing composition, geometry and material of construction of the preform and physical properties of the abrasive. For example, diamond can graphitize at temperatures above about 1000°C in air and above about 1200°C under vacuum or inert atmosphere. Hence, it is often desirable to braze at the lowest possible temperatures. The metal brazing composition should be selected to braze preferably at about 800-1025°C, and more preferably, at about 850-950°C.

The metal braze composition is usually employed in fine particulate form. The components of the metal braze composition can be present as prealloyed particles, as a mixture of separate component powders or a combination of both forms. The metal braze composition can be conveniently delivered to the braze site in paste form by mixing a liquid binder with the dry particulate components. The liquid binder facilitates blending of the dry particulate components to uniform composition and provides a vehicle for dispensing precise amounts of metal braze composition.

The liquid binder should be sufficiently volatile to evaporate or pyrolize below the melting temperature of the metal braze composition so as not to interfere with the formation of a secure bond between abrasive and preform. However, the volatility should not be so great that the paste dries too quickly. The paste should remain fluid for a reasonable time to permit assembly of the abrasive tool. Preferably, the paste should be fluid for at least several minutes and up to about an hour at ambient temperature and humidity conditions. Liquid binders are well known in the industry. Representative paste-forming binders suitable for use in the present invention include Braz™-Binder Gel from Vitta Company; "S" binder from Wall Colmonoy Corporation, Madison Heights, Michigan; and Cusil-ABA, Cusin-ABA, and Incusil-ABA pastes from Wesgo, Belmont, California. Active metal braze composition pastes including binder premixed with metal braze composition components can be obtained from Lucas-Millane Company, Cudahy, Wisconsin under the Lucanex ™ tradename, such as Lucanex 721.

The present invention uses a stencil to place abrasive parcels in a pattern on the abrasive tool. Generally, the stencil is a flat sheet structure. The sheet can be flexible

which permits it to conform to a curved cutting surface and to be rolled up for storage or for deployment in an endless belt configuration.

The stencil material should be capable of being perforated with a plurality of precisely positioned, selectively shaped holes. Perforating can be done by any well known technique, such as stamping with a die, photoetching, drilling and cutting. Stainless steel sheet can be reused repeatedly, is wear resistant, is generally not affected by a wide range of chemicals, and therefore, is a preferred stencil material. For one-time or limited reuse stencils, disposable material, such as plastic film and fiberboard sheeting, also is contemplated to fall within the scope of this invention.

The perforations will extend completely through the stencil. Shape and placement of the perforations determine the size and location of abrasive parcels on the tool. Any regular or non-regular geometric, area-enclosing shape can be employed. Uncut regions of the stencil correspond to open channels on the tool between abrasive parcels.

In use, one side of the stencil is brought in contact with the tool preform adjacent the cutting surface. The other side of the stencil remains exposed. The interior walls of the perforations and the cutting surface within the perimeters of the perforations define vacant cavities. On the exposed side of the stencils, the cavities are open.

The cavities are filled with brazing paste. Filling preferably is accomplished by forcing the paste into the cavities with a squeegee-like tool. That is, a thick bead of brazing paste is dispensed on the exposed side of the stencil, generally at one end of the cutting surface. The bead length extends slightly beyond the width of the cutting surface. A straight edged blade longer than the bead length is drawn with slight pressure from behind the bead across the exposed side of the stencil. The blade forces the paste into the cavities and removes the excess paste above the cavities flush with the exposed side of the stencil. The blade also wipes away excess paste from the exposed side of the stencil for reuse or disposal.

It is seen that the thickness of the stencil sheet will determine the height of the abrasive parcels on the tool. The thickness can vary widely to suit the needs of a particular grinding application. Generally, the thickness will be about equal to the maximum cross section dimension of the abrasive particles, although a different thickness can be used, especially if the binder concentration of the brazing paste varies outside the range of about 20-25 wt%. One can also appreciate that the size of the metal braze

composition particles should be small enough to form a smooth paste that will flow into the cavities. Particle size of 325 U.S. standard mesh or smaller, *i.e.,* at most 44 μm, is generally suitable.

The stencil is peeled away from the cutting surface. The parcels of brazing paste remain stuck to the cutting surface. Thus the brazing paste is disposed on the cutting surface in discrete islands separated from neighboring parcels by paste-free channels.

In one aspect, abrasive grains are deposited onto the still soft parcels of abrasive paste. Grains can be placed individually or dusted over the whole surface. In an embodiment, abrasive grains are at least about 100 μm and only one abrasive grain is deposited onto each of most parcels. A feeding apparatus can be used to facilitate individual placement of a single abrasive grain in each parcel of paste. Such feeding apparatus also advantageously may orient grain placement to optimize exposure of each grain's cutting facet relative to the workpiece. The fabricator thus can control the tool at the individual grain level to provide maximum cutting speed, minimum energy consumption, minimum grain fracture, or combinations of these parameters. The metal brazing composition will liquefy during brazing. Consequently, it may be necessary to provide means to preserve the orientation of individually placed grains until a permanent bond is formed at the conclusion of brazing. For example, this may be achieved by utilizing a stencil or feeding apparatus of a thermally stable composition, such as graphite or ceramic. The thermally stable stencil or feeding apparatus may be left in place during all or part of the brazing step.

In another embodiment the abrasive grains have a particle size of at most 10 μm. Preferably, the small grains are dusted onto the cutting surface to embed the grains in the parcels. Excess grains which dust into the paste-free channels are not embedded in the parcels. They can be removed by inverting the preform, by vacuum, by blowing with gas jets or like procedures. After removing excess grains, loosely embedded grains can be further buried in the parcels of paste. The grains can be deeply planted by placing a flexible release film over the parcel-populated cutting surface and applying pressure with a manual or automated roller, for example.

In yet another embodiment, the abrasive grains are premixed with the brazing paste prior to filling the cavities. The premixed grains should be smaller than the cross section

dimension of the perforations to permit the grains to enter the cavities. Preferably the premixed grains should be smaller than 75% of the stencil thickness.

Premixing of small grains with the paste can provide a uniform concentration throughout the paste. This technique will embed grains over the complete depth of the parcel. Moreover, the small grains can impart self-sharpening behavior to the premixed parcels. That is, each parcel on the tool will constitute a plurality of abrasive grains bonded within a matrix of metallic braze. Such parcels tend to wear by dislodging the most exposed abrasive grains. This will expose underlying fresh, sharp grains to continue grinding. Consequently, tools fabricated in this manner generally provide consistent, superior grinding performance as the parcels wear away over time in service.

Once the abrasive grains are embedded in the parcels of brazing paste, the preform can be fired by traditional methods. A brazing treatment causes the residual liquid binder to dissipate or burn off at intermediate temperature. At high temperature the metal braze composition components permanently unite the abrasive grains to the preform. Control of the thermal cycle variables permits the braze composition components to sinter without significantly changing the shape or placement of the parcels. One of ordinary skill in the art can select appropriate brazing time and temperature parameter to optimize parcel shape retention.

It is sometimes desirable to create a patterned abrasive on a tool exhibiting non-planar or extreme surface curvature. Deployment of a stencil directly against such a cutting surface may be problematic. In another aspect of this invention, this problem is solved by forming parcels of brazing paste on a transfer medium, and subsequently transferring the parcels to the cutting surface of a metal preform. The transfer medium can be a resilient, rubbery pad that is capable of conforming to the shape of the preform cutting surface. The operative face of the transfer medium preferably has a closed cell, smooth surface structure to facilitate transfer of paste parcels.

According to this variation of the invention, a stencil is provided with a plurality of perforations. Each perforation has a precise shape and is placed apart from neighboring perforations. One side of the stencil is brought in contact with a generally flat sheet of transfer medium while the other side of the stencil remains exposed. The interior walls of the perforations and the transfer medium within the perimeters of the perforations define vacant cavities. On the exposed side of the stencils, the cavities are open.

The cavities are filled with brazing paste. Filling preferably is accomplished by forcing the paste into the cavities, as explained above. The stencil is peeled away leaving the parcels of brazing paste stuck to the transfer medium. The parcel-bearing side of the transfer medium is pressed against the cutting surface of a tool preform. This can be accomplished to some advantage by first placing the parcel-free side of the transfer medium on a stable working surface, such as a table top or similar holding structure. The parcel-bearing side of the medium is held stationary and exposed. Then the cutting surface of the preform is forced against the stationary transfer medium. The parcels transfer to the cutting surface. Thereafter, abrasive particles can be added and the tool can be fired to permanently attach the abrasives.

EXAMPLES

EXAMPLE 1

The example can be better understood with reference to Fig. 1. Mask the surface of a 15 inch long by 15 inch wide by 0.010 inch thick stainless steel sheet with a U.V. impenetrable coating. The mask **1** is a continuous network **2** with exposed regular hexagonal areas **4** of 0.115 inches length on each side **6** and center-to-center distance **8** of 0.32 inches. The gap **10** between neighboring hexagons is 0.12 inches. Photoetch the sheet to open hexagonal perforations at the exposed areas and remove the mask.

Mount the perforated stainless steel stencil to a sturdy, rigid rectangular frame to maintain flatness. Place a 0.030 inch thick, 9.875 inch diameter, flat, circular steel preform for an abrasive disk on a table with the cutting surface facing up. Align the stencil centrally over the disk and clamp the frame to the preform so that the face of the disk contacts one side of the stencil. Maintain the exposed side of the stencil facing up in a horizontal plane.

Dispense an approximately 0.5 inch diameter, 12 inch long bead of Lucanex™ 721 braze paste just inside one edge of the rectangular frame. Use a 14 inch long, hard rubber squeegee, to draw the bead in a steady speed stroke across the exposed face of the stencil with slight downward pressure and to force the braze paste into the hexagonal cross-section cavities to a depth flush with the exposed surface of the stencil, *i.e.,* approximately 0.010 inch. Use only a single pass to prevent braze paste from bleeding under the stencil between perforations.

Unclamp the frame from the preform and lift the stencil vertically away from the disk face. Sprinkle 120/140 U.S. mesh type PDA 989 diamond abrasive grains from DAC Company, New York, New York to evenly dust grains over the disk face. Lift the preform from the table and invert to drop excess abrasive grains into a collection pan. Place the abrasive bearing preform cutting surface side up on a horizontal work surface. Align a 0.25 inch thick, 14 inch diameter circular rigid acrylic plastic sheet to overlay the preform and push down evenly to embed the abrasive grains into the braze paste parcels.

Remove the acrylic sheet and fire the preform in a vacuum furnace at about 15°C per minute to a maximum temperature of about 900°C, while maintaining pressure within the furnace below 10^{-4} Torr. Hold the preform at 900°C for 10 minutes and allow to cool to room temperature. This example demonstrates the manufacture of a flat, single diamond layer metal abrasive disk.

EXAMPLE 2

Drill 2.0 mm diameter circular holes on 5 mm centers in a 60° isometric pattern through a 0.2 inch thick by 12 inch wide by 12 inch long stainless steel sheet to form a stencil. Mount the stencil in a sturdy, rigid frame to maintain stencil flatness. Align the stencil over a 1 inch thick by 12 inch wide by 12 inch long pad of smooth-faced urethane rubber. Bring the stencil and rubber pad in laminating contact. Maintain the exposed side of the stencil facing up in a horizontal plane.

Dispense an approximately 0.5 inch diameter, 12 inch long bead of Incusil™ ABA braze paste along one edge of
the stencil. Use a 14 inch long, hard rubber squeegee, to draw the bead in a steady speed stroke across the exposed face of the stencil with slight downward pressure and to force the braze paste into the cylindrical cavities to a depth flush with the exposed surface of the stencil, *i.e.,* approximately 0.2 inch. Use only a single pass to prevent braze paste from bleeding under the stencil between perforations.

Lift the stencil vertically away from the face of the rubber pad. Sprinkle a 50/50 vol/vol mixture of 60/80 U.S. mesh diamond and cubic boron nitride abrasive grains from General Electric Company, Columbus, Ohio to evenly dust grains over the rubber pad. Lift the pad from the table and invert to drop excess abrasive grains into a collection pan. Replace the pad with abrasive/paste side up on a horizontal work surface.

Place a spherical steel preform firmly in a manual jig to expose the convex cutting surface of the preform. Press the preform vertically downward against the pad. Apply a slight rolling motion to the sphere to evenly transfer the parcels of abrasive laden brazing paste onto the cutting surface of the preform. Remove the manual jig and fire the preform as in Example 1. This example demonstrates the manufacture of an abrasive tool with a transfer medium according to the present invention. The abrasive tool is useful for grinding concave ball joints.

What is claimed is

1.A process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a cutting surface on the abrasive tool with the stencil whereby the perforations define cavities adjacent the cutting surface;

(C) providing a brazing paste including a metal braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form parcels of brazing paste on the cutting surface, each parcel being separated from neighboring parcels by paste-free channels;

(F) depositing abrasive grains onto the parcels; and

(G) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

2. The invention of claim 1 wherein the filling step includes forcing the brazing paste into the cavities with a straight-edged blade.

3. The invention of claim 2 wherein the abrasive grains are mixed with the brazing paste prior to filling the cavities.

4. The invention of claim 3 wherein the abrasive grains have a particle size of at most 10 μm.

5. The invention of claim 2 wherein the depositing step includes:

(i) dusting grains onto the cutting surface to embed grains into the parcels; and

(ii) removing non-embedded grains.

6. The invention of claim 5 wherein the depositing step further includes pressing the embedded grains into the parcels.

7. The invention of claim 1 wherein the abrasive grains have a particle size of at least about 100 μm and only one abrasive grain is deposited onto each of most parcels.

8. A process for making an abrasive tool comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a transfer medium with the stencil whereby the perforations define cavities adjacent the transfer medium;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form a patterned face of parcels of brazing paste on the transfer medium, each parcel being separated from neighboring parcels by paste-free channels;

(F) forcing the patterned face against a cutting surface of the abrasive tool;

(G) peeling the transfer medium away to leave the parcels on the cutting surface;

(H) depositing abrasive grains onto the parcels; and

(I) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

9. The invention of claim 8 wherein the filling step includes forcing the brazing paste into the cavities with a straight-edged blade.

10. The invention of claim 9 wherein the abrasive grains are mixed with the brazing paste prior to filling the cavities.

11. The invention of claim 10 wherein the abrasive grains have a particle size of at most 10 μm.

12. The invention of claim 9 wherein the depositing step includes:

(i) dusting grains onto the cutting surface to embed grains into the parcels; and

(ii) removing non-embedded grains.

13. The invention of claim 12 wherein the depositing step further includes pressing the embedded grains into the parcels.

14. The invention of claim 8 wherein the abrasive grains have a particle size of at least about 100 μm and only one abrasive grain is deposited onto each of most parcels.

15. The invention of claim 8 wherein the cutting surface is a three dimensional, curvilinear surface and the transfer medium is a flexible, resilient pad.

16. An abrasive tool fabricated by a process comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a cutting surface on the abrasive tool with the stencil whereby the perforations define cavities adjacent the cutting surface;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form parcels of brazing paste on the cutting surface, each parcel being separated from neighboring parcels by paste-free channels;

(F) depositing abrasive grains onto the parcels; and

(G) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

17. An abrasive tool fabricated by a process comprising the steps of:

(A) providing a stencil having a plurality of perforations of selected shape;

(B) contacting a transfer medium with the stencil whereby the perforations define cavities adjacent the transfer medium;

(C) providing a brazing paste including a braze composition and a binder component;

(D) filling the cavities with brazing paste;

(E) removing the stencil to form a patterned face of parcels of brazing paste on the transfer medium, each parcel being separated from neighboring parcels by paste-free channels;

(F) forcing the patterned face against a cutting surface of the abrasive tool;

(G) peeling the transfer medium away to leave the parcels on the cutting surface;

(H) depositing abrasive grains onto the parcels; and

(I) thermally processing the abrasive tool to braze the abrasive grains to the cutting surface.

18. The invention of claim 17 wherein the cutting surface includes a convex, spherical portion.

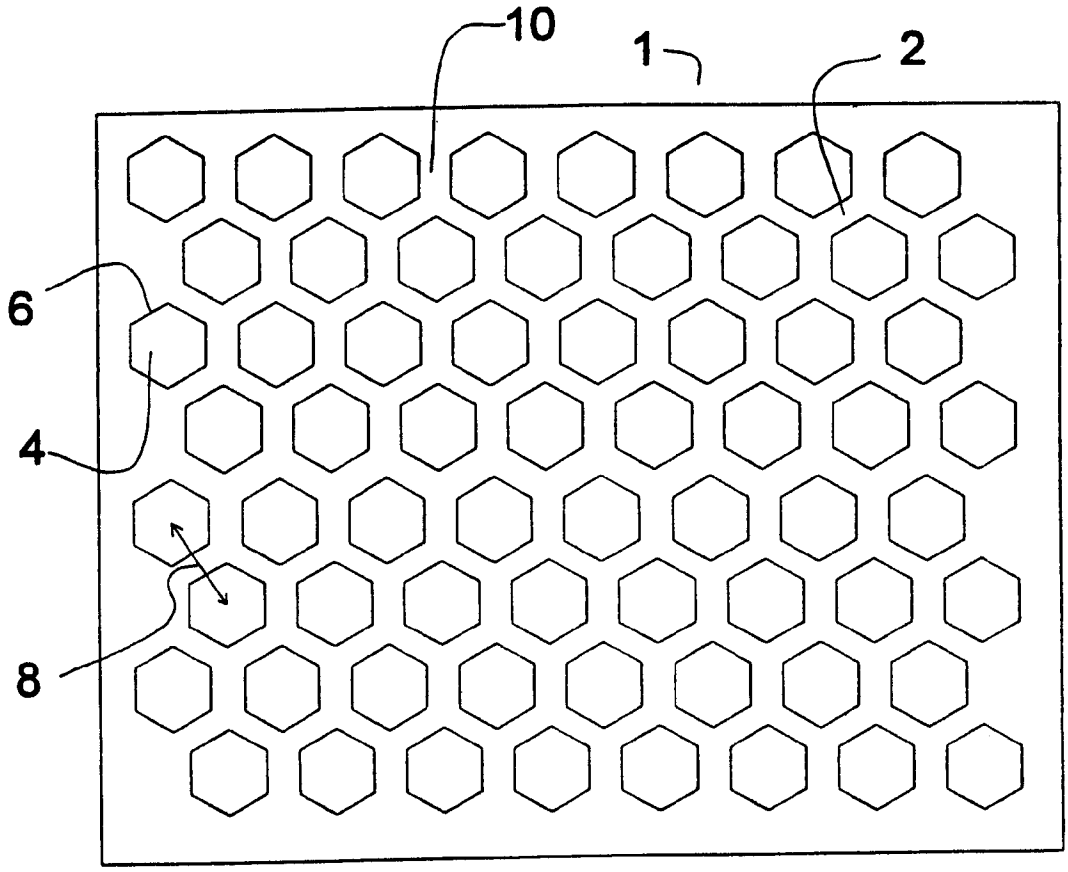


FIG. 1

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/US 98/05537

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B24D11/00 B24D18/00

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B24D

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	US 5 380 390 A (TSELESIN NAUM N) 10 January 1995 see column 3, line 13 - column 5, line 6; figures 1-4	1,16 8,17
A	US 3 774 355 A (DAWSON C ET AL) 27 November 1973 see column 2, line 32 - line 58; figures 1-6,11	1,8,16, 17
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A	US 5 219 462 A (BRUXVOORT WESLEY J ET AL) 15 June 1993 see column 3, line 62 - line 68; figure 2	2,3,9,10

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

☒ Patent family members are listed in annex.

° Special categories of cited documents :

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

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

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

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

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Date of the actual completion of the international search	Date of mailing of the international search report
24 June 1998	02/07/1998

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Eschbach, D

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter ›nal Application No
PCT/US 98/05537

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		WO 9313912 A	22-07-1993
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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
18 April 2002 (18.04.2002)

PCT

(10) International Publication Number
WO 02/31078 A2

(51) International Patent Classification[7]: C09K 3/14, B24D 3/00

(21) International Application Number: PCT/IB01/01875

(22) International Filing Date: 9 October 2001 (09.10.2001)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
00/5624 12 October 2000 (12.10.2000) ZA

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(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.

(84) Designated States *(regional)*: ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

WO 02/31078 A2

(54) Title: POLYCRYSTALLINE ABRASIVE GRIT

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

POLYCRYSTALLINE ABRASIVE GRIT

BACKGROUND OF THE INVENTION

This invention relates to polycrystalline abrasive grit.

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

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

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

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

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

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

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

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

SUMMARY OF THE INVENTION

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

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

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

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

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

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

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

3. A combination of 1 and 2.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

EXAMPLE 1

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

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

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

EXAMPLE 2

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

EXAMPLE 3

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

CLAIMS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 November 2004 (04.11.2004)

PCT

(10) International Publication Number
WO 2004/094106 A1

(51) International Patent Classification[7]: B24B 37/04, 53/007

(21) International Application Number:
PCT/US2003/039969

(22) International Filing Date:
15 December 2003 (15.12.2003)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
10/402,578 28 March 2003 (28.03.2003) US

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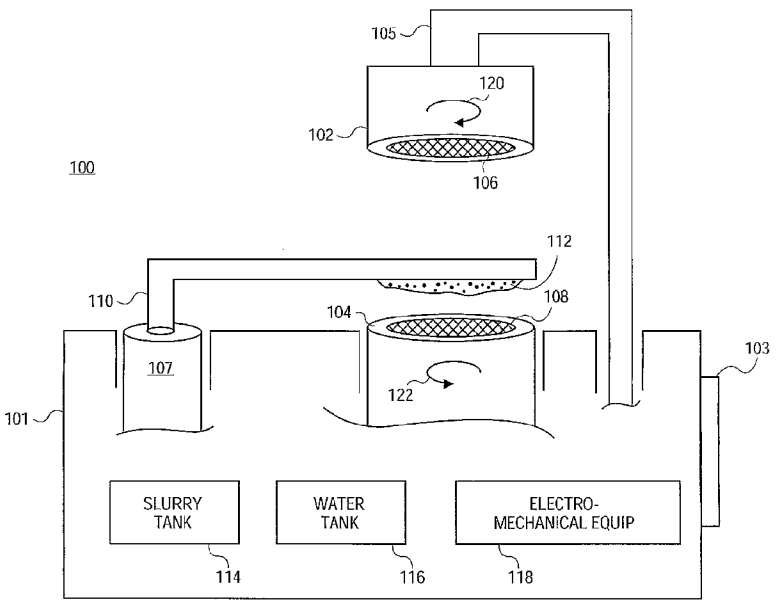
(81) Designated States *(national)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(regional)*: ARIPO patent (BW, GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:
— *with international search report*

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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



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

WO 2004/094106 A1

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

BACKGROUND

1. Field

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

2. Discussion of Related Art

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

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

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

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

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

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

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

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

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

DETAILED DESCRIPTION OF THE ILLUSTRATED EMBODIMENTS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

CLAIMS

What is claimed is:

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

conditioning a soft polishing pad using diamond conditioner.

2. The method of claim 1, further comprising:

rotating a soft polishing pad on a platen;

rinsing the soft polishing pad; and

passing a diamond conditioner over the soft polishing pad.

3. The method of claim 2, further comprising:

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

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

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

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

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

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

a head mounted in a housing;

a wafer mounted to the head;

a platen mounted in the housing;

a soft polishing pad mounted to the platen;

a pad conditioning arm mounted in the housing; and

a diamond conditioner mounted to the pad conditioning arm.

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

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

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

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

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

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

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

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

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

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

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

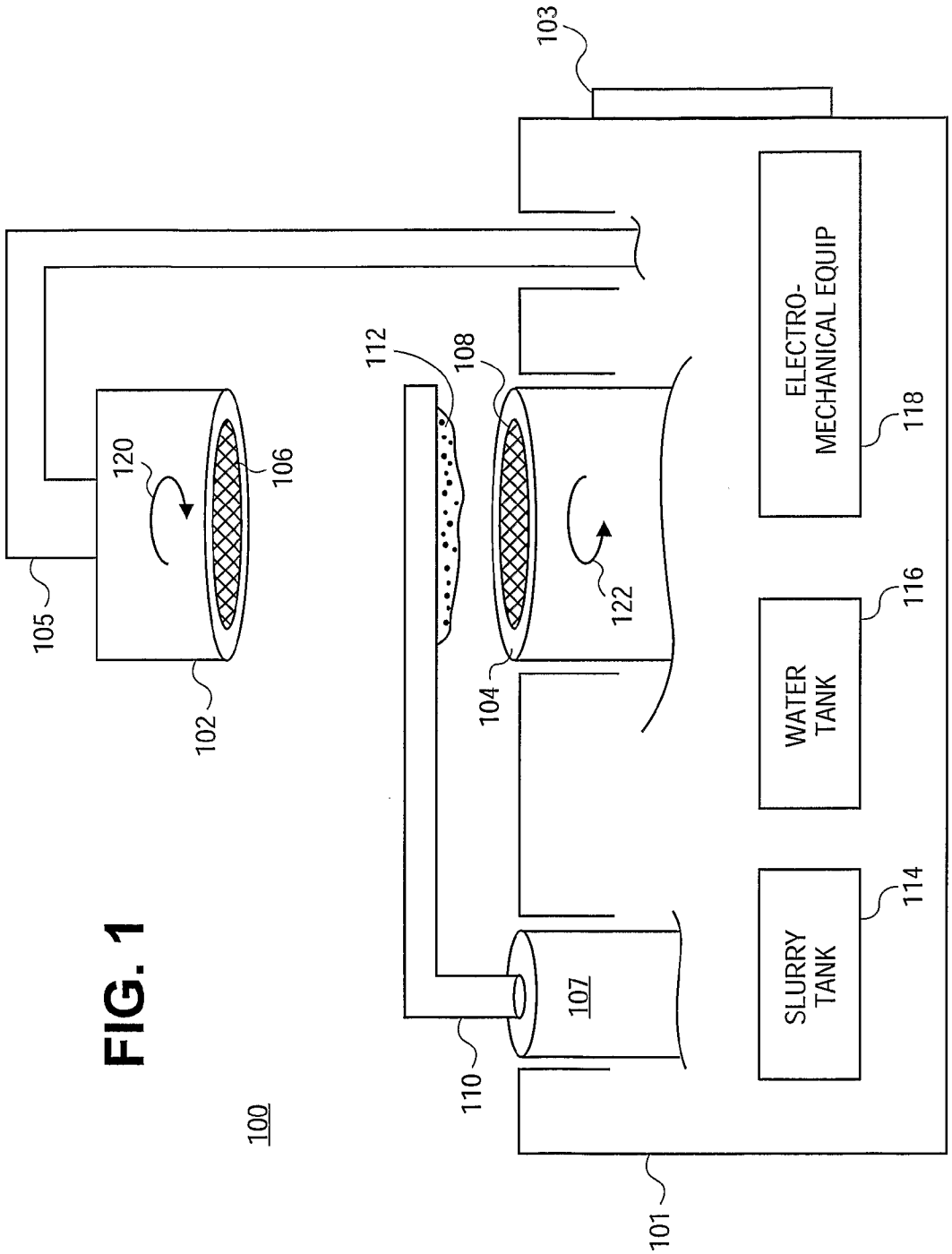

103
ELECTRO-
MECHANICAL EQUIP
118
112
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WATER
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SLURRY
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FIG. 1

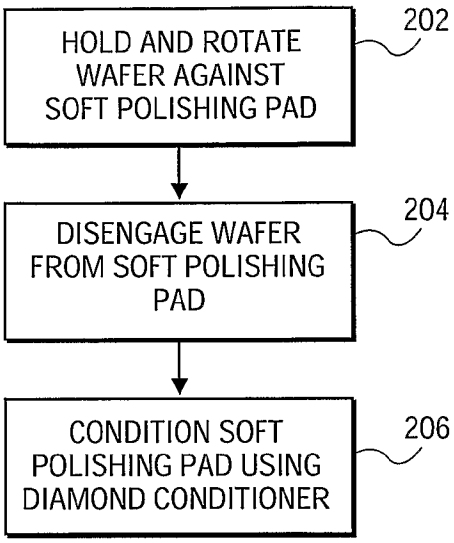

HOLD AND ROTATE WAFER AGAINST SOFT POLISHING PAD
202
DISENGAGE WAFER FROM SOFT POLISHING PAD
204
CONDITION SOFT POLISHING PAD USING DIAMOND CONDITIONER
206

FIG. 2

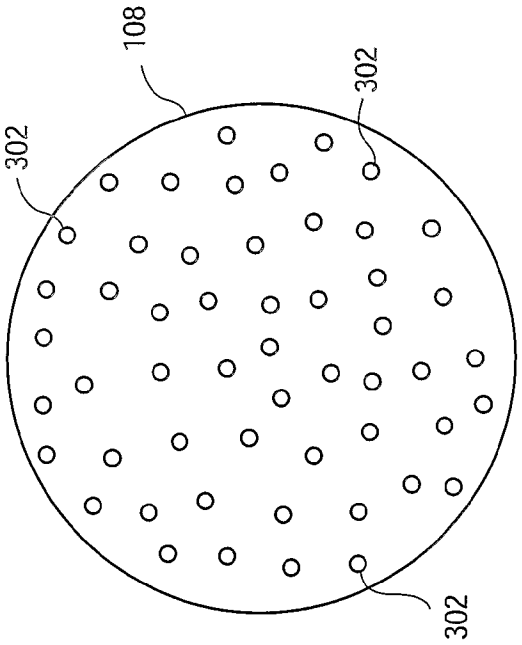


FIG. 3

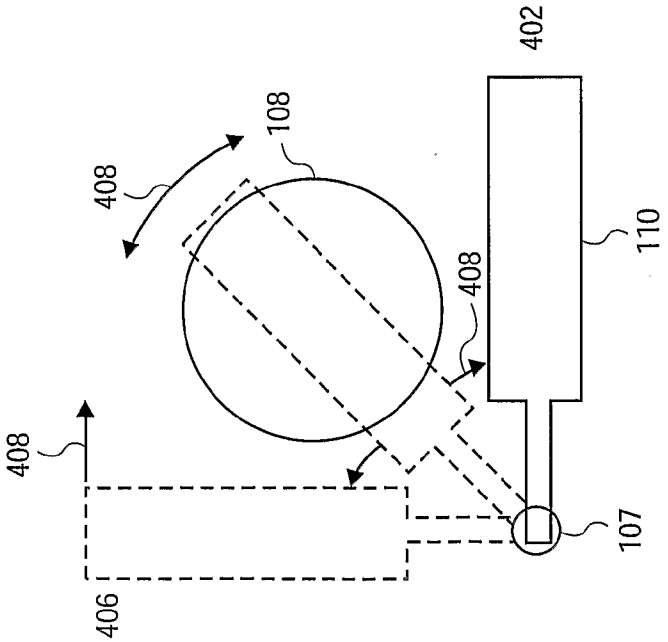


FIG. 4

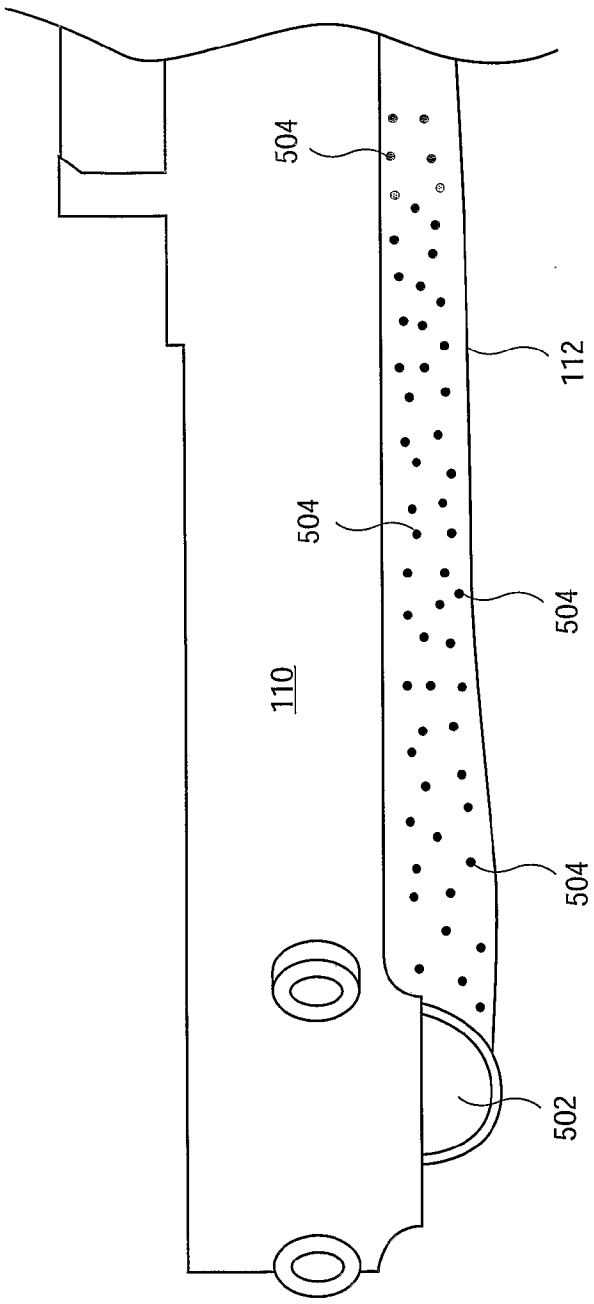


FIG. 5

INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 03/39969

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 B24B37/04 B24B53/007

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

B. FIELDS SEARCHED

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

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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

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

☒ Patent family members are listed in annex.

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

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

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

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

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

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

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

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL – 2280 HV Rijswijk Tel. (+31–70) 340–2040, Tx. 31 651 epo nl, Fax: (+31–70) 340–3016	Do Huu Duc, J

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/US 03/39969

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2001029155 A1	11-10-2001	NONE	
US 2002137436 A1	26-09-2002	US 6340326 B1	22-01-2002
		AU 2940301 A	07-08-2001
		EP 1250215 A1	23-10-2002
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		TW 471994 B	11-01-2002
		WO 0154862 A1	02-08-2001
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(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
23 November 2006 (23.11.2006)

PCT

(10) International Publication Number
WO 2006/124792 A2

(51) International Patent Classification:
B24D 3/00 (2006.01) *B24D 11/00* (2006.01)
B24D 18/00 (2006.01)

(21) International Application Number:
PCT/US2006/018761

(22) International Filing Date: 12 May 2006 (12.05.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/681,798 16 May 2005 (16.05.2005) US
11/357,713 17 February 2006 (17.02.2006) US

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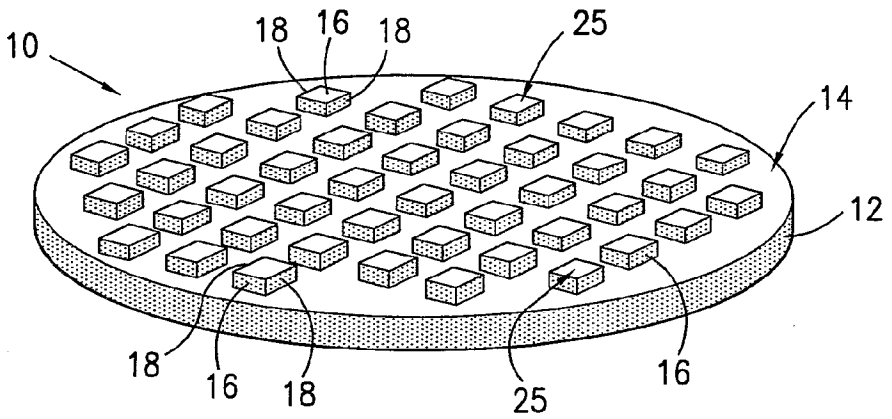
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SM, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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

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(54) Title: SUPERHARD CUTTERS AND ASSOCIATED METHODS



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

WO 2006/124792 A2

SUPERHARD CUTTERS AND ASSOCIATED METHODS

FIELD OF THE INVENTION

The present invention relates generally to cutting devices used to plane workpieces formed of various materials. Accordingly, the present invention involves the fields of chemistry, physics, and materials science.

BACKGROUND OF THE INVENTION

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

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

In addition to these considerations, the line wide (e.g., nodes) of the circuitry on semiconductors is now approaching the virus domain (e.g., 10-100 nm). In addition, more layers of circuitry are now being laid down to meet the increasing demands of advanced logic designs. In order to deposit layers for making nanometer sized features, each layer must be extremely flat and smooth during the semiconductor fabrication. While diamond grid pad conditioners have been effectively used in dressing CMP pads for polishing

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

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

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

SUMMARY OF THE INVENTION

Accordingly, the present invention provides a cutting device, including a base having a working side that can be oriented to face a workpiece from which material is to be removed. A plurality of individual cutting elements can be arranged on the working side of the base. Each cutting element can have a peak that comprises at least one cutting edge that is formed from a polycrystalline superhard material. The peaks of the cutting elements can be aligned in a common plane. The base and each of the cutting elements can be formed from an integral piece of polycrystalline superhard material.

In accordance with another aspect of the invention, a cutting device is provided, including a base having a working side that can be oriented to face a workpiece from

which material is to be removed. The base can be formed from an integral piece of a polycrystalline superhard material. A plurality of individual cutting elements can be integrally formed with the working side of the base. Each cutting element can have a peak that comprises at least a tip. The peaks of the cutting elements can be aligned in a common plane.

In accordance with another aspect of the invention, a method of forming the cutting device above is provided, including the steps of: providing a polycrystalline superhard material compact; and removing material from a working side of a base of the polycrystalline superhard material compact to form the plurality of individual cutting elements from the polycrystalline superhard material compact.

In accordance with another aspect of the invention, a product is provided that can be formed by the process comprising: engaging a surface of a workpiece with a plurality of individual cutting elements of a cutting device, the individual cutting elements being integrally formed from a working side of an integral piece of a polycrystalline superhard material and each cutting element having a peak that is aligned in a common plane; and moving the workpiece and the cutting device relative to one another to thereby remove material from the workpiece with the cutting elements.

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 2 is a side, plan view of the cutting device of FIG. 1;

FIG. 3 is a schematic, partial side view of a cutting element cutting a workpiece in accordance with an embodiment of the invention;

FIG. 4A is a perspective, more detailed view of a series of cutting elements in accordance with an embodiment of the invention;

FIG. 4B is a perspective view of a cutting device having arcuate cutting elements in accordance with an embodiment of the invention;

FIG. 5 is a sectional view of a pair of cutting elements of the cutting device of FIG. 1;

FIG. 6 is a sectional view of a cathode and an anode of an electrical discharge machining process;

FIG. 7A is a top view of a cutting device in accordance with an embodiment of the invention;

FIG. 7B is a sectional view of a series of cutting elements of the cutting device of FIG. 7A;

FIG. 8 is an image of a cutting device with a magnified image of a cutting element in accordance with an aspect of the invention; and

FIG. 9 is an image of a cutting device with a magnified image of a cutting element in accordance with an aspect of the invention.

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

DETAILED DESCRIPTION

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

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

Definitions

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

As used herein, "particle" and "grit" may be used interchangeably, and when used in connection with a carbonaceous material, refer to a particulate form of such material. Such particles or grits may take a variety of shapes, including round, oblong, square, euhedral, etc., as well as a number of specific mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes. All mesh sizes referred to herein are U.S. mesh unless otherwise indicated. Further, mesh sizes are generally understood to indicate an average mesh size of a given collection of particles since each particle within a particular "mesh size" may actually vary over a small distribution of sizes.

As used herein, "substantial," or "substantially," refers to the functional achievement of a desired purpose, operation, or configuration, as though such purpose or configuration had actually been attained. Therefore, cutting edges that are substantially aligned in a common plane function as though, or nearly as though, they were precisely aligned in such a plane.

Furthermore, when used in an exclusionary context, such as a material "substantially lacking" or being "substantially devoid of, or free of" an element, the terms "substantial" and "substantially" refer to a functional deficiency of the element to which reference is being made. Therefore, it may be possible that reference is made to a material in which an element is "substantially lacking," when in fact the element may be present in the material, but only in an amount that is insufficient to significantly affect the material, or the purpose served by the material in the invention.

As used herein, "working side" refers to the side of a tool which contacts or is configured to contact material of a workpiece during a planing or dressing procedure. In some aspects, the working side may merely face a workpiece to be worked, but may not actually contact the workpiece.

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

As used herein, cutting "edge" refers to a portion of a cutting element that includes

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

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

As used herein, "vapor deposition" refers to a process of depositing materials on a substrate through the vapor phase. Vapor deposition processes can include any process such as, but not limited to, chemical vapor deposition (CVD) and physical vapor deposition (PVD). A wide variety of variations of each vapor deposition method can be performed by those skilled in the art. Examples of vapor deposition methods include hot filament CVD, rf-CVD, laser CVD (LCVD), metal-organic CVD (MOCVD), sputtering, thermal evaporation PVD, ionized metal PVD (IMPVD), electron beam PVD (EBPVD), reactive PVD, and the like.

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

As used herein, the term "cutting element" refers to a protrusion or an indentation formed in a cutting device that includes one or more cutting edges or tips that are configured to cut or plane material from a surface of a workpiece. While not so limited,

cutting elements described herein can include a frontal surface and an upper surface that meet at substantially a 90° angle to form the cutting edge. In some cases, cutting elements of the present invention have a three-dimensional configuration with relatively substantial width, depth and height. Each cutting element can include one or more cutting edges that have a cutting width coinciding with one of the width or depth of the cutting element.

As used herein, the term "peak" refers to a relative portion of a cutting element that extends the greatest distance from a base of a cutting element. Thus, when oriented to contact a workpiece, the peaks of cutting elements of a cutting device would contact the surface of the workpiece prior to any other portion of the cutting device contacting the workpiece.

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

Concentrations, amounts, particle sizes, volumes, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited.

As an illustration, a numerical range of "about 1 micrometer to about 5 micrometers" should be interpreted to include not only the explicitly recited values of about 1 micrometer to about 5 micrometers, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc. This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides a cutting device and associated methods that can be utilized in cutting or otherwise affecting a workpiece to remove material from the

workpiece and provide a finished, smooth and/or flat surface to the workpiece. Cutting devices of the present invention can be advantageously utilized, for example, as planing devices that plane material from a workpiece, as dressing devices that dress various workpieces, and as polishing devices that polish various workpieces.

In the embodiment of the invention illustrated in FIG. 1, the cutting device 10 can include a base 12 that can have a working side 14 that faces a workpiece (19 in FIG. 3) to be cut or planed. A plurality of individual cutting elements 16 can be arranged on the working side of the base. Each of the cutting elements can include at least one cutting edge or tip 18, each of which can be aligned in a common plane 20, shown schematically in FIG. 2. As discussed in more detail below, the cutting edges can be engaged with the workpiece 19, and the workpiece and the cutting edges can be moved relative to one another, to cut, slice, plane or otherwise remove small pieces or chips from the workpiece to create a surface on the workpiece that is both very flat and very smooth.

In one aspect of the invention, each of the cutting elements 16 can include one or a plurality of cutting edges 18 aligned in the common plane 20. Thus, in the embodiment illustrated in FIG. 1, each of the cutting elements includes four cutting edges, which can each serve to cut or plane material from a workpiece. By including a plurality of cutting elements, each with a plurality of cutting edges, a total length of cutting edges per cutting element can be advantageously increased. In addition, since each cutting element is of substantially the same height, relative to the working surface of the base, all of the cutting edges from all of the cutting elements can be aligned in the same common plane. By aligning each of the cutting edges in a common plane, the cutting device is substantially self-aligned to shave higher regions of the workpiece first, then continue cutting until all "high" points on the workpiece have been reduced, leaving a smooth and flat workpiece surface.

The cutting edges 18 of the cutting elements 16 can be formed from a variety of materials including, in one embodiment, a polycrystalline superhard material. While not so limited, the polycrystalline superhard material can be a polycrystalline diamond compact ("PCD") or a polycrystalline cubic boron nitride compact ("PcBN"). The PCD or PcBN compact can be formed in a variety of manners, as discussed in more detail below. In the aspect of the invention shown in FIG. 1, the base 12 and each of the cutting elements 16 and cutting edges 18 are integrally formed from an integral piece of polycrystalline superhard material.

The cutting device of the present invention can be utilized in a number of applications, and in one embodiment is particularly well adapted for use in planing substantially brittle materials, such as silicon wafers, glass sheets, metals, used silicon wafers to be reclaimed by planarization, LCD glass, LED substrates, SiC wafers, quartz wafers, silicon nitride, zirconia, etc. In conventional silicon wafer processing techniques, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movements of the platen and the carrier. Thus, the silicon wafer is essentially ground or polished, by very fine abrasives, to a relatively smooth surface.

While grinding of silicon wafers has been used with some success, the process of grinding materials such as silicon wafers often results in pieces of the material being torn or gouged from the body of the material, resulting in a less than desirable finish. This is due, at least in part, to the fact that grinding or abrasive processes utilize very sharp points of abrasive materials (which are often not level relative to one another) to localize pressure to allow the abrasives to remove material from a workpiece.

In contrast to conventional polishing or grinding processes, the present invention can utilize one or more cutting edges of cutting elements to cut material from a workpiece to finish or plane a surface of the workpiece. In general, when a cut is made in a material, the region of the cut will either deform plastically or will crack in a brittle manner. If the plastic deformation is slower than the crack propagation, then the material is known as brittle. The reverse is true for ductile deformation. However, under a high pressure, the rate of crack propagation is suppressed. In this case, a brittle material (e.g. silicon) may exhibit more ductile characteristics, similar to soft metals. When a sharp cutting edge of the present invention is pressed against the surface of brittle silicon, the area of the first contact is extremely small (e.g. a few nanometers across). Consequently, the pressure can be very high (e.g. several GPa). Because the cracks are suppressed, the sharp diamond edge can penetrate silicon plastically. As a result, the external energy can be transferred to the very small volume of silicon continually to sustain the ductile cutting. In other words, the sharp cutting edges can shave or plane silicon in a manner not previously achieved.

The PCD or PcBN compacts of the present invention are generally superhard, resulting in little yielding by the cutting elements when pressed against a wafer. As hardness is generally a measure of energy concentration, e.g., energy per unit volume, the

PCD or PcBN compacts of the present invention are capable of concentrating energy to a very small volume without breaking. These materials can also be maintained with a very sharp cutting edge due to their ability to maintain an edge within a few atoms.

As the ductility of the silicon is maintained by applying pressure to a very small volume, the penetrating radius is generally kept relatively small. This is shown by example in FIG. 2, where the depth of the cutting elements 16 is shown generally by the letter "d" and is on the order of about 0.1 mm. In addition, the shape of the cutting edge must be kept relatively sharp; in some cases with a radius on the order of 2 nm. In order to accommodate these dual traits, the material of the cutting edge of the present invention is hard enough to withstand deformation during the cutting or planing process. In this manner, both sharpness and hardness of the cutter is realized to ensure the ductility of the workpiece. The ductile process of cutting and removing material from a workpiece is shown schematically in FIG. 3, where cutting edge 18 of cutting element 16 is shown shaving chip 24 from the workpiece 19.

Each of the cutting elements 16 can include a substantially planar face 25 that can define a workpiece contact area. A combined workpiece contact area of all of the cutting elements can comprise from between about 5% of a total area of the base to about 20% of a total area of the base. Thus, in one aspect of the invention, if a PCD cutter has a diameter of about 100 mm, and the combined contact areas of the cutting element will be about 10% of that total, then the total contact area of all cutting elements can be about 7850 mm^2. An edge-to-area ratio of each cutting element can be about 4/mm, resulting in a total edge length being about 31400 mm.

The life of the PCD or PcBN cutting devices can often be limited by the radius of the cutting edge. When the edge becomes worn such that the radius is increased to about 10 nm, the contact area may increase up to 100 times. This will reduce the contact pressure significantly. As a result, the edge will not "bite" into the silicon but will rather slide against its surface. In this case, heat will be generated, and the wafer surface might become thermally damaged. Thus, in it can be important that a sharp edge be maintained on the cutting edges, less than about 10 nm in radius for many applications.

The contact area of a cutting device in accordance with the present invention will generally determine the pressure applied to the workpiece. Generally, the larger the area ratio is between the cutting element contact area and the groove, the smaller the contact pressure between the cutting element and the workpiece will be. The contact pressure (P)

will determine the penetration depth (d) as the following expression:

$$d = Pt/B,$$

where t is the thickness of the wafer; and B is the bulk modulus of the workpiece.

In general, bulk modulus measures the incompressibility of a material. Its value generally correlates to the pressure to compress a material completely (zero thickness) at the initial rate of volume reduction. Bulk modulus of a PCD compact is about 4 Mb (megabars); the bulk modulus of silicon is about 1 Mb. Thus, silicon is about four times more compressible than a PCD compact. When a PCD cutting device or planer is pressed against a silicon wafer, the relative displacement of the wafer is due primarily to the sink of silicon wafer surface relative to the PCD surface. A typical silicon wafer is about 1 mm in thickness, so the shaving depth may be approximated by:

$d = 10^{-6}$ P mm, where P is expressed in bar or atmospheric pressure.

If P = 1 bar, then the shaving thickness is about 1 nm. This is about five atomic layers. At this penetration depth, if the cutting edge is sharp (e.g. radius < 1 nm), then the shaving or cutting is ductile, resulting in a finished, planed surface that is very smooth, in some cases smoother than a mirror finish. For this reason, it is important to shave, cut or plane a silicon wafer with very sharp edge of the PCD planer. If the edge becomes overly dull, the ductility of silicon can be lost and the resulting brittle fracturing may destroy the wafer surface.

The cutting devices of the present invention can be utilized in either a wet system or a dry system. In a dry application, the cutting elements can be used to cut or plane chips from a workpiece without the presence of a liquid slurry. In a typical application, the cutting device can be mounted to a holder cushion that can be coupled to a rotatable chuck. The workpiece, for example, a silicon wafer, can be coupled to a vacuum chuck that provides for rotation of the workpiece. Both the rotatable chuck and the vacuum chuck can be rotated in either a clockwise or a counterclockwise direction to remove material from the workpiece. By changing the rotation of one element relative to another, more or less material can be removed in a single rotation of the workpiece. For example, if the workpiece and planer are rotated in the same direction (but at different speeds), less material will be removed than if they are rotated counter to one another.

In this typical application, a slurry can be applied that can aid in planing the workpiece surface. The slurry can be either a water slurry or a chemical slurry. In the case where a chemical slurry is used, the chemical can be selected to provide cooling or to react with the surface of the workpiece to soften the workpiece to provide a more efficient cutting process. It has been found that the wear rate of a silicon wafer can be dramatically increased by softening its surface. For example, a chemical slurry that contains an oxidizing agent (e.g. H_2O_2) may be used to form a relatively highly viscous oxide that will tend to "cling" on the wafer surface. In this case, the PCD cutting devices of the present invention need not necessarily cut the wafer, but rather can scrape the oxide off the surface of the wafer. Consequently, the sharpness of the cutting edge becomes less critical. In addition, the service life of the cutting device can be greatly extended by utilizing a slurry. For example, a PCD scraper used with a slurry may last 1000 times longer than a PCD cutter.

Another way to expedite the removal of silicon wafer is by applying a DC current across the wafer surface. Although diamond is an insulator, PCD is often electrically conducting due to its inclusions of metallic cobalt. In this case, the silicon wafer can be connected to an anode (not shown) and the PCD can be connected to a cathode (not shown). An electrolytically conducting slurry may be used to bridge the two electrodes. In this case, the surface of the silicon may be oxidized by anodation. Furthermore, silicon or its surface circuitry can be dissolved by electrolysis that will further accelerate the material removal process.

Thus, if the cutting device is used to shave or plane in a dry system, it may last for a few passes on a 12 inch wafer. However, chemical slurry may increase the scraped surface area by a thousand times, and if electrical current is applied to assist the material removal, the cutting device may last an even longer time.

FIG. 4A illustrates a variety of cutting elements 16a, 16b, 16c in accordance with an embodiment of the invention. In this aspect of the invention, the cutting elements can be sized and shaped with rectangular cross sections, oval cross sections, circular cross sections, triangular, polygonal, pyramidal cross sections, etc. The various sized and shaped cutting elements can be formed by varying locations, and widths, of grooves cut on the surface of the PCD or PcBN compacts. While not shown in the figures, the cutting elements can also be formed below the surface of a PCD or a PcBN compact, such that the cutting elements comprise inset cavities that include, for example, circular or polygonal

shapes.

As shown in FIG. 4B, the cutting elements 16d can be formed in elongate, arcuate fashion, with grooves cut or formed between the cutting elements. The grooves or depressed regions of the PCD or PcBN compacts can serve as the reservoirs for slurry used to cut wafer, as well as for cut debris. The pattern of the network and the depth of the grooves or recessions can affect the flow for both slurry and debris. Each PCD cutting element design can be optimized for the individual process of planarization of a particular workpiece.

FIG. 5A illustrates two additional embodiments of the invention in which cutting element 16 of the cutting device 10 of FIG. 1 includes a series of secondary cutting elements 40a and 40b formed on an upper surface or face of the cutting element. In this aspect of the invention, the secondary cutting elements can be configured to maintain a sharpness of each of the cutting edges during use of the cutting device. As shown, the secondary cutting elements can vary in shape, and can include pyramidal-shaped cutting elements. The secondary cutting elements can also be formed in a truncated pyramidal shape (not shown). By utilizing secondary cutting elements on the primary cutting elements, the total cutting edge length of the cutting element can be extended by as much as 10,000 times.

FIGs. 7A and 7B illustrate another embodiment of the invention in which a plurality of cutting elements 16e and 16f are formed in a PCD base 12a. As can be appreciated from FIG. 7A, the present invention can provide for the integral formation from a superhard polycrystalline material of cutting elements having differing sizes and configurations. For example, in the embodiment shown, the larger cutting elements 16e can be used as cutting, planing or dressing elements while the smaller cutting elements 16f can be used primarily as "stopping" elements. In other words, the larger cutting elements can extend further from the base 12a of the PCD to cut further, or deeper, into the workpiece (not shown in this figure) on which the PCD is being used.

When the larger cutting elements 16e extend sufficiently far, or deep, into the workpiece, the smaller cutting elements can "bottom out" on the surface of the workpiece to limit further traveling of the larger elements 16e into the workpiece. To facilitate this concept, the larger cutting elements can be made sharper than the smaller cutting elements: for example, they can terminate in an apex point, while the smaller cutting elements can terminate in a flat, planar face. In this manner, the larger cutting elements can more easily

cut the workpiece than can the smaller cutting elements, causing the smaller elements to serve as depth "stopping" elements. In this manner, the present invention can provide very accurate control of the depth that the cutting elements cut into a workpiece (e.g., a PCD pad that is being dressed).

FIGs. 8 and 9 present images taken of cutting elements 16g and 16h, respectively, formed from an integral piece of PCD. As will be appreciated, the present invention provides a great deal of flexibility in the shape and size of the cutting elements that can be formed, with some cutting elements formed in an upright "mesa" configuration, and others formed in a pyramidal configuration.

In addition, as the cutting elements of the present invention can be formed from an integral piece of polycrystalline superhard material, there generally remains a useful excess portion of polycrystalline superhard material below the cutting elements on the base of the cutting device (or that forms the base of the cutting device). Thus, in one aspect of the invention, once the cutting elements have become dull or damaged during use, the cutting device can be sharpened by removing a thin layer of the superhard material across the entire face of the cutting device in the same pattern that was originally created on the face of the device. Cutting devices of the present invention can thus be relatively easily sharpened or repaired, so long as sufficient polycrystalline material remains beneath the cutting elements to allow for further sharpening of the cutting elements.

The PCD or PcBN compacts utilized in the present can be formed in a variety of manners. In one embodiment of the invention, the PCD compact can contain micron (e.g. 1 to 10 μm) diamond, and can be polished before use. In another aspect, the diamond grains can be large (e.g. 50 μm) and the surface can be ground without polishing. In one aspect of the invention, SiC grains can be mixed with diamond grains as the feed stock for a PCD compact. The PCD can include a diamond content of about 80% to about 98% by volume.

The cutting elements of the present invention can be formed on or in the polycrystalline superhard material in a variety of manners. In one aspect, the grooves between the individual cutting elements can be formed on a PCD surface with electro-chemical machining, by laser ablation, by plasma etching, by oxidation (to form carbon dioxide or monoxide gas), hydrogenation (to form methane gas), etc. Laser beams with relatively longer wavelengths (e.g. ND:YAG) have been shown to form grooves on PCD effectively. Laser beams with relatively short wavelengths (e.g. excimers) may be used to

carve out the secondary cutting elements on top of the primary cutting elements (as shown in FIG. 5). While the latter may be slower in cutting speed, it is generally more precise due to the shorter wavelength used. Moreover, the surface damage can be less with more concentrated energy in higher frequencies. This has been found suitable for shaving or planing a silicon wafer in accordance with the present invention.

In another aspect of the invention, material can be removed from a polycrystalline superhard material compact to integrally form the individual cutting elements from the polycrystalline superhard material compact. In other words, the cutting elements can be formed by removing the polycrystalline material from around and about the cutting elements, leaving the cutting elements as the only remaining material above the base of the cutting device.

In one aspect of the invention, the material is removed from the PCD or PcBN compact by electrical discharge machining ("EDM"). In this aspect, the EDM process can utilize one or more electrodes that include diamond. For example, the cathode used in the EDM process can be a boron doped diamond material and the anode used in the EDM process can be the PCD (in this case, the PCD would generally need to be at least partially electrically conductive). As current is applied through the boron doped diamond material, the material of the PCD can be carefully and controllably removed to form various patterns on the PCD.

As shown for example in FIG. 6, in one aspect of the invention, the anode 30 of the EDM process can comprise a portion of a boron doped diamond ("BDD") material through which current is applied. The BDD anode can include a series of "V"-shaped protrusions 31 that, during the EDM process, form a series of corresponding channels 32 in the PCD compact 34 (which, in turn, define a plurality of cutting elements in the PCD compact). While the protrusions are shown as being generally V-shaped, it is of course contemplated that they can be formed in a variety of shapes that can be selected to form channels having desired shapes in the PCD compact. As is known to those having ordinary skill in the art, the EDM process will generally utilize an insulating liquid such as oil or deionized water, the details of which are not illustrated in the drawings.

It has been found that, while the configuration illustrated in FIG. 6 (in which the PCD compact serves as the cathode of the EDM process and the BDD material serves as the anode) performs well, the reverse configuration can also be used. For example, in this aspect of the invention, the BDD material is used as the anode and the PCD is used as the

cathode, resulting in the PCD material removal rate being relatively fast (note that both the BDD material and the PCD material will be consumed, at varying rates, during the EDM process). However, by reversing the polarity (e.g., by using the BDD as the cathode and the PCD as the anode), the PCD material removal rate will be slower than in the first configuration but the surface finish of the PCD will better.

It is contemplated that the use of an electrically conducting diamond containing material as an electrode to remove material from another electrically conducting diamond containing material (as the other electrode) can be extended to a variety of applications in addition to those explicitly discussed herein. For example the diamond-diamond EDM process can be utilized to remove material from an electrically conductive diamond material that is used in: abrasive applications, load bearing applications, protective covering applications, heat spreading applications, material molding applications, acoustic applications, semiconductor applications, etc.

In accordance with another aspect, the present invention provides a product formed by a process comprising: engaging a surface of a workpiece with a plurality of individual cutting elements of a cutting device, the individual cutting elements being integrally formed from a working side of an integral piece of a polycrystalline superhard material and each cutting element having a peak that is aligned in a common plane; and moving the workpiece and the cutting device relative to one another to thereby remove material from the workpiece with the cutting elements.

Examples

The following examples present various methods for making the cutting tools of the present invention. Such examples are illustrative only, and no limitation on present invention is meant thereby.

Example 1:

A boron doped diamond film ("BDD") having a resistivity of about 0.001 ohm-cm and a thickness of about 500 μm has a "zigzag" pattern formed on one edge via a wire EDM process. The resulting blade is mounted on an EDM machine as a cathode. The anode is a flat PCD about 100 mm in diameter and about 2 mm in thickness. The diamond table used is about 500 μm in thickness. An electrically conducting fluid is used to carry the electricity between the two electrodes. During the EDM process, the PCD is gradually traversed across the stationary BDD blade. This process is repeated while the BDD is

gradually descending into the PCD compact. The portion of the PCD that is brought in close proximity to the edge of the BDD is selectively eroded away by electrical discharging, electrolysis, and dissolution.

In this manner, a corresponding "zigzag" pattern of ridges is gradually formed on the flat PCD top. When the grooves reach a predetermined height (e.g., 80 μm), the serrated ridges so formed are cleaned for measurements of geometry. Subsequently, the PCD is rotated 90 degrees and the process is repeated such that pyramid shapes are formed. The angle of the pyramids produced generally matches the angle of the zigzag pattern on the BDD. The tips of these pyramids also duplicate the pattern of recesses of the zigzag pattern on the BDD.

The PCD planer so formed has improved dimension tolerances compared to PCD planers formed by metallic electrodes used in an EDM process. In addition, the consumption rate of BDD blade is much lower. Also, the voltage (90 V) and current (30A) utilized are much lower than metallic electrode processes (e.g. 120 V and 80A). During the process of EDM, the pulsation period for EDD (20 micro seconds on by 20 micro seconds off) can be 10 times longer due to diamond's exceptional thermal stability, thermal conductivity, and chemical inertness. It was estimated that the maximum electrode temperature (about 400° C, compared to oxidation threshold temperature of 750° C) during the BDD EDM process was about 200° C lower than that of the metallic process. The wear rate of the BDD (0.3%) was also fractional compared to the wear rate of copper tungsten (30%). The EDM speed (20 microns per minutes) was twice as fast.

Example 2

The above example was repeated with the reverse polarity: e.g., the BDD was positively biased. In this case, the EDM process was still viable except that the wear rate of the BDD was more than doubled. However, the surface finish of the ADD improved due to a slower erosion rate on the surface.

Example 3

The process of Example 1 was repeated except that the cathode was replaced by a PCD blank of 1.6 mm in thickness (PCD table 0.5 mm thick, cemented tungsten carbide 1.5 mm thick). The PCD used had a 25 μm diamond grain size, it contained 10 wt% of cobalt and had an electrical resistivity of 0.001 ohm-cm.

Example 4

BDD grits of 100/120 mesh were used to make a bronzed bonded grinding wheel. The outside diameter was shaped by a BDD EDM process to form a zigzag pattern thereon. The BDD wheel was then used as a cathode for an EDM process performed on a PCD blank. During the traversing of the PCD surface, the BDD wheel was slowly turned to uniformly expose the contact edge from which electrical current was emitted. After the ridges were formed, the PCD was rotated to traverse in a perpendicular direction until a series of pyramidal cutting elements were formed on the PCD.

Example 5

A BDD was formed to an "A" point and used as an anode in an EDM process. A PCD compact was rotated about the "A" point to gradually form a V notch in the PCD compact. The V notch was formed at several radius positions in order to produce concentric ridges on the PCD surface. The resulting tool can be used as a PCD planer for truing workpieces.

Example 6

The process of Example 5 was repeated followed by traversing the "zigzag"-patterned BDD in three equally spaced directions. The resulting triangular pyramid formed concentric island chains. The resulting tool included excellent radial slurry/debris passages as well as very sharp cutting points.

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

CLAIMS

What is claimed is:

1. A cutting device, comprising:

a base having a working side that can be oriented to face a workpiece from which material is to be removed; and

a plurality of individual cutting elements arranged on the working side of the base, each cutting element having a peak that comprises at least one cutting edge that is formed from a polycrystalline superhard material, the peaks of the cutting elements being aligned in a common plane.

2. The device of claim 1, wherein the base and each of the cutting elements are formed from an integral piece of polycrystalline superhard material.

3. A cutting device, comprising:

a base having a working side that can be oriented to face a workpiece from which material is to be removed, the base being formed from an integral piece of a polycrystalline superhard material; and

a plurality of individual cutting elements integrally formed with the working side of the base, each cutting element having a peak that comprises at least a tip, the peaks of the cutting elements being aligned in a common plane.

4. The device of either of claim 2 or claim 3, wherein the polycrystalline superhard material comprises a polycrystalline diamond compact.

5. The device of claim 4, wherein the polycrystalline diamond compact has a diamond grain size of about 50 μm or smaller.

6. The device of claim 5, wherein the polycrystalline diamond compact has a diamond grain size of about 1 μm to about 10 μm.

7. The device of claim 4, wherein the polycrystalline diamond compact has a diamond content of about 80% to about 98% by volume.

8. The device of either of claim 2 or claim 3, wherein the polycrystalline superhard material comprises a polycrystalline cubic boron nitride compact.

9. The device of claim 1, wherein the cutting device comprises a planing device.

10. The device of claim 3, wherein the cutting device comprises a dressing device.

11. The device of claim 1, further comprising a series of secondary cutting elements formed on a face of each of the cutting elements, the secondary cutting elements being configured to maintain a sharpness of each of the cutting edges during use of the cutting device.

12. The device of either of claim 1 or claim 3, wherein the peaks of the cutting element are operable to cut a substantially brittle material.

13. The device of claim 12, wherein the brittle material is a member selected from the group consisting of: a metal, a silicon wafer, a used silicon wafer to be reclaimed by planarization, LCD glass, an LED substrate, a SiC wafer, a quartz wafer, silicon nitride, zirconia, sapphire, lithium niobate, lithium titantate, PZT, gallium arsenide, gallium nitride, indium nitride, boron phosphate, aluminum nitride and boron nitride.

14. The device of either of claim 1 or claim 3, wherein the peak of each of the cutting elements includes a plurality of cutting edges aligned in the common plane.

15. The device of either of claim 1 or claim 3, wherein the peak of each of the cutting elements includes a shape selected from the group consisting of: a square, a rectangle, a triangle, a hexagon, a circle and an oval.

16. The device of either of claim 1 or claim 3, further comprising a series of secondary cutting elements having at least a tip aligned in a second common plane, the second common plane being disposed closer to an opposing side of the base than is the common plane, the secondary cutting elements being configured to limit a depth to which the cutting elements can cut into the workpiece.

17. The device of claim 16, wherein the secondary cutting elements terminate in a planar face.

18. The device of either of claim 1 or claim 3, wherein the peaks of the cutting elements are leveled relative to the common plane within about 0.5 μm to about 50 μm.

19. The device of claim 18, wherein the peaks of the cutting elements are leveled relative to the common plane within about 25 μm.

20. The device of either of claim 1 or claim 3, wherein the common plane is pitched from about 200 μm to about 2000 μm across the working side of the cutting device.

21. A method of forming the cutting device as recited in either claim 2 or claim 3, comprising the step of:

providing a polycrystalline superhard material compact; and

removing material from a working side of a base of the polycrystalline superhard material compact to form the plurality of individual cutting elements from the polycrystalline superhard material compact.

22. The method of claim 21, wherein the polycrystalline superhard material compact comprises a polycrystalline diamond compact.

23. The method of claim 22, wherein the polycrystalline diamond compact has a diamond grain size of about 50 μm or smaller.

24. The method of claim 23, wherein the polycrystalline diamond compact has a diamond grain size of about 1 μm to about 10 μm.

25. The method of claim 22, wherein the polycrystalline diamond compact has a diamond content of about 80% to about 98% by volume.

26. The method of claim 21, wherein the polycrystalline superhard material compact comprises a polycrystalline cubic boron nitride compact.

27. The method of claim 21, further comprising forming a series of secondary cutting elements on an upper surface of each of the cutting elements, the secondary cutting elements being configured to maintain a sharpness of each of the cutting elements during use of the cutting device.

28. The method of claim 21, wherein cutting edges of the cutting elements are operable to cut a substantially brittle material.

29. The method of claim 28, wherein the brittle material is a member selected from the group consisting of: a metal, a silicon wafer, a used silicon wafer to be reclaimed by planarization, LCD glass, an LED substrate, a SiC wafer, a quartz wafer, silicon nitride, zirconia, sapphire, lithium niobate, lithium titantate, PZT, gallium arsenide, gallium nitride, indium nitride, boron phosphate, aluminum nitride and boron nitride.

30. The method of claim 21, wherein forming the cutting elements includes aligning a plurality of cutting edges of each cutting element in the common plane.

31. The method of claim 21, wherein the peak of each of the cutting elements includes a shape selected from the group consisting of: a square, a rectangle, a triangle, a circle and an oval.

32. The method of claim 21, wherein removing material from the working side of the base includes removing material by a process selected from the group consisting of: laser ablation, electro-chemical machining, plasma etching, oxidation and hydrogenation.

33. The method of claim 21, wherein removing material from the working side of the base includes removing material by electrical discharge machining.

34. The method of claim 33, wherein the electrical discharge machining process utilizes an electrode that includes diamond.

35. The method of claim 34, wherein the electrode is an anode that includes boron doped diamond.

36. The method of claim 35, wherein the boron doped diamond anode includes a series of shaped protrusions extending therefrom, the shaped protrusions being configured to remove material from the face of the compact in a grooved pattern.

37. The method of claim 34, wherein the electrode is a cathode that includes boron doped diamond.

38. The method of claim 35, wherein the boron doped diamond cathode includes a series of shaped protrusions extending therefrom, the shaped protrusions being configured to remove material from the face of the compact in a grooved pattern.

39. The method of claim 21, wherein removing material from the face of the compact further comprises forming a series of secondary cutting elements having at least a tip aligned in a second common plane, the second common plane being disposed closer to an opposing side of the compact than is the common plane, the secondary cutting elements being configured to limit a depth to which the cutting elements can cut into the workpiece.

40. The method of claim 39, wherein each of the secondary cutting elements terminates in a planar face.

41. The method of claim 21, wherein the peaks of the cutting elements are leveled relative to the common plane within about 0.5 μm to about 50 μm.

42. The method of claim 41, wherein the peaks of the cutting elements are leveled relative to the common plane within about 25 μm.

43. The method of claim 21, wherein the common plane is pitched from about 200 μm to about 2000 μm across the face of the cutting device.

44. A product formed by a process comprising:

engaging a surface of a workpiece with a plurality of individual cutting elements of a cutting device, the individual cutting elements being integrally formed from a working side of an integral piece of a polycrystalline superhard material and each cutting element having a peak that is aligned in a common plane; and

moving the workpiece and the cutting device relative to one another to thereby remove material from the workpiece with the cutting elements.

45. The product of claim 44, wherein the polycrystalline superhard material comprises a polycrystalline diamond compact.

46. The product of claim 45, wherein the polycrystalline diamond compact has a diamond grain size of about 50 μm or smaller.

47. The product of claim 46, wherein the polycrystalline diamond compact has a diamond grain size of about 1 μm to about 10 μm.

48. The product of claim 45, wherein the polycrystalline diamond compact has a diamond content of about 80% to about 98% by volume.

49. The product of claim 44, wherein the polycrystalline superhard material comprises a polycrystalline cubic boron nitride compact.

50. The product of claim 44, wherein each of the plurality of cutting elements includes a cutting edge aligned in the common plane.

51. The product of claim 44, wherein the process further comprises engaging the surface of the workpiece with a series of secondary cutting elements having at least a tip aligned in a second common plane, the second common plane being disposed closer to an opposing side of the polycrystalline superhard material than is the common plane, to thereby limit a depth to which the cutting elements cut into the workpiece.

52. The product of claim 51, wherein the secondary cutting elements terminate in a planar face.

53. The product of claim 44, wherein the peaks of the cutting elements are leveled relative to the common plane within about 0.5 μm to about 50 μm.

54. The product of claim 44, wherein the peaks of the cutting elements are leveled within about 15 μm.

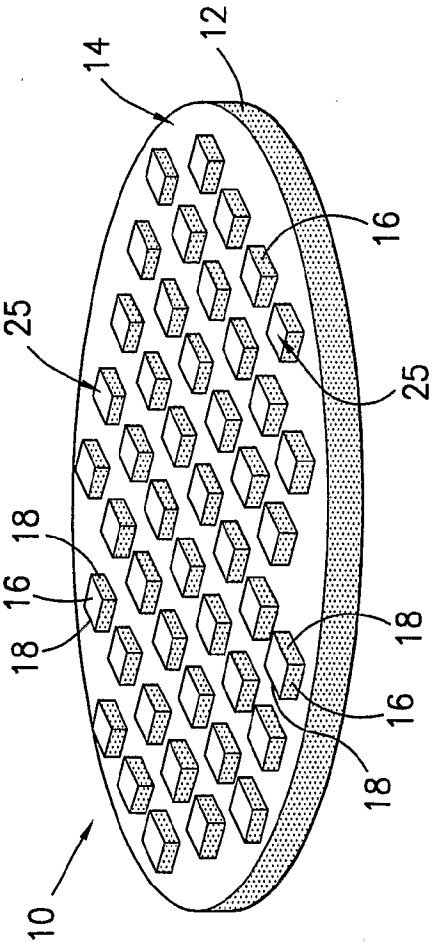


FIG. 1

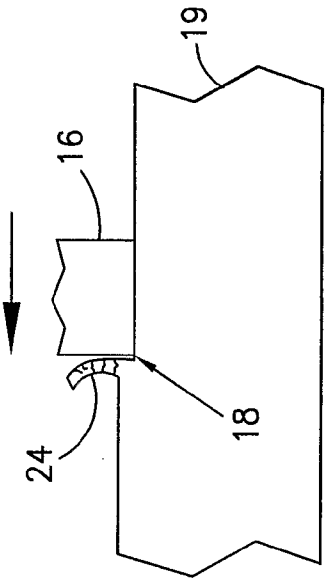


FIG. 3

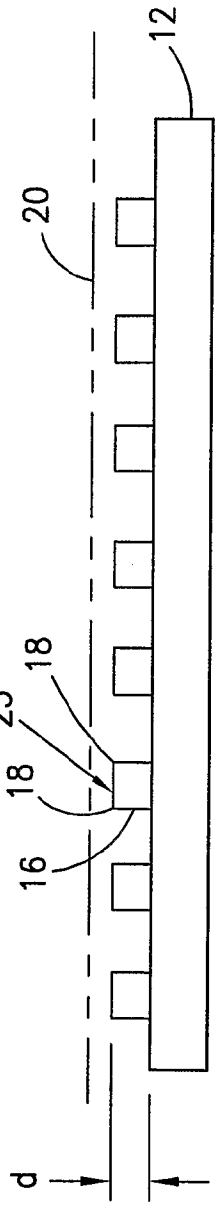


FIG. 2

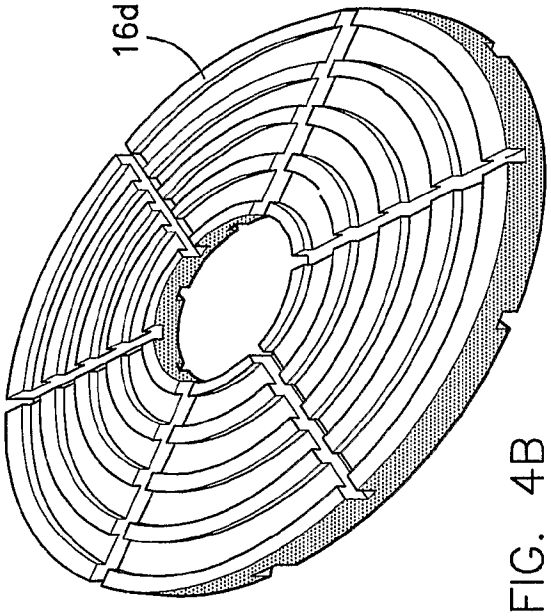


FIG. 4B

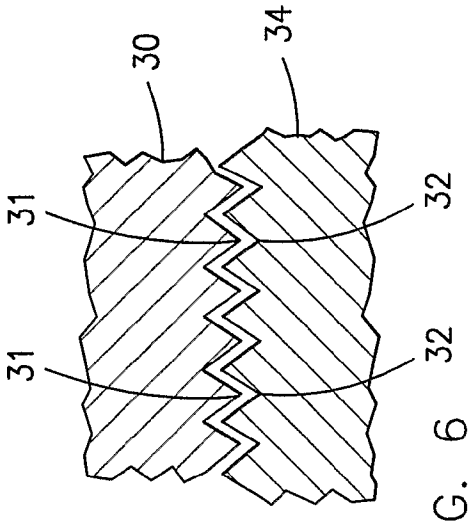


FIG. 6

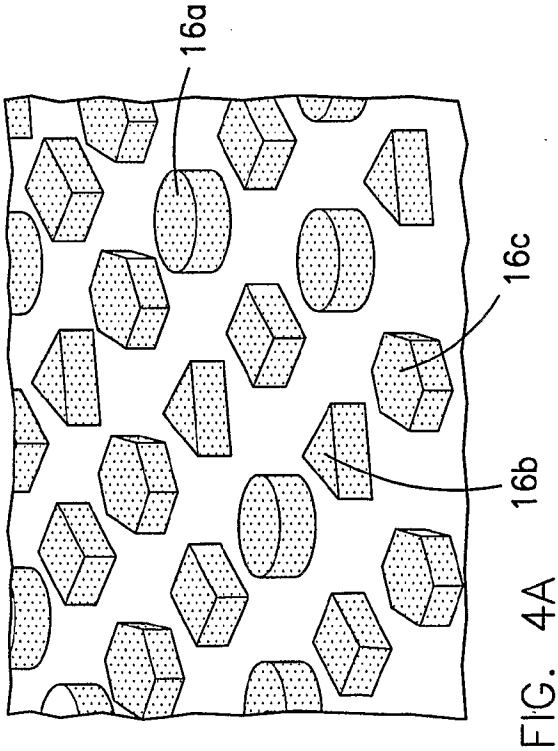


FIG. 4A

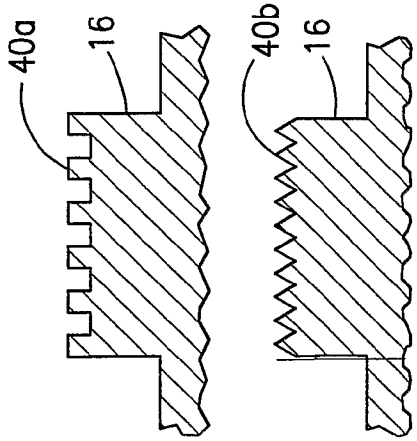


FIG. 5

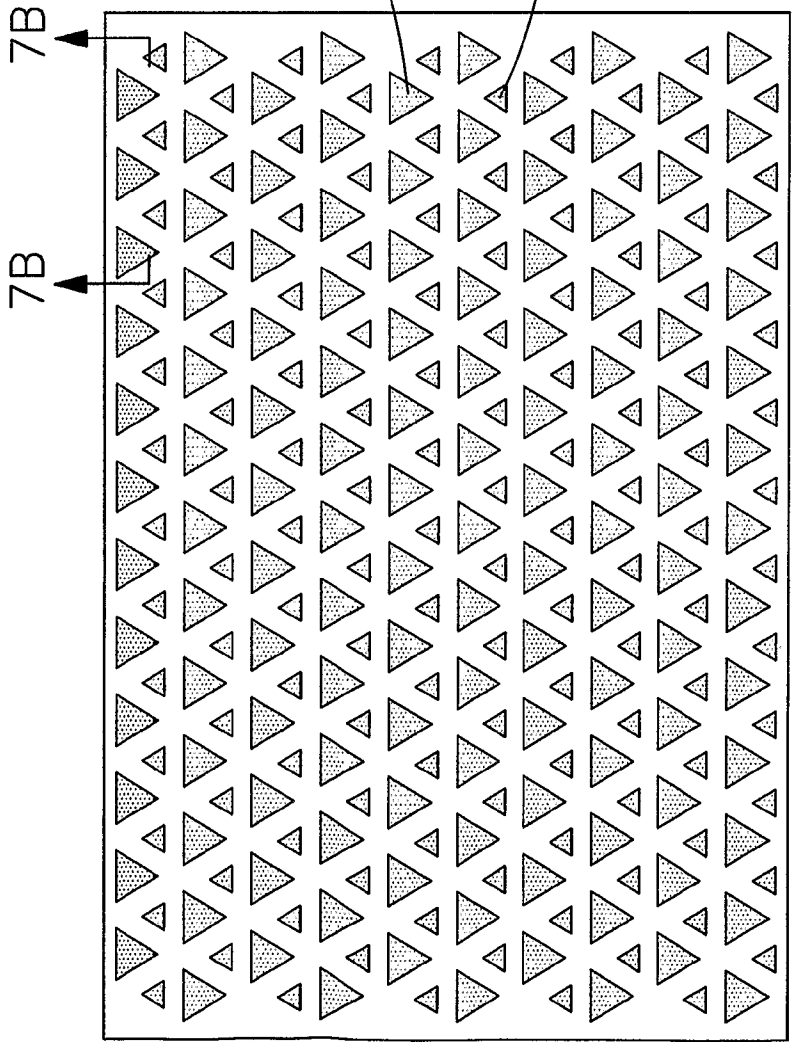


FIG. 7A

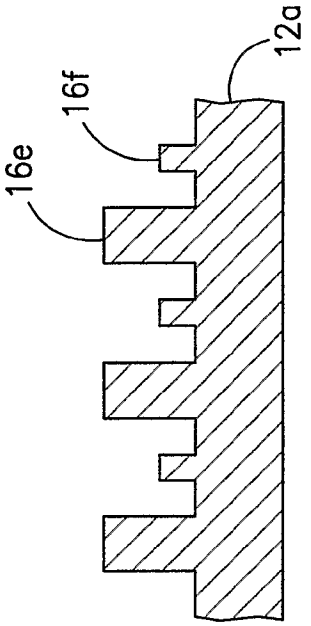


FIG. 7B

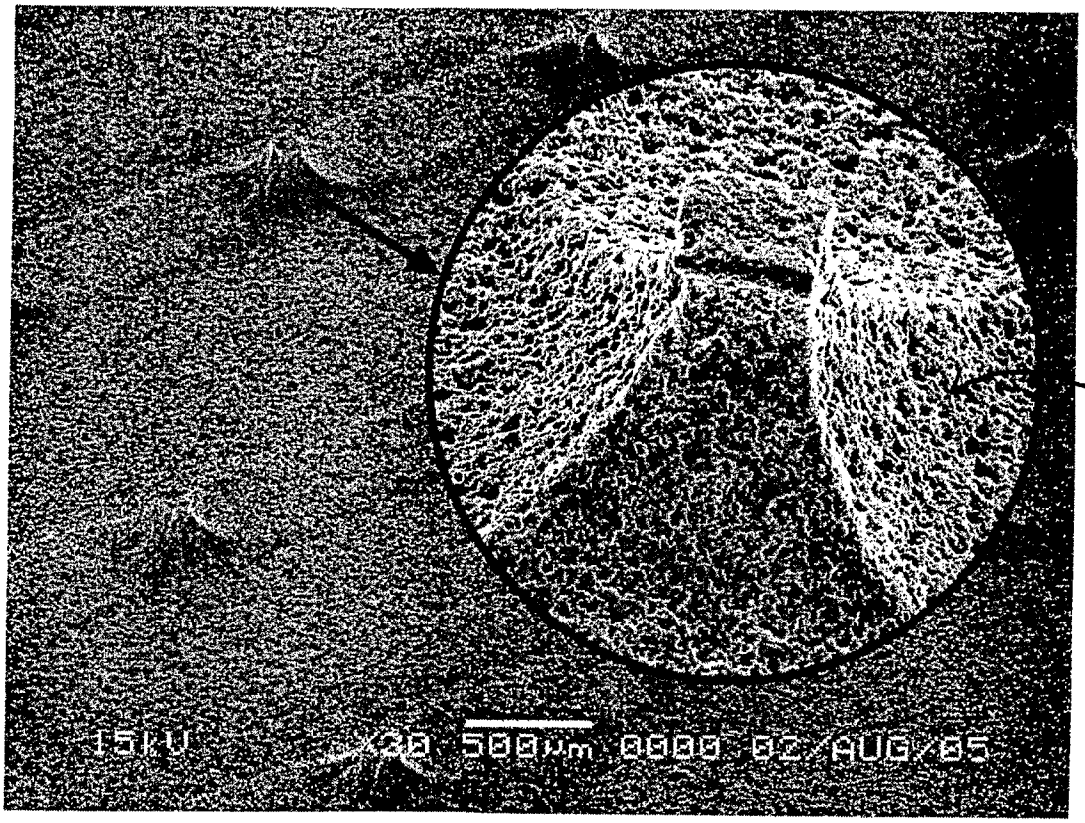


FIG. 8

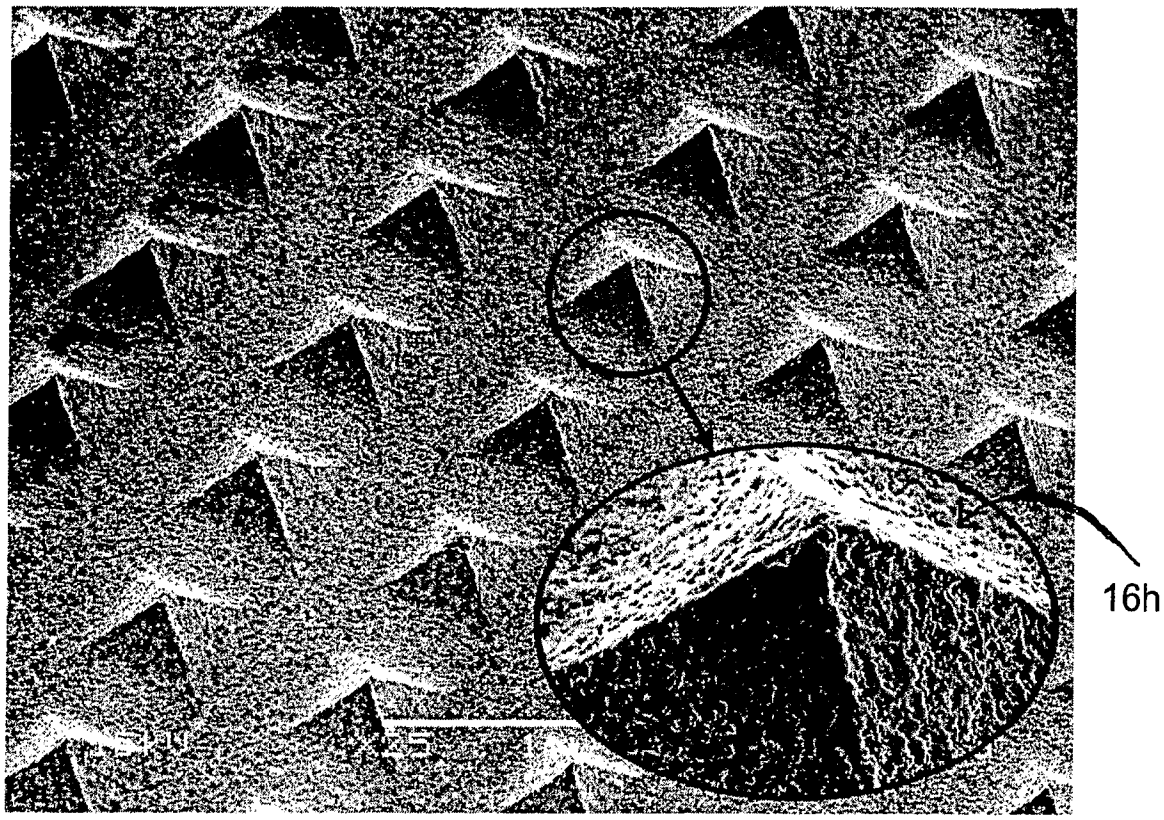


FIG. 9

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
22 March 2007 (22.03.2007)

PCT

(10) International Publication Number
WO 2007/032946 A2

(51) International Patent Classification:
B24B 1/00 (2006.01) *B23F 21/03* (2006.01)

(21) International Application Number:
PCT/US2006/034425

(22) International Filing Date:
1 September 2006 (01.09.2006)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/223,786 9 September 2005 (09.09.2005) US

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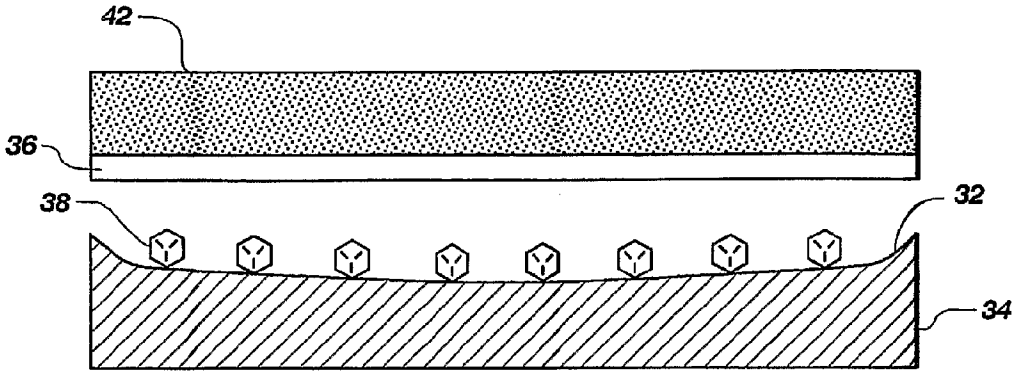
(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LV, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

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



(57) Abstract: Superabrasive tools and their methods of manufacture are disclosed. In one aspect, a method of improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool, a portion of each of said superabrasive particles protruding out of the solidified organic material layer is provided. The method may include securing a plurality of superabrasive particles (12) in the solidified organic material layer (14) in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle (12) when used to abrade a work piece. As an example, the arrangement of the plurality of superabrasive particles (12) may be configured to uniformly distribute frictional forces across substantially each superabrasive particle (12).

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METHODS OF BONDING SUPERABRASIVE PARTICLES IN AN ORGANIC MATRIX

FIELD OF THE INVENTION

The present invention relates generally to tools having superabrasive particles embedded in an organic material matrix and associated methods. Accordingly, the present invention involves the chemical and material science fields.

BACKGROUND OF THE INVENTION

Many industries utilize a chemical mechanical polishing (CMP) process for polishing certain work pieces. Particularly, the computer manufacturing industry relies heavily on CMP processes for polishing wafers of ceramics, silicon, glass, quartz, and metals. Such polishing processes generally entail applying the wafer against a rotating pad made from a durable organic substance such as polyurethane. A chemical slurry is utilized that contains a chemical capable of breaking down the wafer substance and an amount of abrasive particles which act to physically erode the wafer surface. The slurry is continually added to the rotating CMP pad, and the dual chemical and mechanical forces exerted on the wafer cause it to be polished in a desired manner.

Of particular importance to the quality of polishing achieved is the distribution of the abrasive particles throughout the pad. The top of the pad holds the particles by means of fibers or small pores, which provide a friction force sufficient to prevent the particles from being thrown off of the pad due to the centrifugal force exerted by the pad's spinning motion. Therefore, it is important to keep the top of the pad as flexible as possible, to keep the fibers as erect as possible, and to assure that there is an abundance of open pores available to receive newly applied abrasive particles.

One problem that arises with regard to maintaining the pad surface, however, is an accumulation of polishing debris coming from the work piece, the abrasive slurry, and the pad dresser. This accumulation causes a "glazing" or hardening of the top of the pad, mats the fibers down, and thus makes the pad surface less able to hold the abrasive particles of the slurry. These effects significantly decrease the pad's overall polishing performance. Further, with many pads, the pores used to hold the slurry, become clogged, and the overall asperity of the pad's polishing surface becomes depressed and matted. A CMP pad dresser can be used to revive the pad surface by "combing" or

"cutting" it. This process is known as "dressing" or "conditioning" the CMP pad. Many types of devices and processes have been used for this purpose. One such device is a disk with a plurality of superhard crystalline particles such as diamond particles attached to a metal-matrix surface.

Ultra-large-scale integration (ULSI) is a technology that places at least 1 million circuit elements on a single semiconductor chip. In addition to the tremendous density issues that already exist, with the current movement toward size reduction, ULSI has become even more delicate, both in size and materials than ever before. Therefore, the CMP industry has been required to respond by providing polishing materials and techniques that accommodate these advances. For example, lower CMP polishing pressures, smaller size abrasive particles in the slurry, and polishing pads of a size and nature that do not over polish the wafer must be used. Furthermore, pad dressers that cut asperities in the pad which can accommodate the smaller abrasive particles, and that do not overdress the pad must be used.

There are a number of problems in attempting to provide such a pad dresser. First, the superabrasive particles must be significantly smaller than those typically used in currently know dressing operations. Generally speaking, the superabrasive particles are so small that a traditional metal matrix is often unsuitable for holding and retaining them. Further, the smaller size of the superabrasive particles, means that the particle tip height must be precisely leveled in order to uniformly dress the pad. Traditional CMP pad dressers can have particle tip height variations of more than 50 μm without compromising dressing performance. However, such a variation would render a dresser useless if it were required to dress a CMP pad and achieve a uniform asperity depth of 20 μm or less, for example.

In addition to issues with properly holding very small superabrasive particles, the tendencies of metal to warp and buckle during a heating process, cause additional issues in obtaining a CMP pad dresser having superabrasive particle tips leveled to within a narrow tolerance range. While other substrate materials such as polymeric resins have been know, such materials typically are not able to retain superabrasive particles to a degree that is sufficient for CMP pad dressing.

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

Ex. 1003, Page 753

SUMMARY OF THE INVENTION

Accordingly, the present invention provides superabrasive tools and methods that are, without limitation, suitable to groom the CMP pads used for the delicate polishing applications as recited above. In one aspect, a method is provided for improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool, where a portion of each of the superabrasive particles protrude out of the solidified organic material layer. The method may include securing a plurality of superabrasive particles in the solidified organic material layer in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle when used to abrade a work piece. As an example, the arrangement of the plurality of superabrasive particles may be configured to uniformly distribute drag forces across substantially each superabrasive particle.

Various methods are contemplated for minimizing the mechanical stress impinging on the superabrasive particles held in the abrading tool. One example may include superabrasive particle arrangement according to protrusion height. As such, each of the plurality of superabrasive particles may protrude to a predetermined height above the solidified organic material layer. In one aspect, the predetermined height may produce a cutting depth of greater than about 20 microns when used to abrade a work piece. In another aspect, the predetermined height may produce a cutting depth of from about 1 micron to about 20 microns when used to abrade a work piece. In yet another aspect, the predetermined height may produce a cutting depth of from about 10 micron to about 20 microns when used to abrade a work piece.

Arranging superabrasive particles such that they define a profile may also prove to be useful in distributing impinging mechanical forces. As such, the superabrasive particles may protrude to a predetermined height that is along a designated profile. In one aspect, the plurality of superabrasive particles may be arranged such that their tips protrude to less than about 40 microns above the organic material matrix. In another aspect, the plurality of superabrasive particles may be arranged such that their tips protrude to less than about 30 microns above the organic material matrix. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips protrude to less than about 20 microns above the organic material matrix. Thus the designated profile defines the extent to which a plurality of superabrasive particles protrude from the

solidified organic material layer. In one aspect, the designated profile may be a plane. In another aspect, the designated profile may have a slope. In yet another aspect, the designated profile may have a curved shape. In a further aspect, the designated profile may have a dome shape. Additionally, though it is intended that the plurality of superabrasive particles be arranged according to the designated profile, a small amount of deviation therefrom may be likely.

The size of the plurality of superabrasive particles may also affect the distribution of mechanical forces. In one aspect, the plurality of superabrasive particles may be of substantially the same size. Any superabrasive particle size that would provide benefit to the methods and tools of the present invention are considered to be within the present claim scope. In one specific aspect, the plurality of superabrasive particle may be from about 30 microns to about 250 microns in size. In another aspect, the plurality of superabrasive particles are from about 100 microns to about 200 microns in size. Additionally, variations in the size of the plurality of superabrasive particles or the variation thereof may also affect the distribution of mechanical forces. This is particularly true for tools in which impinging mechanical forces vary depending on superabrasive particle location, such as with circumferentially rotating tools. In one aspect, superabrasive particles in a central location of the abrading tool may be larger in size than superabrasive particles in a peripheral location on the abrading tool.

The orientation of the plurality of superabrasive particles may also affect the distribution of mechanical forces in the abrading tool. In one aspect, securing the plurality of superabrasive particles includes arranging the plurality of superabrasive particles according to a predetermined attitude. Though various attitudes are possible, in one specific aspect the predetermined attitude is a uniform attitude across substantially all of the plurality of superabrasive particles. In another aspect, the plurality of superabrasive particles are substantially configured with an apex portion oriented towards a work piece. In addition to uniform attitudes, some aspects include variations in attitude across the abrading tool. For example, in one aspect superabrasive particles in a central location on the abrading tool may be configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the abrading tool may be configured with a face oriented towards the work piece.

The arrangement or distribution of superabrasive particle along the surface of an abrading tool may also function to effectively distribute mechanical forces. In one aspect,

the plurality of superabrasive particles may be arranged as a grid. In another aspect, the plurality of superabrasive particles may be evenly spaced at a distance of from about 2 times to about 4 times the average size of the superabrasive particles. In yet another aspect, the plurality of superabrasive particles may be evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles. In a further aspect, superabrasive particles in a central location on the abrading tool may be spaced farther apart than superabrasive particles in a peripheral location on the abrading tool.

The present invention further encompasses superabrasive tools having improved superabrasive particle retention. As such, in one aspect a superabrasive tool may include a solidified organic material layer and a plurality of superabrasive particles secured in the solidified organic material layer in an arrangement according to the methods recited herein.

Any superabrasive material capable of being utilized according to the methods provided herein would be considered to be within the scope of the present invention. For example, the plurality of superabrasive particles may include, without limitation, diamond, polycrystalline diamond, cubic boron nitride, polycrystalline cubic boron nitride, and combinations thereof.

Various organic materials are also contemplated to hold and secure the superabrasive particles. For example, and without limitation, the solidified organic material layer may include amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof. The solidified organic material layer may also include additional components that modify the characteristics of the material. In one aspect, a reinforcing material may be disposed within at least a portion of the solidified organic material layer. The reinforcing material may be, without limitation, ceramics, metals, or combinations thereof. Examples of ceramic materials include alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof.

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

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a CMP pad dresser made in accordance with one embodiment of the present invention.

FIG. 2 is a cross-sectional view of superabrasive particles disposed on a temporary substrate in accordance with one embodiment of the present invention.

FIG. 3 is a cross-sectional view of superabrasive particles disposed on a temporary substrate in accordance with one embodiment of the present invention.

FIG. 4 is a cross-sectional view of superabrasive particles disposed on a temporary substrate in accordance with one embodiment of the present invention.

FIG. 5 is a cross-sectional view of superabrasive particles disposed in an organic material layer in accordance with one embodiment of the present invention.

FIG. 6 is a cross-sectional view of a CMP pad dresser in accordance with one embodiment of the present invention.

FIG. 7 is a cross-sectional view of superabrasive particles disposed along a layer of organic material in accordance with one embodiment of the present invention.

FIG. 8 is a cross-sectional view of superabrasive particles being pressed into a layer of organic material in accordance with one embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Definitions

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

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

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

As used herein, "superhard" and "superabrasive" may be used interchangeably, and refer to a crystalline, or polycrystalline material, or mixture of such materials having a Vicker's hardness of about 4000 Kg/mm^2 or greater. Such materials may include without limitation, diamond, and cubic boron nitride (cBN), as well as other materials known to those skilled in the art. While superabrasive materials are very inert and thus difficult to form chemical bonds with, it is known that certain reactive elements, such as chromium and titanium are capable of chemically reacting with superabrasive materials at certain temperatures.

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

As used herein, "particle" and "grit" may be used interchangeably, and when used in connection with a superabrasive material, refer to a particulate form of such material. Such particles or grit may take a variety of shapes, including round, oblong, square, euhedral, etc., as well as a number of specific mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes.

As used herein, "mechanical bond" and "mechanical bonding" may be used interchangeably, and refer to a bond interface between two objects or layers formed primarily by frictional forces. In some cases the frictional forces between the bonded objects may be increased by expanding the contacting surface areas between the objects, and by imposing other specific geometrical and physical configurations, such as substantially surrounding one object with another.

As used herein, "leading edge" means the edge of a CMP pad dresser that is a frontal edge based on the direction that the CMP pad is moving, or the direction that the pad is moving, or both. Notably, in some aspects, the leading edge may be considered to encompass not only the area specifically at the edge of a dresser, but may also include

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portions of the dresser which extend slightly inward from the actual edge. In one aspect, the leading edge may be located along an outer edge of the CMP pad dresser. In another aspect, the CMP pad dresser may be configured with a pattern of abrasive particles that provides at least one effective leading edge on a central or inner portion of the CMP pad dresser working surface. In other words, a central or inner portion of the dresser may be configured to provide a functional effect similar to that of a leading edge on the outer edge of the dresser.

As used herein, "centrally located particle," "particle in a central location" and the like mean any particle of a tool that is located in an area of the tool that originates at a center point of the tool and extends outwardly towards the tool's edge for up to about 90% of the radius of the tool. In some aspects, the area may extend outwardly from about 20% to about 90% of the radius. In other aspects, the area may extend out to about 50% of the radius. In yet another aspect, the area may extend out to about 33% of the radius of a tool.

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

As used herein, "working end" refers to an end of a particle which is oriented towards the work piece being abraded by a tool. Most often the working end of a particle will be distal from a substrate to which the particle is attached.

As used herein, "ceramic" refers to a hard, often crystalline, substantially heat and corrosion resistant material which may be made by firing a non-metallic material, sometimes with a metallic material. A number of oxide, nitride, and carbide materials considered to be ceramic are well known in the art, including without limitation, aluminum oxides, silicon oxides, boron nitrides, silicon nitrides, and silicon carbides, tungsten carbides, etc.

As used herein, "grid" means a pattern of lines forming multiple squares.

As used herein, "attitude" means the position or arrangement of a superabrasive particle in relation to a defined surface, such as a substrate to which it is attached, or a

work piece to which it is to be applied during a work operation. For example, a superabrasive particle can have an attitude that provides a specific portion of the particle in orientation toward the work piece.

As used herein, "substantially" refers to situations close to and including 100%. Substantially is used to indicate that, though 100% is desirable, a small deviation therefrom is acceptable. For example, substantially all superabrasive particles includes groups of all superabrasive particles and groups of all superabrasive particles minus a relatively small portion of superabrasive particles.

As used herein, "mechanical force" and "mechanical forces" refer to any physical force that impinges on an object that causes mechanical stress within or surrounding the object. Example of mechanical forces would be frictional forces or drag forces. As such, the terms "frictional force" and "drag force" may be used interchangeably, and refer to mechanical forces impinging on an object as described.

As used herein, "mechanical stress" refers to a force per unit area that resists impinging mechanical forces that tend to compact, separate, or slide an object.

As used herein, the term "profile" refers to a contour above an organic material layer surface to which the superabrasive particles are intended to protrude.

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

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

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This same principle applies to ranges reciting only one numerical value. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides organic material-based CMP pad dressers including methods for their use and manufacture. Though much of the following discussion relates to CMP pad dressers, it should be understood that the methods and tools of the presently claimed invention are equally applicable to any tool that utilizes abrasive or superabrasive materials, all of which are considered to be within the scope of the present invention. The inventor has found that the retention of a superabrasive particle in an organic material layer can be improved by arranging the superabrasive particles in the organic material layer such that mechanical stress impinging on any individual superabrasive particle is minimized. By reducing the stress impinging on each individual superabrasive particle they can be more readily retained in a solidified organic material layer, particularly for delicate tasks.

Accordingly, one aspect of the present invention provides a method of improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool having a portion of the superabrasive particles protruding out of the solidified organic material layer. The method can include securing a plurality of superabrasive particles in the solidified organic material layer in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle when used to abrade a work piece. Though various methods of minimizing mechanical stress are possible, in one aspect the arrangement of the plurality of superabrasive particles may be configured to uniformly distribute frictional forces across substantially each superabrasive particle. Such a uniform distribution of frictional force prevents any individual superabrasive particle from being overstressed and pulling out of the solidified organic material layer.

Various configurations or arrangements are contemplated for minimizing the mechanical stress impinging on the superabrasive particles held in the abrading tool. One potentially useful parameter may include the height that the superabrasive particles protrude above the organic material layer. A superabrasive particle that protrudes to a significantly greater height than other superabrasive particles will experience a greater proportion of the impinging mechanical forces and thus is more prone to pull out of the

solidified organic material layer. Thus an even height distribution of superabrasive particles may function to more effectively preserve the integrity of the abrading tool as compared to abrading tools lacking such an even height distribution. As such, in one aspect, a majority of the plurality of superabrasive particles may protrude to a predetermined height above the solidified organic material layer. Though any predetermined height that would be useful in an abrading tool would be considered to be within the presently claimed scope, in one specific aspect the predetermined height may produce a cutting depth of less than about 20 microns when used to abrade a work piece. In another specific aspect, the predetermined height may produce a cutting depth of from about 1 micron to about 20 microns when used to abrade a work piece. In yet another specific aspect, the predetermined height may produce a cutting depth of from about 10 micron to about 20 microns when used to abrade a work piece. It should also be noted that the leveling of superabrasive particles to a predetermined height may be dependent on superabrasive particle spacing. In other words, the farther superabrasive particles are separated, the more the impinging forces will affect each superabrasive particle. As such, patterns with increased spacing between the superabrasive particles may benefit from a smaller variation from predetermined height.

It may also be beneficial for the superabrasive particles to protrude from the solidified organic material layer to a predetermined height or series of heights that is/are along a designated profile. Numerous configurations for designated profiles are possible, depending on the particular use of the abrading tool. In one aspect, the designated profile may be a plane. In planar profiles, the highest protruding points of the superabrasive particles are intended to be substantially level. It is important to point out that, though it is preferred that these points align with the designated profile, there may be some height deviation between superabrasive particles that occur due to limitations inherent in the manufacturing process.

In addition to planar profiles, in another aspect of the present invention the designated profile has a slope. Tools having sloping surfaces may function to more evenly spread the frictional forces impinging thereon across the superabrasive particles, particularly for rotating tools such as disk sanders and CMP pad dressers. The greater downward force applied by higher central portions of the tool may offset the higher rotational velocity at the periphery, thus reducing the mechanical stress experienced by superabrasive particles in that location. As such, the slope may be continuous from a

central point of the tool to a peripheral point, or the slope may be discontinuous, and thus be present on only a portion of the tool. Similarly, a given tool may have a single slope or multiple slopes. In certain aspects, the tool may slope in a direction from a central point to a peripheral point, or it may slope from a peripheral point to a central point. Various slopes are contemplated that may provide a benefit to solidified organic material layer tools. It is not intended that the claims of the present invention be limited as to specific slopes, as a variety of slopes in numerous different tools are possible. In one aspect, however, a CMP pad dresser may benefit from an average slope of 1/1000 from the center to the periphery.

As a variation on tools having a slope, in certain aspects the designated profile may have a curved shape. One specific example of a curved shape is a dome shape tool. Such curved profiles function in a similar manner to the sloped surfaces. Tools may include such curved profiles in order to more effectively distribute the frictional forces between all of the superabrasive particles, thus reducing failures of individual particles and prolonging the life of the tool.

As has been mentioned herein, while it is intended that the tips of the superabrasive particles align along the designated profile, some level of deviation may occur. These deviations may be a result of the design or manufacturing process of the tool. Given the wide variety of sizes of superabrasive particles that may potentially be utilized in a given tool, such deviations may be highly dependent on a particular application. Also, when referring to the designated profile, it should be noted that the term "tip" is intended to include the highest protruding point of a superabrasive particle, whether that point be an apex, an edge, or a face. As such, in one aspect a majority of the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 1 micron to about 150 microns. In another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 5 microns to about 100 microns. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 10 microns to about 75 microns. In a further aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 10 microns to about 50 microns. In another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 50 microns to about 150 microns. In yet another aspect,

the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 20 microns to about 100 microns. In a further aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 20 microns to about 50 microns. In another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by from about 20 microns to about 40 microns. Additionally, in one aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 20 microns. In another aspect the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 10 microns. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 5 microns. In yet another aspect, the plurality of superabrasive particles are arranged such that their tips vary from the designated profile by less than about 1 microns. In a further aspect, a majority of the plurality of superabrasive particles are arranges such that their tips vary from the designated profile to less than about 10% of the average size of the superabrasive particles.

Variations in superabrasive particle size between different locations on the tool may also help to more evenly distribute the frictional forces impinging thereon. Larger superabrasive particles will most likely experience greater frictional force than would smaller particles. Additionally, in the case circumferentially rotating tools such as CMP pad dressers, superabrasive particles located near the periphery will most likely experience greater frictional force than particles located more centrally due to the greater rotational velocity at the periphery. In such a case, frictional forces may be distributed across the CMP pad by locating larger superabrasive particles more centrally to offset this increase. As a result, the frictional forces are more evenly spread across all superabrasive particles, thus reducing particle failure. As such, in one aspect superabrasive particles in a central location of the abrading tool are larger in size than superabrasive particles in a peripheral location on the abrading tool. In another aspect, superabrasive particles in a central location of the abrading tool may be smaller than superabrasive particles in a peripheral location on the abrading tool. This configuration may provide benefit to circumferentially rotating tools, where the mechanical stresses on superabrasive particles are greater at the periphery. The larger superabrasive particles extend deeper into the organic material layer, and are thus more firmly supported therein. Also, for CMP pad

dressers, larger particles at the periphery may provide more slurry clearance than smaller particles. Additionally, although a variety of sizes are contemplated, in one aspect the plurality of superabrasive particle may be from about 30 microns to about 500 microns in size. In another aspect the plurality of superabrasive particles are from about 100 microns to about 200 microns in size. It is also contemplated that the plurality of superabrasive particles may be of substantially the same size.

Variations in the attitude of superabrasive particles in the solidified organic material layer may also function to more effectively distribute frictional forces across the abrading tool. Orienting superabrasive particles in particular locations of the abrading tool such that similar apexes, edges, and/or faces are exposed may allow a more even distribution of frictional forces, particularly if the densities of superabrasive particles in those locations are concomitantly arranged. As such, in one aspect securing the plurality of superabrasive particles in the solidified organic material layer may include arranging the plurality of superabrasive particles according to a predetermined attitude. In various aspects, the predetermined attitude may be a uniform attitude across substantially all of the plurality of superabrasive particles. In other words, similar apexes, edges, or faces for substantially all of the superabrasive particles in the abrading tool may be facing the same direction. In one aspect, the plurality of superabrasive particles may be substantially configured with an apex portion oriented towards a work piece. As such, impinging frictional forces may be reduced by orienting the plurality of superabrasive particles such that their tips or apexes are substantially oriented towards the work piece. This may be partially due to the smaller surface area of the apex region of the superabrasive particles coming in contact with the work piece during abrading as compared to the larger surface areas of the edge or face regions. Also, the attitude of the plurality of superabrasive particles can also vary depending on the location of particles on the abrading tool. For example, in one aspect superabrasive particles in a central location on the abrading tool may be configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the abrading tool may be configured with a face oriented towards the work piece. In another aspect, superabrasive particles in a central location on the abrading tool may be configured with an apex portion oriented towards a work piece, superabrasive particles in a peripheral location on the abrading tool may be configured with a face oriented towards the work piece, and superabrasive

particles in a middle location on the abrading tool may be configured with an edge oriented towards the work piece.

It may be preferable to utilize superabrasive particles smaller than about 40 microns when orienting face portions towards the work piece. In this case, the face is not big enough to overstress those superabrasive particles. Faces also have the advantage of having four edges that can be used to cut the work piece.

The distribution of frictional forces may also be varied through the arrangement or distribution of the superabrasive particles in the solidified organic material layer. For example, in one aspect the plurality of superabrasive particles may be arranged as a grid. Though the even or uniform spacing of the superabrasive particle can exhibit wide variation across abrading tools, in one specific aspect the plurality of superabrasive particles may be evenly spaced at a distance of from about 2 times to about 4 times the average size of the superabrasive particles. In another specific aspect the plurality of superabrasive particles may be evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles. In yet another specific aspect the plurality of superabrasive particles may be evenly spaced at a distance of from about 3 times to about 4 times the average size of the superabrasive particles. In a further aspect, the plurality of superabrasive particles may be evenly spaced at a distance of from about 4 times to about 5 times the average size of the superabrasive particles. In yet another aspect, the plurality of superabrasive particles may be evenly space at a distance of from about 100 microns to about 800 microns. As has been discussed herein, however, if all superabrasive particles are evenly spaced, those particles near the periphery will experience greater mechanical stress due to the higher rotational velocity of the abrading tool at that location. The larger the tool, the greater the disparity in the impinging mechanical forces between the center of the tool and the periphery. Because of this, it may be beneficial to vary the spacing of the superabrasive particle depending on location to more effectively distribute frictional forces across the abrading tool. In one aspect, for example, superabrasive particles in a central location on the abrading tool may be spaced farther apart than superabrasive particles in a peripheral location on the abrading tool. In this way, the increased frictional forces due to the greater density of superabrasive particles in the central location may offset the increased frictional forces at the periphery due to the greater rotational velocity of the abrading tool.

Turning to organic material layers, numerous organic materials are known to those skilled in the art which would be useful when utilized in embodiments of the present invention, and are considered to be included herein. The organic material layer can be any curable resin material, resin, or other polymer with sufficient strength to retain the superabrasive grit of the present invention. It may be beneficial to use an organic material layer that is relatively hard, and maintains a flat surface with little or no warping. This allows the abrading tool to incorporate very small superabrasive particles at least partially therein, and to maintain these small superabrasive particles at relatively level and consistent heights. Additionally, various organic materials may act to absorb mechanical forces impinging on the superabrasive particles disposed therein, and thus spread and equalize such forces across the abrading tool.

Methods of curing the organic material layer can be any process known to one skilled in the art that causes a phase transition in the organic material from at least a pliable state to at least a rigid state. Curing can occur, without limitation, by exposing the organic material to energy in the form of heat, electromagnetic radiation, such as ultraviolet, infrared, and microwave radiation, particle bombardment, such as an electron beam, organic catalysts, inorganic catalysts, or any other curing method known to one skilled in the art. In one aspect of the present invention, the organic material layer may be a thermoplastic material. Thermoplastic materials can be reversibly hardened and softened by cooling and heating respectively. In another aspect, the organic material layer may be a thermosetting material. Thermosetting materials cannot be reversibly hardened and softened as with the thermoplastic materials. In other words, once curing has occurred, the process is essentially irreversible.

Organic materials that may be useful in embodiments of the present invention include, but are not limited to: amino resins including alkylated urea-formaldehyde resins, melamine-formaldehyde resins, and alkylated benzoguanamine-formaldehyde resins; acrylate resins including vinyl acrylates, acrylated epoxies, acrylated urethanes, acrylated polyesters, acrylated acrylics, acrylated polyethers, vinyl ethers, acrylated oils, acrylated silicons, and associated methacrylates; alkyd resins such as urethane alkyd resins; polyester resins; polyamide resins; polyimide resins; reactive urethane resins; polyurethane resins; phenolic resins such as resole and novolac resins; phenolic/latex resins; epoxy resins such as bisphenol epoxy resins; isocyanate resins; isocyanurate resins; polysiloxane resins including alkylalkoxysilane resins; reactive vinyl resins; resins

marketed under the Bakelite trade name, including polyethylene resins, polypropylene resins, epoxy resins, phenolic resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, ethylene copolymer resins, acrylonitrile-butadiene-styrene (ABS) resins, acrylic resins, and vinyl resins; acrylic resins; polycarbonate resins; and mixtures and combinations thereof. In one aspect of the present invention, the organic material may be an epoxy resin. In another aspect, the organic material may be a polyimide resin. In yet another aspect, the organic material may be a polyurethane resin. In yet another aspect, the organic material may be a polyurethane resin.

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

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of each superabrasive particle to facilitate the retention of the superabrasive particles in the organic material matrix via chemical bonding. A wide variety of organic and organometallic compounds are known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive particles and the organic material matrix, thus increasing the retention of the particles therein. In this way, the organometallic coupling agent acts as a bridge to form bonds between the organic material matrix and the surface of the superabrasive particles. In one aspect of the present invention, the organometallic coupling agent can be a titanate, zirconate, silane, or mixture thereof.

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

(available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.); and additional examples of suitable silane coupling agents can be found in U.S. Pat. Nos. 4,795,678, 4,390,647, and 5,038,555, which are each incorporated herein by reference.

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

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

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

The amount of organometallic coupling agent used depends on the coupling agent and on the surface area of the superabrasive particles. Typically, 0.05% to 10% by weight of the organic material layer is sufficient.

The superabrasive particles used in embodiments of the present invention may be selected from a variety of specific types of diamond (e.g., polycrystalline diamond) and cubic boron nitride (e.g., polycrystalline cBN). It may be useful to select a superabrasive material capable of chemically bonding with a reactive material, such as those described herein. Further, these particles may take a number of different shapes as required to accommodate a specific purpose for the tool into which it is anticipated that they will be incorporated. However, in one aspect, the superabrasive particle may be diamond, including natural diamond, synthetic diamond, and polycrystalline diamond (PCD). In yet another aspect, the superabrasive particle may be cubic boron nitride (cBN), either single crystals or polycrystalline. In yet another aspect, the superabrasive particle may be a member selected from the group consisting of SiC, Al_2O_3, Zr O_2, and WC.

Numerous uses of aspects of the present invention will be apparent to one skilled in the art in possession of the present disclosure. Superabrasive particles can be arranged into tools of various shapes and sizes, including one-, two-, and three-dimensional tools.

Tools may incorporate a single layer or multiple layers of superabrasive particles and may exhibit improved retention through the distribution of impinging frictional forces. In one aspect, for example, a superabrasive tool having improved superabrasive particle retention is provided. The superabrasive tool may include a solidified organic material layer and a plurality of superabrasive particles secured in the solidified organic material layer in an arrangement according to the methods recited herein.

Superabrasive particles can be arranged in various configurations that may help to distribute the frictional forces impinging on the too. For example, in one aspect each of the plurality of superabrasive particles may protrude to a predetermined height above the solidified organic material layer. By minimizing the variance in the protrusion of the plurality of superabrasive particles above the solidified organic material layer, mechanical forces impinging on individual superabrasive particles can be minimized. Though the predetermined height may vary between tool applications, in one aspect the predetermined height may be greater than about 20 microns. In another aspect the variation from the predetermined height may be from about 1 micron to about 20 microns. In yet another aspect the variation from the predetermined height may be from about 5 microns to about 20 microns. In a further aspect the variation from the predetermined height may be from about 10 microns to about 20 microns. Superabrasive particles may also be arranged according to the methods disclosed herein with respect to arrangement or distribution, attitude, size, etc.

One example of a tool incorporating a single layer of superabrasive particles in an organic material matrix is a CMP pad dresser. As recited herein, traditional metal matrix CMP pad dressers are not suitable for bonding very small superabrasive particles. It is intended that the scope of the present invention include superabrasive particles of all conceivable sizes that would be useful in dressing a CMP pad. Aspects of the present invention, however, specifically allow the retention of superabrasive particles in a CMP pad dresser of sizes that have not previously been feasible for use in metal tools with particles exposed and arranged in a pattern. In one aspect, superabrasive particles may range in size from about 30 microns to about 250 microns. In another aspect, superabrasive particles may range in size from about 100 microns to about 200 microns. In yet another aspect, superabrasive particles can range from 100 microns to 150 microns.

Embodiments of the present invention also provide CMP pad dressers with improved superabrasive particle retention as recited herein. Referring to FIG. 1, the CMP

pad dresser 20 may include an organic material layer 14 and superabrasive particles 12 held in the organic material layer 14 in an arrangement according to the various methods presented herein. Such an arrangement may increase the retention of the superabrasive particles 12 in the organic material layer 14 due to a substantially even distribution of frictional forces across all the superabrasive particles in the tool. This distribution of forces improves retention by minimizing mechanical stress impinging on any individual particle. Additionally, in one aspect the organic material layer 14 may be coupled to a support substrate 22.

In order for the CMP pad dresser 20 to condition a CMP pad, the superabrasive particles 12 should protrude at least partially from the organic material layer 14. The protruding superabrasive particles 12 can cut into the CMP pad to a depth that is essentially the distance of the protrusion. In one aspect of the present invention, the superabrasive particles can protrude to a predetermined height. The heights of each superabrasive particle can be essentially the same, or they may vary depending on the particular application of the dresser. For example, superabrasive particles near the center of the CMP pad dresser may protrude to a greater height than the superabrasive grit near the dresser periphery.

Various methods for making a CMP pad dresser according to embodiments of the present invention may be contemplated by one of skill in the art. Generally, a method for making a CMP pad dresser may include disposing superabrasive particles in an organic material layer according to an arrangement such that the superabrasive particles protrude at least partially from the organic material layer. As described herein, the superabrasive particles may be arranged in order to distribute frictional forces across the tool in order to improve retention. In one aspect of the present invention, a reinforcing material may also be applied to at least a portion of the organic material layer in the proximity of the superabrasive grit to further improve retention. The reinforcing material may also protect the organic material layer from acid and provide wear resistance. In one aspect, the reinforcing material may be a ceramic powder. As discussed herein, the ceramic powder may be any ceramic powder known to one skilled in the art, including alumina, aluminum carbide, silica, silicon carbide, zirconia, zirconium carbide, and mixtures thereof. In one aspect the ceramic powder is silicon carbide. In another aspect, the ceramic powder is aluminum carbide. In yet another aspect, the ceramic powder is silica.

Disposing superabrasive grit according to an arranged pattern may be accomplished by applying spots of glue to a substrate, by creating indentations in the substrate to receive the particles, by adhesive transfer, vacuum transfer, or by any other means known to one skilled in the art. Additional methods may be found in U.S. Pat. Nos. 6,039,641 and 5,380,390, which are incorporated herein by reference.

Orienting superabrasive particles according to a particular attitude can be accomplished by various methods, all of which would be considered to be within the scope of the present invention. For example, in various aspects the plurality of superabrasive particles may have an apex oriented away from the plane of the organic material matrix. In one specific aspect, superabrasive particles may be picked up and positioned with a surface containing numerous flared holes providing suction. An apex portion of a superabrasive particle is sucked into the flared section of each of the holes in the surface. Because the flared portion and the holes are smaller than the superabrasive particles, the particles will be held in a pattern along the surface. Also, due to the shape of the flared sections, the apex portions of the superabrasive particles will be oriented towards the surface. This pattern of superabrasive particles can then be disposed along a substrate having an adhesive or directly into an organic material matrix. Accordingly, the tips of the superabrasive particles will have the same orientation or attitude and also be substantially leveled.

In another aspect, it may be desired to orient apexes and edges away from the plane of the organic material matrix. This can be accomplished by applying a micro sieve such as nylon or other similar template-like material to a substrate that is coated with an adhesive. The holes in the micro sieve may be, without limitation, approximately ½ the size of the superabrasive particles. A template oriented on the micro sieve can position the superabrasive particles in a pattern. Apexes and edges but not the faces of the superabrasive particles can pass through the micro sieve and into the adhesive. Those faces that do adhere to the adhesive through the micro sieve will not affect the cutting of the tool, as they will be recessed in height as compared to superabrasive particles having tips and edges oriented towards the adhesive, and thus will not contact the CMP pad during dressing.

Following casting of such a tool in an organic material matrix, a portion of the organic material can be removed along with the sieve to expose the superabrasive particles. Care should be taken, however, to carefully control the amount of organic

material matrix removed when exposing the superabrasive particles. Removing too much will overexposed the superabrasive particles, and thus cause increased pullout. Removing too little will not expose the superabrasive particles sufficiently to allow efficient penetration for cutting, debris removal, and slurry flow.

One potential method for controlling the depth of removal of the organic material matrix may include disposing stopping aids in the organic material matrix at a controlled depth. The stopping aids can be any material known to one skilled in the art, and may be disposed in the organic material matrix prior to, during, or following curing of the organic material matrix. The stopping aids may also be disposed onto a tool substrate prior to adding the organic material matrix. In one aspect, graphite strips can be glued to stainless steel bars that are placed radially within the organic material matrix where superabrasive particle placement is not required. After curing the organic material matrix, the epoxy and graphite can be abraded away. Abrading will stop when the abrading tool reaches the harder stainless steel bars.

Various reverse casting methods may be utilized to manufacture the CMP pad dresser of the present invention. As shown in FIG. 2, a spacer layer 36 may be applied to a working surface 32 of a temporary substrate 34. The spacer layer 36 has superabrasive particles 38 at least partially disposed therein, which protrude at least partially from the spacer layer 36 opposite the working surface 32 of the temporary substrate 34. Any method of disposing superabrasive particles into a spacer layer such that the superabrasive particles protrude to a predetermined height may be utilized in the present invention. In one aspect, as shown in FIG. 3, the spacer layer 36 is disposed on working surface 32 of the temporary substrate 34. A fixative may be optionally applied to the working surface 32 to facilitate the attachment of the spacer layer 36 to the temporary substrate 34. Superabrasive particles 38 are disposed along one side of the spacer layer 36 opposite to the working surface 32. A fixative may be optionally applied to the spacer layer 36 to hold the superabrasive particles 38 essentially immobile along the spacer layer 36. The fixative used on either surface of the spacer layer may be any adhesive known to one skilled in the art, such as, without limitation, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a pariffin, a phenolic resin, a wax emulsion, an acrylic resin, or combinations thereof. In one aspect, the fixative is a sprayed acrylic glue.

A press 42 may be utilized to apply force to the superabrasive particles 38 in order to dispose the superabrasive particles 38 into the spacer layer 36, as shown in FIG 2. The press 42 may be constructed of any material know to one skilled in the art able to apply force to the superabrasive particles 38. Examples include, without limitation, metals, wood, plastic, rubber, polymers, glass, composites, ceramics, and combinations thereof. Depending on the application, softer materials may provide a benefit over harder materials. For example, if unequal sizes of superabrasive particles are used, a hard press may only push the largest superabrasive particles through the spacer layer 36 to the working surface 32. In one aspect of the present invention, the press 42 is constructed of a porous rubber. A press 42 constructed from a softer material such as a hard rubber, may conform slightly to the shape of the superabrasive particles 38, and thus more effectively push smaller as well as larger superabrasive particles through the spacer layer 36 to the working surface 32.

The spacer layer may be made from any soft, deformable material with a relatively uniform thickness. Examples of useful materials include, but are not limited to, rubbers, plastics, waxes, graphites, clays, tapes, grafoils, metals, powders, and combinations thereof. In one aspect, the spacer layer may be a rolled sheet comprising a metal or other powder and a binder. For example, the metal may be a stainless steel powder and a polyethylene glycol binder. Various binders can be utilized, which are well known to those skilled in the art, such as, but not limited to, a polyvinyl alcohol (PVA), a polyvinyl butyral (PVB), a polyethylene glycol (PEG), a pariffin, a phenolic resin, a wax emulsions, an acrylic resin, and combinations thereof.

In another aspect, shown in FIG. 4, the superabrasive particles 38 may be disposed along the working surface 32 of the temporary substrate 34. An adhesive may be optionally applied to the working surface 32 to hold the superabrasive particles 38 essentially immobile along the temporary substrate 34. A spacer layer 36 may then be applied to the working surface 32 such that the superabrasive particles 38 become disposed therein, as shown in FIG. 2. A press 42 may be utilized to more effectively associate the spacer layer 36 with the working surface 32 and the superabrasive particles 38.

Referring now to FIG. 5, an at least partially uncured organic material 62 may be applied to the spacer layer 36 opposite the working surface 32 of the temporary substrate 34. A mold 66 may be utilized to contain the uncured organic material 62 during

manufacture. Upon curing the organic material 62, an organic material layer 64 is formed, bonding at least a portion of each superabrasive particle 38. A permanent substrate 68 may be coupled to the organic material layer 64 to facilitate its use in dressing a CMP pad. In one aspect, the permanent substrate 68 may be coupled to the organic material layer 64 by means of an appropriate fixative. The coupling may be facilitated by roughing the contact surfaces between the permanent substrate 68 and the organic material layer 64. In another aspect, the permanent substrate 68 may be associated with the organic material 62, and thus become coupled to the organic material layer 64 as a result of curing. The mold 66 and the temporary substrate 34 can subsequently be removed from the CMP pad dresser.

As shown in FIG. 6, the spacer layer has been removed from the organic material layer 64. This may be accomplished by peeling, grinding, sandblasting, scraping, rubbing, abrasion, etc. The distance of the protrusion of the superabrasive particles 38 from the organic material layer 64 will be approximately equal to the thickness of the now removed spacer layer. The organic material layer 64 may be acid etched to further expose the superabrasive particles 38.

One distinction between the various methods of disposing superabrasive particles into the spacer layer may be seen upon removal of the spacer layer. In those aspects where the superabrasive particles are pressed into the spacer layer, the spacer layer material in close proximity to a superabrasive particle will be deflected slightly towards the working surface of the temporary substrate. In other words, the spacer layer material surrounding an individual superabrasive particle may be slightly concave on the side opposite of the working surface due to the superabrasive particle being pushed into the spacer layer. This concave depression will be filled with organic material during the manufacture of the dresser, and thus the organic material will wick up the sides of the superabrasive particle once the organic material layer is cured. For those aspects where the spacer layer is pressed onto the superabrasive particles, the opposite is true. In these cases, the spacer layer material in close proximity to a superabrasive particle will be deflected slightly away from the working surface of the temporary substrate. In other words, the spacer layer material surrounding an individual superabrasive particle may be slightly convex on the side opposite of the working surface due to the spacer layer being forced around the superabrasive particle. This convex protrusion may cause a slight concave depression in the organic material layer surrounding each superabrasive particle.

This slight concave depression may decrease retention, resulting in premature superabrasive grit pullout from the organic material layer. For these aspects, various means of improving retention may be employed by one skilled in the art. For example, the spacer layer may be heated to reduce the slightly convex protrusion of the spacer layer surrounding a superabrasive particle prior to curing the organic material layer. Also, additional organic material may be applied to the slight concave depression in the organic material layer surrounding the superabrasive particle.

The temporary substrate may be made of any material capable of supporting the organic material layer and withstanding the force of the press as described herein. Example materials include glasses, metals, woods, ceramics, polymers, rubbers, plastics, etc. Referring back to FIG. 2, the temporary substrate 34 has a working surface 32 upon which the spacer layer 36 is applied. The working surface 32 can be level, sloped, flat, curved, or any other shape that would be useful in the manufacture of a CMP pad dresser. The working surface 32 may be roughened to improve the orientation of the superabrasive particles 38. When a superabrasive particle is pressed onto a very smooth temporary substrate, it may be more likely that a flat surface of the superabrasive particle will align parallel to the temporary substrate. In this situation, when the spacer layer is removed the flat surface of the superabrasive particle will protrude from the organic material layer. Roughening the surface of the temporary substrate will create pits and valleys that may help to align the superabrasive grit such that the tips of individual superabrasive particle will protrude from the organic material layer.

An alternative aspect of the present invention comprises a method of disposing superabrasive particles in an organic material layer. The method may include providing an organic material arranged as a layer, disposing superabrasive particles on the organic material, pressing the superabrasive particles into the organic material, and curing the organic material to form an organic material layer. FIG. 7 shows a permanent substrate 82 upon which a layer of organic material 84 is applied. Superabrasive particles 86 are disposed along the surface of the layer of organic material 84. A fixative may be utilized to at least partially immobilize the superabrasive particles 86 to the layer of organic material 84. The superabrasive particles 86 may be arranged according to an arrangement by any means known to one skilled in the art. Figure 7 shows superabrasive particles arranged by means of a template 88.

Turning to FIG. 8, a press 92 may be utilized to dispose the superabrasive particles 86 at least partially into the layer of organic material 84. In one aspect, the superabrasive particles 86 protrude above the layer of organic material 84 to a predetermined height. The layer of organic material 84 is subsequently cured to form a solidified organic material layer. In one aspect the organic material layer is a thermoplastic resin. In this case the thermoplastic can be softened by heating in order to receive the superabrasive particles 86, and subsequently cooled to cure the thermoplastic into a solidified organic material layer. The layer of organic material 84 can be any organic material known to one skilled in the art, with the proviso that the uncured organic material be viscous enough to support the superabrasive particles prior to curing, or another form of physical support for the superabrasive particles be provided.

The following examples present various methods for making the coated superabrasive particles and tools of the present invention. Such examples are illustrative only, and no limitation on present invention is meant thereby.

Examples

Example 1

80/90 mesh diamond particles (MBG-660, Diamond Innovations) are arranged with a template on a 100 mm diameter, 10 mm thick flat base plate. The diamond particles form a grid pattern with an inter-diamond pitch of about 500 microns. The plate is placed at the bottom of a steel mold and covered with a polyimide resin powder. Subsequently, the entire assembly is pressed to 50 MPa pressure and 350° C for 10 minutes. The polyimide consolidated plate is 7 mm thick with nickel coated diamond particles forming a grid on one side. A conventional grinding wheel with silicon carbide grit is used to grind the surface to expose the diamond particles to about 60 microns. The final product is a pad conditioner with uniformly exposed diamonds.

Example 2

The same procedure is followed as Example 1, however a phenolic resin is used in place of the polyimide resin, and the forming temperature is reduced to 200° C.

Example 3

The same procedure is followed as Example 1, however the base plate is precoated with a layer of clay that is about 60 microns thick. After hot pressing, the clay is scraped off, exposing the diamond particles protruding from the polyimide resin layer.

Example 4

The same procedure is followed as Example 1, however the pressed polyimide resin disk is 1 mm thick and is glued on a 420 stainless steel backing to form a pad conditioner.

Example 5

80/90 mesh diamond particles are mixed with an epoxy binder to form a slurry. The slurry is spread over a polyethylene terephthalate (PET) sheet. A blade is used to thin the slurry so that it contains one layer of diamond particles. The epoxy is then cured by an UV light to harden. Subsequently, circular disks are punched out of the epoxy sheet. The disks are glued with an acrylic onto stainless steel substrates with the diamond facing away from the glue. A fine sand paper is used to polish the exposed surface and remove the epoxy until approximately half the height of the diamond particles are exposed. The final product is a pad conditioner with diamond particles securely embedded in an epoxy matrix.

Example 6

80/90 mesh diamond particles are arranged by a template on a PET sheet. Subsequently, an epoxy resin is deposited to cover the single layer of diamond particles. After curing, the PET sheet is punched to form disks. The disks are then glued on stainless steel substrates, and the top surface is then sanded off.

Example 7

A 108 mm diameter plastic sheet is covered on both sides with an adhesive. One side is pressed into a steel mold with a smooth surface that exhibits a slightly concave profile. The slope of the concave profile is about 1/1000. A transition in the concave profile toward the center of the mold functions to avoid a sharp point at the center of the completed tool. About 5 mm from the peripheral edge of the mold the slope increases in order to smoothly transition to the mold edge.

80/90 mesh diamond particles are distributed onto a thin sheet coated with an adhesive that is less tacky than the adhesive coated on the plastic sheet. The diamond particles are arranged on the sheet in a grid having a diamond-to-diamond spacing of about 700 microns. The diamond particles are then transferred to the plastic sheet in the mold. The mold is then enclosed in a ring mold.

An epoxy is poured into the ring mold until the thickness exceeds about 10 mm. The mold system is enclosed in a vacuum environment (10^{-3} torr) to remove air bubbles during the curing of the epoxy. After hardening, the epoxy layer is removed from the

mold and the diamond particles are exposed to about 1/3 of the average diamond size. Excess epoxy is machined away from the back of the epoxy layer opposite to the diamond particles to leave a thickness of about 1 mm. The diamond attached epoxy layer is glued to a stainless steel (410) substrate, with the diamonds facing away from the substrate.

Example 8

An acrylic mold is machined to exhibit a radius with a very gentle dishing having an average tangential slope of no greater than 1/1000. The mold is covered with a double stick adhesive. A nylon sieve with an opening of about 100 microns is pressed against the other side of the adhesive. A stainless steel template with holes larger than one diamond size but smaller than two diamond sizes is placed on the top of the nylon sieve. Diamond particles (80/90 mesh, MBG-660 manufactured by Diamond Innovations) are dispersed over the template. The mold is turned upside down to allow diamonds not stuck in the adhesive to fall out. The remaining diamond particles are stuck to the adhesive but, because of the nylon sieve, the large portions of the diamond particles cannot penetrate though to the adhesive. As a result, the diamond particles are stuck with an edge or a tip in the adhesive.

The acrylic mold is placed in a retaining ring and epoxy resin is mixed and poured over the mold and diamond particles. The mold is placed under vacuum to remove air during curing of the epoxy material. The mold is removed mechanically, and the nylon sieve is removed by using a lathe to trim the surface.

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

CLAIMS

What is claimed is:

1. A method of improving retention of superabrasive particles held in a solidified organic material layer of an abrading tool, a portion of each of said superabrasive particles protruding out of the solidified organic material layer, comprising:

securing a plurality of superabrasive particles in the solidified organic material layer in an arrangement that minimizes mechanical stress impinging on the protruding portion of any individual superabrasive particle when used to abrade a work piece.

2. The method of claim 1, wherein the arrangement of the plurality of superabrasive particles is configured to uniformly distribute drag forces across substantially each superabrasive particle.

3. The method of claim 1, wherein a majority of the plurality of superabrasive particles protrudes to a predetermined height above the solidified organic material layer.

4. The method of claim 3, wherein the predetermined height produces a cutting depth of less than about 20 microns when used to abrade a work piece.

5. The method of claim 3, wherein the predetermined height produces a cutting depth of from about 1 micron to about 20 microns when used to abrade a work piece.

6. The method of claim 3, wherein the predetermined height produces a cutting depth of from about 10 micron to about 20 microns when used to abrade a work piece.

7. The method of claim 3, wherein the superabrasive particles protrude to a predetermined height that is along a designated profile.

8. The method of claim 7, wherein the designated profile is a plane.

9. The method of claim 7, wherein the designated profile has a slope.

10. The method of claim 7, wherein the designated profile has a curved shape.

11. The method of claim 10, wherein the designated profile has a dome shape.

12. The method of claim 7, wherein a majority of the plurality of superabrasive particles are arranged such that their tips vary from the designated profile to less than about 10% of the average size of the superabrasive particles.

13. The method of claim 3, wherein a majority of the plurality of superabrasive particles are arranged such that their tips protrude to less than about 40 microns.

14. The method of claim 3, wherein a majority of the plurality of superabrasive particles are arranged such that their tips protrude to less than about 30 microns.

15. The method of claim 3, wherein a majority of the plurality of superabrasive particles are arranged such that their tips protrude to about 20 microns.

16. The method of claim 1, wherein the plurality of superabrasive particles are of substantially the same size.

17. The method of claim 1, wherein the plurality of superabrasive particle are from about 30 microns to about 500 microns in size.

18. The method of claim 1, wherein the plurality of superabrasive particles are from about 100 microns to about 200 microns in size.

19. The method of claim 1, wherein superabrasive particles in a central location of the abrading tool are smaller in size than superabrasive particles in a peripheral location on the abrading tool.

20. The method of claim 1, wherein securing the plurality of superabrasive particles includes arranging the plurality of superabrasive particles according to a predetermined attitude.

21. The method of claim 20, wherein the predetermined attitude is a uniform attitude across substantially all of the plurality of superabrasive particles.

22. The method of claim 20, wherein the plurality of superabrasive particles are substantially configured with an apex portion oriented towards a work piece.

23. The method of claim 20, wherein superabrasive particles in a central location on the abrading tool are configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the abrading tool are configured with a face portion oriented towards the work piece.

24. The method of claim 1, wherein the plurality of superabrasive particles are arranged as a grid.

25. The method of claim 24, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles.

26. The method of claim 24, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 100 microns to about 800 microns.

27. The method of claim 20, wherein arranging the superabrasive particles according to a predetermined attitude further comprises:

applying an adhesive to a substrate;

applying a flexible sieve to the adhesive;

disposing superabrasive particles across a template positioned on the flexible sieve such that a portion of the superabrasive particles adhere to the adhesive by either an edge or an apex portion; and

removing the template and the un-adhered superabrasive particles from the flexible sieve.

28. The method of claim 27, wherein the flexible sieve is a nylon sieve.

29. The method of claim 1, wherein superabrasive particles in a central location on the abrading tool are spaced farther apart than superabrasive particles in a peripheral location on the abrading tool.

30. A superabrasive tool having improved superabrasive particle retention, comprising:

a solidified organic material layer; and

a plurality of superabrasive particles secured in the solidified organic material layer in an arrangement as recited in claim 1.

31. The tool of claim 30, wherein each of the plurality of superabrasive particles protrudes to a predetermined height above the solidified organic material layer.

32. The tool of claim 31, wherein the predetermined height is greater than about 20 microns.

33. The tool of claim 31, wherein variation from the predetermined height is from about 1 micron to about 20 microns.

34. The tool of claim 31, wherein variation from the predetermined height is from about 5 microns to about 20 microns.

35. The tool of claim 31, wherein variation from the predetermined height is from about 10 microns to about 20 microns.

36. The tool of claim 31, wherein the plurality of superabrasive particles protrude to a predetermined height is along a designated profile.

37. The tool of claim 36, wherein the designated profile is a plane.

38. The tool of claim 36, wherein the designated profile has an average slope from a high point near a center location of the tool to a low point near a peripheral edge of the tool.

39. The tool of claim 38, wherein the average slope is about 1/1000.

40. The tool of claim 36, wherein the designated profile has a curved shape.

41. The tool of claim 31, wherein the plurality of superabrasive particles are arranged such that their tips protrude to about 10% of the average size of the superabrasive particles.

42. The tool of claim 31, wherein the plurality of superabrasive particles are arranged such that their tips protrude from about 20 to about 30 microns.

43. The tool of claim 30, wherein the arrangement is a grid.

44. The tool of claim 43, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 3 times to about 5 times the average size of the superabrasive particles.

45. The tool of claim 43, wherein the plurality of superabrasive particles are evenly spaced at a distance of from about 100 microns to 800 microns.

46. The tool of claim 30, wherein superabrasive particles in a central location on the tool are spaced farther apart than superabrasive particles in a peripheral location on the tool.

47. The tool of claim 30, wherein superabrasive particles in a central location on the tool are larger in size than superabrasive particles in a peripheral location on the tool.

48. The tool of claim 30, wherein the plurality of superabrasive particles are arranged according to a predetermined attitude.

49. The tool of claim 48, wherein the plurality of superabrasive particles are substantially configured with an apex portion oriented towards a work piece.

50. The tool of claim 48, wherein superabrasive particles in a central location on the tool are configured with an apex or an edge portion oriented towards a work piece, and superabrasive particles in a peripheral location on the tool are configured with a face portion oriented towards the work piece.

51. The tool of claim 30, wherein the plurality of superabrasive particles include a member selected from the group consisting of diamond, polycrystalline diamond, cubic boron nitride, polycrystalline cubic boron nitride, and combinations thereof.

52. The tool of claim 51, wherein the plurality of superabrasive particles includes diamond.

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

54. The tool of claim 53, wherein the plurality of superabrasive particles are from about 100 microns to about 200 microns in size.

55. The tool of claim 30, wherein the solidified organic material layer comprises a member selected from the group consisting of amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof.

56. The tool of claim 55, wherein the solidified organic material layer is an epoxy resin.

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57. The tool of claim 55, wherein the solidified organic material layer is a polyurethane resin.

58. The tool of claim 55, wherein the solidified organic material layer is a polyimide resin.

59. The tool of claim 30, further comprising a reinforcing material disposed within at least a portion of the solidified organic material layer.

60. The tool of claim 59, wherein the reinforcing material is a material selected from the group consisting of ceramics, metals, or combinations thereof.

61. The tool of claim 60, wherein the reinforcing material is a ceramic.

62. The tool of claim 61, wherein the ceramic comprises a member selected from the group consisting of alumina, aluminum carbide, tungsten carbide, silica, silicon carbide, silicon nitride, zirconia, zirconium carbide, and mixtures thereof.

63. The tool of claim 59, wherein the reinforcing material is an organometallic coupling agent.

64. The tool of claim 30, wherein the tool is a polishing or grinding pad.

65. The tool of claim 30, wherein the tool is a CMP pad dresser.

66. The tool of claim 30, wherein the tool is for shaping dental materials.

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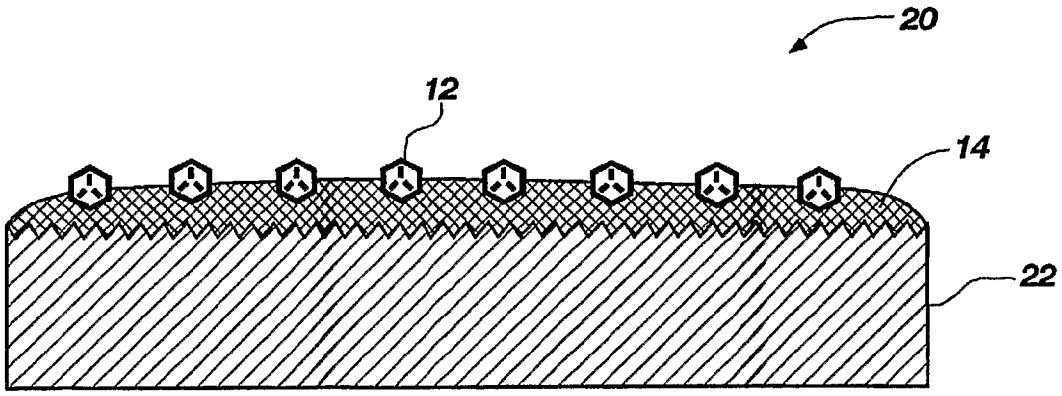


FIG. 1

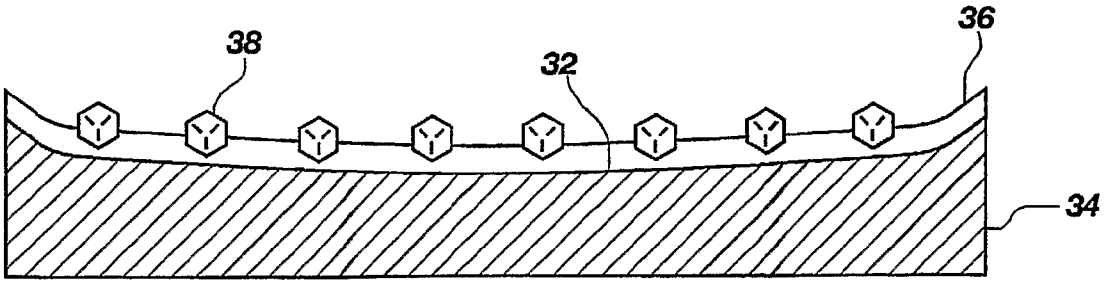


FIG. 2

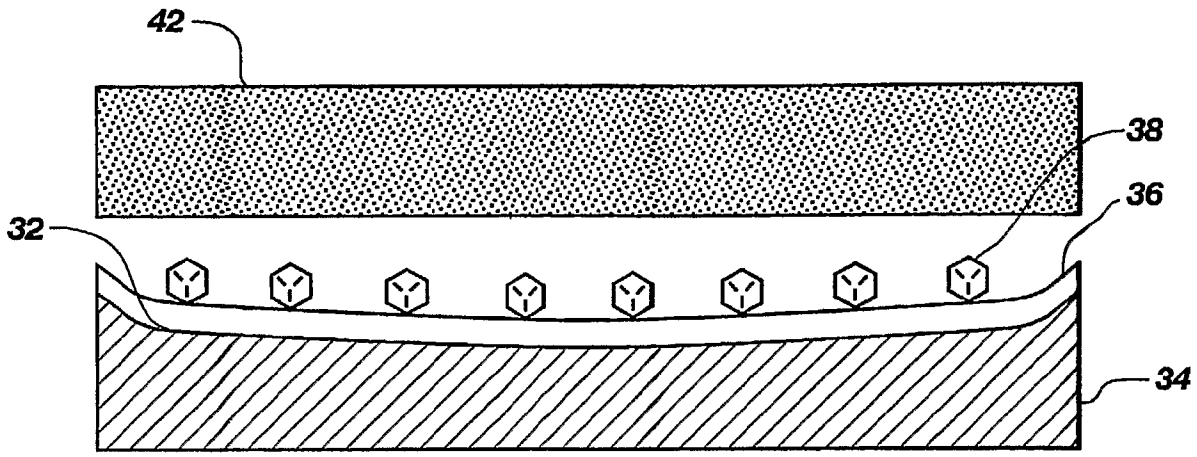


FIG. 3

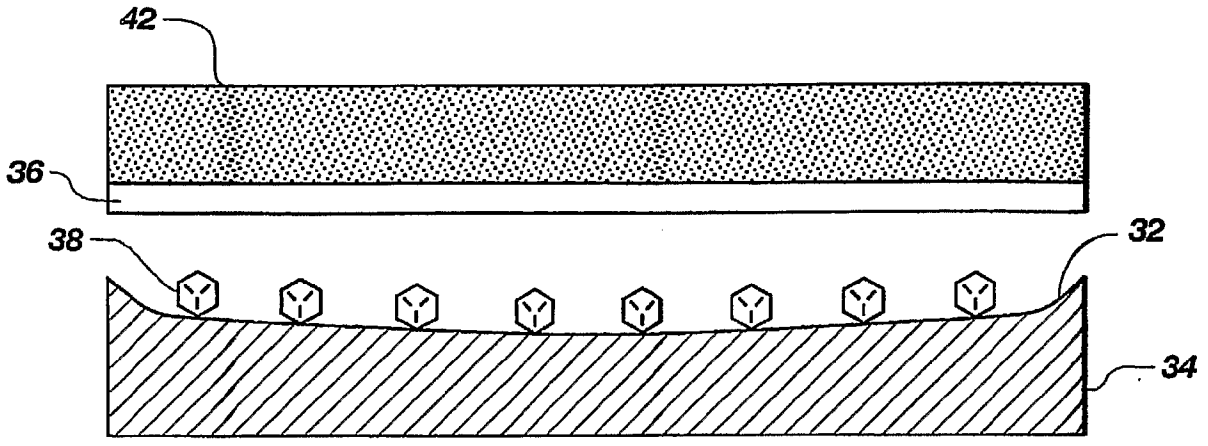


FIG. 4

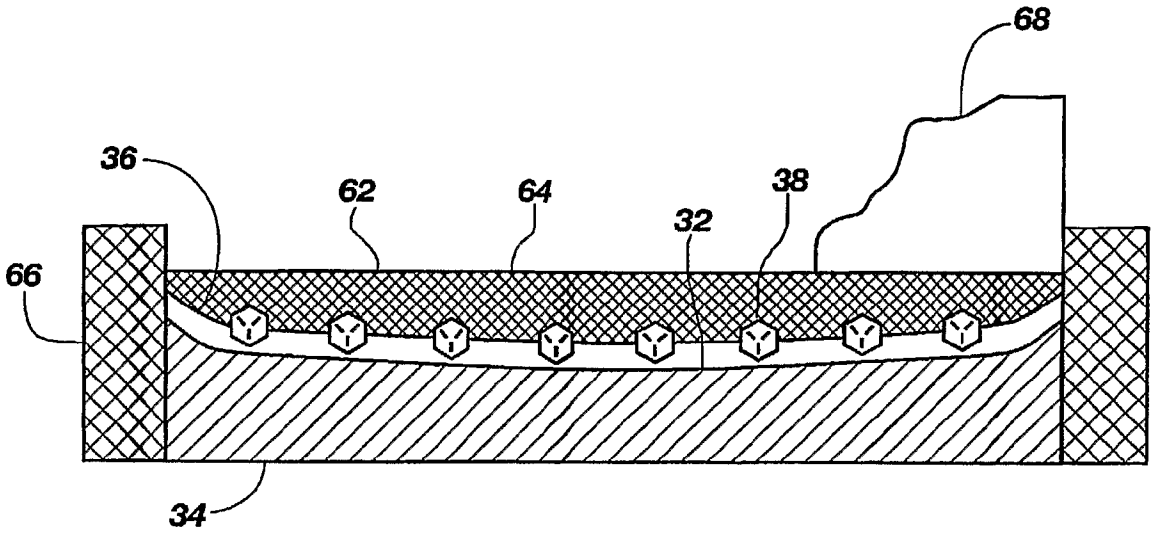


FIG. 5

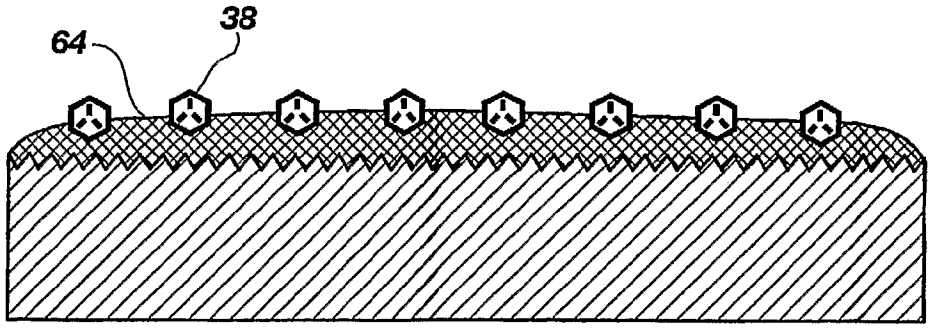


FIG. 6

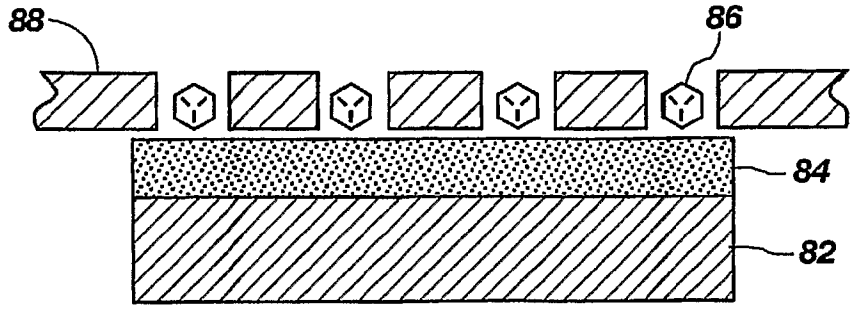


FIG. 7

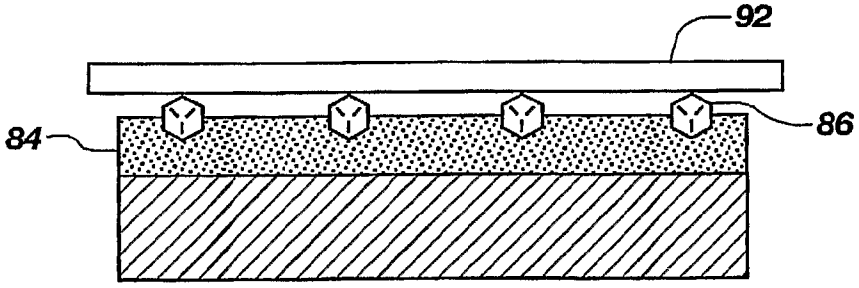


FIG. 8

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
29 May 2008 (29.05.2008)

PCT

(10) International Publication Number
WO 2008/063599 A2

(51) International Patent Classification: Not classified

(21) International Application Number:
PCT/US2007/024165

(22) International Filing Date:
16 November 2007 (16.11.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/560,817 16 November 2006 (16.11.2006) US
11/786,426 10 April 2007 (10.04.2007) US

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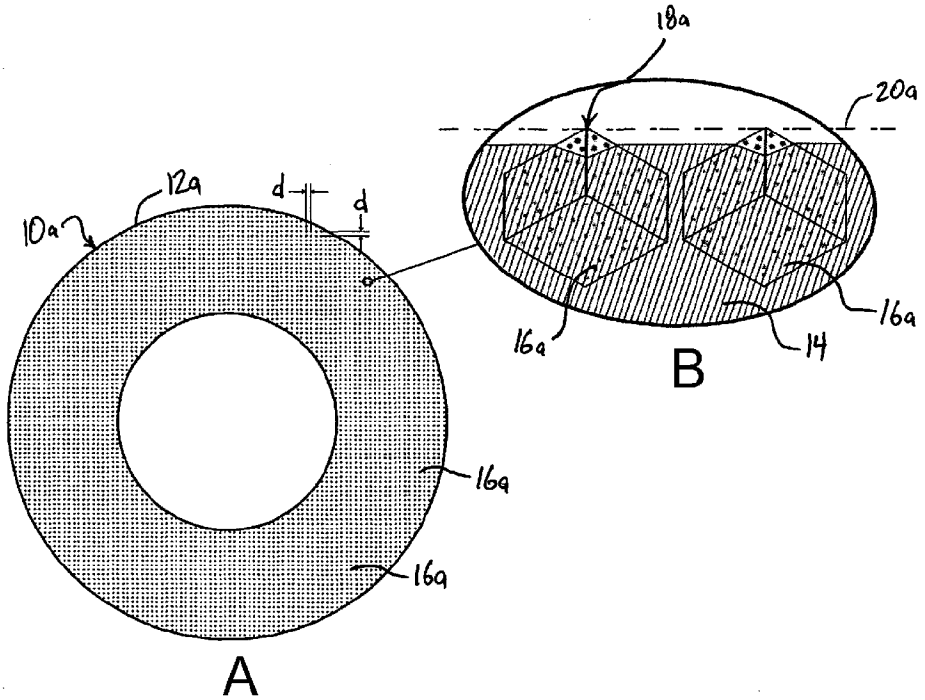
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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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

(54) Title: SUPERHARD CUTTERS AND ASSOCIATED METHODS



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

WO 2008/063599 A2

SUPERHARD CUTTERS AND ASSOCIATED METHODS

FIELD OF THE INVENTION

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

BACKGROUND OF THE INVENTION

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

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

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

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

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

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

SUMMARY OF THE INVENTION

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

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

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

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

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

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

DETAILED DESCRIPTION

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

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

Definitions

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

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

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

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

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

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

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

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

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

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

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

As used herein, "particle," when used in connection with a superabrasive material, refer to a particulate form of such material. Such particles may take a variety of shapes, including round, oblong, square, euhedral, etc., as well as a number of specific mesh sizes. As is known in the art, "mesh" refers to the number of holes per unit area as in the case of U.S. meshes.

As used herein, "particle" and "grit" may be used interchangeably.

As used herein, "cutting element" describes a variety of structures capable of removing (e.g., cutting) material from a workpiece. A cutting element can be a mass having several cutting points, ridges or mesas formed thereon or therein. It is notable that such cutting points, ridges or mesas may be from a multiplicity of protrusions or asperities included in the mass. Furthermore, a cutting element can also include an individual particle that may have only one cutting point, ridge or mesa formed thereon or therein.

As used herein, "grid" means a pattern of lines forming multiple squares.

As used herein, "mechanical force" and "mechanical forces" refer to any physical force that impinges on an object that causes mechanical stress within or surrounding the object. Example of mechanical forces would be frictional forces or drag forces. As such, the terms "frictional force" and "drag force" may be used interchangeably, and refer to mechanical forces impinging on an object as described.

As used herein, "mechanical stress" refers to a force per unit area that resists impinging mechanical forces that tend to compact, separate, or slide an object.

As used herein, the term "profile" refers to a contour above an organic material layer

surface to which the superabrasive particles are intended to protrude.

As used herein, "mechanical bond" and "mechanical bonding" may be used interchangeably, and refer to a bond interface between two objects or layers formed primarily by frictional forces. In some cases the frictional forces between the bonded objects may be increased by expanding the contacting surface areas between the objects, and by imposing other specific geometrical and physical configurations, such as substantially surrounding one object with another.

As used herein, the term "substantially" refers to the complete or nearly complete extent or degree of an action, characteristic, property, state, structure, item, or result. For example, an object that is "substantially" enclosed would mean that the object is either completely enclosed or nearly completely enclosed. The exact allowable degree of deviation from absolute completeness may in some cases depend on the specific context. However, generally speaking the nearness of completion will be so as to have the same overall result as if absolute and total completion were obtained. The use of "substantially" is equally applicable when used in a negative connotation to refer to the complete or near complete lack of an action, characteristic, property, state, structure, item, or result. For example, a composition that is "substantially free of" particles would either completely lack particles, or so nearly completely lack particles that the effect would be the same as if it completely lacked particles. In other words, a composition that is "substantially free of" an ingredient or element may still actually contain such item as long as there is no measurable effect thereof.

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

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

Concentrations, amounts, and other numerical data may be expressed or presented herein in a range format. It is to be understood that such a range format is used

merely for convenience and brevity and thus should be interpreted flexibly to include not only the numerical values explicitly recited as the limits of the range, but also to include all the individual numerical values or sub-ranges encompassed within that range as if each numerical value and sub-range is explicitly recited. As an illustration, a numerical range of "about 1 to about 5" should be interpreted to include not only the explicitly recited values of about 1 to about 5, but also include individual values and sub-ranges within the indicated range. Thus, included in this numerical range are individual values such as 2, 3, and 4 and sub-ranges such as from 1-3, from 2-4, and from 3-5, etc., as well as 1, 2, 3, 4, and 5, individually.

This same principle applies to ranges reciting only one numerical value as a minimum or a maximum. Furthermore, such an interpretation should apply regardless of the breadth of the range or the characteristics being described.

The Invention

The present invention provides a cutting device and associated methods that can be utilized in cutting or otherwise affecting a workpiece to remove material from the workpiece and provide a finished, smooth and/or flat surface to the workpiece. Cutting devices of the present invention can be advantageously utilized, for example, as planing devices that plane material from a workpiece, as dressing devices that dress various workpieces, and as polishing devices that polish various workpieces.

In the embodiment of the invention illustrated in FIGs. 1A and 1B, a cutting device (e.g., disk) 10a is provided that optionally includes a base 12a that can have a solidified organic material layer (14 in FIGs. 1B and 2B) disposed thereon, attached thereto, or otherwise associated therewith. A plurality of individual polycrystalline cutting elements 16a can be secured in the solidified organic material layer. Each of the plurality of individual polycrystalline cutting elements can have or exhibit a substantially matching geometric configuration, e.g., the geometric configuration of the cutting elements can substantially match that of other of the cutting elements. In the example illustrated in FIG. 1B, each of the plurality of individual polycrystalline cutting elements 16a has geometric configuration that is substantially cubic in nature. In the embodiment illustrated in FIG. 2B, the individual polycrystalline cutting elements 16b have a geometric configuration that can be characterized as a three-dimensional triangular configuration.

As illustrated in both FIGs. 1B and 2B, in one aspect of the invention, the plurality of individual polycrystalline cutting elements 16a, 16b can include at least one cutting tip (18a and 18b, respectively), with the cutting tips of the cutting elements being aligned in a common plane (20a, 20b, respectively). In this example, the common plane is a flat plane of predetermined height above the solidified organic matrix. Thus, the plurality of individual polycrystalline cutting elements can be held within the solidified organic material layer in a very precise manner such that each of the cutting elements contacts a workpiece (not shown) from which material is to be removed at substantially the same depth. In this way, each of the individual polycrystalline cutting elements can be subject to substantially the same level of drag force as the cutting device is moved relative to a workpiece. This feature of the invention can advantageously limit the premature removal of individual cutting elements that might otherwise shorten the life of the tool, and/or damage the workpiece being treated.

The individual cutting elements 16a, 16b can be formed from a variety of materials including, in one embodiment, a polycrystalline material or a superhard polycrystalline material. While not so limited, the superhard polycrystalline material can be a polycrystalline diamond compact ("PCD") or a polycrystalline cubic boron nitride compact ("PcBN"). The PCD or PcBN compact can be formed in a variety of manners, as discussed in more detail below. By forming the individual cutting elements from a polycrystalline material, and attaching the cutting elements individually to the cutting device, the beneficial properties of polycrystalline cutting elements can be achieved without requiring that portions of the cutting device not used for cutting also be formed from the polycrystalline material. Thus, considerable cost savings can be achieved.

The cutting devices of the present invention can be utilized in a number of applications, and in one embodiment are particularly well adapted for use in planing substantially brittle materials, such as silicon wafers, glass sheets, metals, used silicon wafers to be reclaimed by planarization, LCD glass, LED substrates, SiC wafers, quartz wafers, silicon nitride, zirconia, etc. In conventional silicon wafer processing techniques, a wafer to be polished is generally held by a carrier positioned on a polishing pad attached above a rotating platen. As slurry is applied to the pad and pressure is applied to the carrier, the wafer is polished by relative movements of the platen and the carrier. Thus,

the silicon wafer is essentially ground or polished, by very fine abrasives, to a relatively smooth surface.

While grinding of silicon wafers has been used with some success, the process of grinding materials such as silicon wafers often results in pieces of the material being torn or gouged from the body of the material, resulting in a less than desirable finish. This is due, at least in part, to the fact that grinding or abrasive processes utilize very sharp points of abrasive materials (which are often not level relative to one another) to localize pressure to allow the abrasives to remove material from a workpiece.

The PCD or PcBN cutting elements of the present invention are generally superhard, resulting in little yielding by the cutting elements when pressed against a wafer. As hardness is generally a measure of energy concentration, e.g., energy per unit volume, the PCD or PcBN compacts of the present invention are capable of concentrating energy to a very small volume without breaking. These materials can also be maintained with a very sharp cutting edge due to their ability to maintain an edge within a few atoms.

While not so required, in one embodiment of the invention shown in FIG. 1A, the individual polycrystalline cutting elements 16a can be arranged in or across the organic material layer or base in a grid pattern, e.g., in a pattern of squares. The cutting elements can be evenly spaced from one another at a distance "d" of from about 100 microns to about 800 microns. In one aspect of the invention, the individual polycrystalline cutting elements can be evenly spaced from one another at a distance "d" of about 500 microns.

In the embodiment of the invention illustrated in FIG. 2A, the individual polycrystalline cutting elements 16b can be arranged in or across the organic material layer or base as a series of concentric circles. As in the embodiment discussed above, the individual cutting elements can be evenly spaced from one another at a distance "d" of from about 100 microns to about 800 microns. In one aspect, the individual polycrystalline cutting elements can be evenly spaced from one another at a distance "d" of about 500 microns. By evenly spacing the individual cutting elements one from another, the drag force applied to the cutting elements during the cutting process can be evenly distributed among each of the cutting elements, eliminating or reducing the risk of premature pullout of one or more individual cutting elements. Premature pullout of one or more individual cutting elements can result in serious damage being done the workpiece being worked upon.

The retention of an individual polycrystalline cutting element in an organic material layer can be greatly improved by arranging the cutting elements the organic material layer such that mechanical stress impinging on any individual cutting element is minimized. By reducing the stress impinging on each individual cutting element they can be more readily retained in a solidified organic material layer, particularly for delicate tasks.

Various configurations or arrangements are contemplated for minimizing the mechanical stress impinging on the cutting elements held in the abrading tool. In addition to the spacing considerations discussed above, one potentially useful parameter may include the relative heights that the elements protrude above the organic material layer. A cutting element that protrudes to a significantly greater height than other cutting elements will experience a greater proportion of the impinging mechanical forces and thus is more prone to pull out of the solidified organic material layer. Thus, an even height distribution of the cutting elements may function to more effectively preserve the integrity of the abrading tool as compared to abrading tools lacking such an even height distribution.

As such, in one aspect, substantially all of the plurality of individual cutting elements may protrude to a predetermined height above the solidified organic material layer. Though any predetermined height that would be useful in an abrading or cutting tool would be considered to be within the presently claimed scope, in one specific aspect the predetermined height may produce a cutting depth of less than about 20 microns when used to abrade a workpiece. In another specific aspect, the predetermined height may produce a cutting depth of from about 1 micron to about 20 microns when used to abrade a workpiece. In yet another specific aspect, the predetermined height may produce a cutting depth of from about 10 micron to about 20 microns when used to abrade a workpiece. In yet another aspect, the predetermined height may produce a depth of up to or more than 50 or 100 microns.

It should also be noted that the leveling of the individual cutting elements to a predetermined height may be dependent on cutting element spacing. In other words, the farther the cutting elements are separated, the more the impinging forces will affect each cutting element. As such, patterns with increased spacing between the cutting elements may benefit from a smaller variation from predetermined height.

It may also be beneficial for the cutting elements to protrude from the solidified

organic material layer to a predetermined height or series of heights that is/are along a designated profile. Numerous configurations for designated profiles are possible, depending on the particular use of the abrading tool. In one aspect, the designated profile may be a plane. In planar profiles, the highest protruding points of the cutting elements are intended to be substantially level. It is important to point out that, though it is preferred that these points align with the designated profile, there may be some height deviation between cutting elements that occur due to limitations inherent in the manufacturing process.

In addition to planar profiles, in another aspect of the present invention the designated profile has a slope. Tools having sloping surfaces may function to more evenly spread the frictional forces impinging thereon across the cutting elements, particularly for rotating tools such as disk sanders and CMP pad dressers. The greater downward force applied by higher central portions of the tool may offset the higher rotational velocity at the periphery, thus reducing the mechanical stress experienced by cutting elements in that location. As such, the slope may be continuous from a central point of the tool to a peripheral point, or the slope may be discontinuous, and thus be present on only a portion of the tool. Similarly, a given tool may have a single slope or multiple slopes. In certain aspects, the tool may slope in a direction from a central point to a peripheral point, or it may slope from a peripheral point to a central point.

Various slopes are contemplated that may provide a benefit to solidified organic material layer tools. It is not intended that the claims of the present invention be limited as to specific slopes, as a variety of slopes in numerous different tools are possible. In one aspect, however, a CMP pad dresser may benefit from an average slope of 1/1000 from the center to the periphery.

As a variation on tools having a slope, in certain aspects the designated profile may have a curved shape. One specific example of a curved shape is a dome shape tool. Such curved profiles function in a similar manner to the sloped surfaces. Tools may include such curved profiles in order to more effectively distribute the frictional forces between all of the cutting elements, thus reducing failures of individual particles and prolonging the life of the tool.

As has been mentioned herein, while it is intended that the tips of the cutting elements align along the designated profile, some level of deviation may occur. These

deviations may be a result of the design or manufacturing process of the tool. Given the wide variety of sizes and shapes of cutting elements that may potentially be utilized in a given tool, such deviations may be highly dependent on a particular application. Also, when referring to the designated profile, it should be noted that the term "tip" is intended to include the highest protruding point of a cutting element, whether that point be an apex, an edge, or a face. Orientational positioning, tip leveling, and other techniques of manipulating superabrasive particles are further described in U.S. Patent Application No. 11/223,786, filed on September 9, 2005, and U.S. Patent Application No. 11/733,325, filed April 10, 2007, both of which are incorporated herein by reference.

As such, in one aspect a majority of the plurality of cutting elements is arranged such that the tips vary from the designated profile by from about 1 micron to about 150 microns. In another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 5 microns to about 100 microns. In yet another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 10 microns to about 75 microns. In a further aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 10 microns to about 50 microns. In another aspect, they are arranged such that their tips vary from the designated profile by from about 50 microns to about 150 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by from about 20 microns to about 100 microns. In a further aspect, they are arranged such that their tips vary from the designated profile by from about 20 microns to about 50 microns.

In another aspect, the plurality of cutting elements are arranged such that their tips vary from the designated profile by from about 20 microns to about 40 microns. Additionally, in one aspect, they are arranged such that their tips vary from the designated profile by less than about 20 microns. In another aspect, they are arranged such that their tips vary from the designated profile by less than about 10 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by less than about 5 microns. In yet another aspect, they are arranged such that their tips vary from the designated profile by less than about 1 micron. In a further aspect, a majority of the plurality of the cutting elements are arranged such that their tips vary from the designated profile to less than about 10% of the average size of the cutting elements.

The determination of the distance that the tips of the cutting elements extend from the organic binder can also be affected by considering how much of the cutting elements extend above the binder compared to how much of the cutting elements remain submerged beneath the binder surface. In the embodiment illustrated in FIGs. 1A and 1B, a ratio of an amount the cutting elements 16a protrude above the binder to an amount submerged beneath the binder is about 4 to 1. In the embodiment illustrated in FIGs. 2A and 2B, about 2/3 of the cutting elements 16b are submerged, with about 1/3 being exposed above the binder. Other ratios are also possible, from a 20 to 1 ratio to about 0.2 to 1, inclusive of ranges therebetween.

By forming the individual cutting elements in the shapes described herein, a relatively large portion of the cutting elements 16a, 16b can be submerged beneath the organic binder. In this manner, the area that affords the greatest cross section for engagement with the binder material is "buried" beneath the greatest amount of binder. This feature of the invention, namely that the widest (i.e. largest cross section of the cutting element) is closer to one end of the particle than the other, and thus the wider end can be placed below the surface of the organic matrix, provides great retention advantages over conventional diamond, or synthetic diamond, grits wherein a largest cross section of the grit is concentrated near a midpoint of the grit, and thus is placed at or near the surface of a matrix in which the grit is held. The widest portion may be at or near the end that is most distal from the working (e.g., cutting) end of the cutting element.

In addition to the shapes of cutting elements illustrated in the figures, in one embodiment of the invention, the cutting elements are formed in pyramidal shapes. The present inventor has found that such a configuration provides a number of advantages. For example, pyramidal-shaped cutting elements concentrate most of the volume/mass of the cutting element toward a lowermost portion of the cutting element, ensuring that the cutting element is more securely held to whichever type of base (e.g., cutting tool) the elements are bonded to, integrated with, or other associated with. In addition, by forming pyramids with a triangular base, the support base of the pyramids is even more massive relative to the tip, and the tip can be made sharper (e.g., 60 degrees) without breaking or fracturing during the dressing of CMP pads.

In general, sharper tips will cut pads faster, leading to a corresponding reduction in total dressing time. Moreover, the asperities formed on the pad are also sharper and more

dense. Such asperities can polish wafers, and/or dress CMP pads faster without causing undesirable non-uniformity on the wafer. Alternatively, square pyramids can be used when a lower cut rate is desired, as the tip angle likely has a larger magnitude (e.g. 90 degrees). Thus creating a wider cut path with greater drag and resulting in a lower cut rate. However, the square PCD cutter can be formed more sharply than conventional, single crystal diamond grits that have variable tip angles ranging from 90 degrees to over 125 degrees. Thus, pyramids formed of polycrystalline materials are generally much more effective cutters, with triangular pyramids (i.e. 3 sided) being particularly effective.

In addition, as the cutting elements of the present invention can be made with very closely controlled geometry, the present polycrystalline cutting elements can cut pads with less tearing. Also, with the addition of the secondary cutting elements formed on the major cutting elements, the present cutting elements can perform even better. In other words, serrations in the cutting surface may improve the cutting action of the cutting elements. In contrast, single crystal grits are generally very smooth, so they can cause a lot of plastic deformation on the pad and tearing of cut "shreds." It should be noted that the irregular surface of the polycrystalline cutting elements additionally improves retention in the organic material layer. Such irregular surfaces allow the organic material to "grip" a cutting element to a greater extent than would be possible with the smooth surfaces of a single crystal cutting element.

In addition, oftentimes pad conditioners dress pads under conditions in which work load is unevenly distributed across the cutting elements. Specifically, the outer rim of cutting elements often must do the most cutting work, with the interior elements not being subject to a as high a degree of stress. One manner in which the present invention addresses this problem is by configuring the "outer" cutting elements, some times as PCD grits, (e.g., those located closer to the outer perimeter of the cutting or dressing tool) more robust, and/or the inner elements slightly higher (e.g. about 10 microns higher) than the outer elements. The outer cutting elements can also be disposed on the cutting tool at a greater density, e.g., they can be spaced closer together, and/or be positioned at a slightly lower elevation. In this design, the distribution of cutting elements may not be in grid form, but can include a series of concentric rings that can be radially symmetric.

In one embodiment of the invention, the outer elements can be formed with larger support bases relative to the cutting tips (in one aspect they can have triangular bases),

and they may also have an edge formed on the cutting tip rather than just a point. Also, the outermost cutting elements may have a small (e.g. 50 microns) mesa formed at their cutting tips that can cut the pad with edge of the mesa rather than with a straight edge or a point.

In one embodiment of the invention, the cutting elements can be pyramids that are asymmetrical in shape. For example, since the cutting force is generally applied from "outside to inside," the pyramid design may have a relatively steeply sloped wall facing the outer perimeter of the cutting device, but with a relatively gentler slope (e.g. 10 degrees from the horizontal plane) in the trailing side. That is, the table portion on the tip of the pyramid may not be horizontal, but may exhibit a slight "tilt" toward inward to allow debris to escape more easily. This aspect of the invention differs from diamond grit cutting pads, as such conventional cutting pads include a negative angle such that the tearing or cutting force is superimposed with a compressive force. This embodiment of the invention can allow cutting without a great deal of compression so the removal of pad "shread" is much easier.

In other words, the present invention allows a majority of the energy consumed to be used in cutting, rather than plastic deformation. This advantage can be further improved upon by forming the vertical wall of the pyramids such that they slope slightly less than 90 degrees (e.g., about 80 degrees). In this case the table of the pyramids can be sharper on the top of the mesa, similar to an inverted pyramid. This can improve the efficiency of pad cutting because the cutting is performed with a positive angle, similar to a razor blade used in shaving. Such a design has not been possible with single crystal diamond designs, as the cutting edge contact with such designs is always negative in angle. The present pyramidal cutting elements can provide positive cutting edges that are not subject to premature failure due, at least in part, to its ability to support such a cutting edge with a more gently sloping wall on the trailing side of the cutting interface (e.g., with the asymmetrical shape of the pyramids). In one aspect, such an asymmetry can be formed by wire-EDM cutting, and it can be formed with pyramids with tips of point, edge, and mesa tops. Also, when the cutting elements are individual particles or grits, such particle or grit can receive the intended configuration, including an assymetrical configuration as described above by using a mold with a proper shape for processing of the PCT particle.

In one embodiment of the invention, the spacing of the pyramids can be adjusted to adjust the contact pressure of each cutting point, edge or mesa. In general, the farther the pyramids are spaced from one another, the higher the contact pressure between the pyramid and the pad. Thus, the fewer tips present to support the applied force, the deeper the penetration of each of the tips and the larger the formed asperities. Generally, the polishing rate of the wafer is dependent on the number and size of the asperities. Denser, smaller asperities can polish as fast as fewer, larger asperites. But the former is more uniform with no excessive force that may cause non-uniformity, scratching, erosion or dishing of the delicate wafer, etc. This can be particularly true with copper smaller than 90 nm and with low-k dielectric having greater than 20% pores.

The individual polycrystalline cutting elements can be formed in a variety of manners and from a variety of materials, as would occur to one having ordinary skill in the relevant art. In one aspect of the invention, the cutting elements are sintered polycrystalline diamond cubes with silicon/SiC as the matrix. Each of the cubes can contain about 90 V% of diamond (about 10 microns in grain size) and the remaining phase can be either silicon or SiC. A very small amount of titanium can be used facilitate the sintering process. The cubes can be pressed in a graphite mold and formed in a size of about 1 mm on each side. While the cubic examples provided above have proven particularly efficacious, it is to be understood that a variety of sizes and configurations of polycrystalline materials can be utilized in the present invention.

By forming the cutting elements from individual units of superhard polycrystalline material, in defined geometric shapes, arrangement of the cutting elements in a very precise manner becomes much easier. As the defined geometric shapes can be replicated fairly precisely from one cutting element to another, the positioning of, and accordingly, the stress impinged upon, each cutting element can be accomplished fairly consistently across the face off the cutting device in question. With prior art abrasive grits, for example, the overall shape and size of each a plurality of grits might change considerably from one grit to another, making precise placement of the grits difficult to accomplish.

The material utilized in the organic material layer 14 can vary widely. Numerous organic materials are known to those skilled in the art which would be useful when utilized in embodiments of the present invention, and are considered to be included herein. The organic material layer can be any curable resin material, resin, or other

polymer with sufficient strength to retain the individual polycrystalline cutting elements of the present invention. It may be beneficial to use an organic material layer that is relatively hard, and maintains a flat surface with little or no warping. This allows the abrading tool to incorporate very small individual polycrystalline cutting elements at least partially therein, and to maintain these small cutting elements at relatively level and consistent heights.

Additionally, various organic materials may act to absorb mechanical forces impinging on the cutting elements disposed therein, and thus spread and equalize such forces across the abrading tool.

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

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

Organic materials that may be useful in embodiments of the present invention include, but are not limited to: amino resins including alkylated urea-formaldehyde resins, melamine-formaldehyde resins, and alkylated benzoguanamine-formaldehyde resins; acrylate resins including vinyl acrylates, acrylated epoxies, acrylated urethanes, acrylated polyesters, acrylated acrylics, acrylated polyethers, vinyl ethers, acrylated oils, acrylated silicons, and associated methacrylates; alkyd resins such as urethane alkyd resins; polyester resins; polyamide resins; polyimide resins; reactive urethane resins; polyurethane resins; phenolic resins such as resole and novolac resins; phenolic/latex resins; epoxy resins such as bisphenol epoxy resins; isocyanate resins; isocyanurate resins; polysiloxane resins including alkylalkoxysilane resins; reactive vinyl resins; resins

marketed under the Bakelite trade name, including polyethylene resins, polypropylene resins, epoxy resins, phenolic resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone resins, ethylene copolymer resins, acrylonitrile-butadiene-styrene (ABS) resins, acrylic resins, and vinyl resins; acrylic resins; polycarbonate resins; and mixtures and combinations thereof. In one aspect of the present invention, the organic material may be an epoxy resin. In another aspect, the organic material may be a polyimide resin. In yet another aspect, the organic material may be a polyurethane resin. In yet another aspect, the organic material may be a polyurethane resin.

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

Additionally, in one aspect a coupling agent or an organometallic compound may be coated onto the surface of each superabrasive particle to facilitate the retention of the superabrasive particles in the organic material matrix via chemical bonding. A wide variety of organic and organometallic compounds are known to those of ordinary skill in the art and may be used. Organometallic coupling agents can form chemicals bonds between the superabrasive particles and the organic material matrix, thus increasing the retention of the particles therein. In this way, the organometallic coupling agent acts as a bridge to form bonds between the organic material matrix and the surface of the superabrasive particles. In one aspect of the present invention, the organometallic coupling agent can be a titanate, zirconate, silane, or mixture thereof.

Specific non-limiting examples of silanes suitable for use in the present invention include: 3- glycidoxypropyltrimethoxy silane (available from Dow Corning as Z-6040); γ-methacryloxy propyltrimethoxy silane (available from Union Carbide Chemicals Company as A-174); β-(3,4-epoxycyclohexyl)ethyltrimethoxy silane, γ-

aminopropyltriethoxy silane, N-(β-aminoethyl)-γ-aminopropylmethyldimethoxy silane (available from Union Carbide, Shin-etsu Kagaku Kogyo K.K., etc.); and additional examples of suitable silane coupling agents can be found in U.S. Pat. Nos. 4,795,678, 4,390,647, and 5,038,555, which are each incorporated herein by reference.

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

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

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

The amount of organometallic coupling agent used depends on the coupling agent and on the surface area of the individual polycrystalline cutting elements. Typically, 0.05% to 10% by weight of the organic material layer is sufficient.

Turning now to FIG. 3A, in one aspect of the invention, the individual polycrystalline cutting elements can be obtained and/or formed from a polycrystalline blank of material. One such blank of material is shown at 30 in FIG. 3A, with the polycrystalline blank being formed in a disk having a diameter of roughly 30 mm and a thickness that can vary from around 0.2 mm to upwards of 2 mm.

The disk 30 can be divided into a series of individual cutting elements in a variety of manners known to those having ordinary skill in the art, including, without limitation, electro-chemical machining, by laser ablation, by plasma etching, by oxidation (to form carbon dioxide or monoxide gas), hydrogenation (to form methane gas), etc. Laser beams with relatively longer wavelengths (e.g. ND:YAG) have been shown to form cutting grooves on PCD effectively (laser beams with relatively short wavelengths (e.g. excimers) may be used to carve out the secondary cutting elements on top of the primary cutting

elements, as shown and discussed in connection with FIG. 3B. While the latter may be slower in cutting speed, it is generally more precise due to the shorter wavelength used. Moreover, the surface damage can be less with more concentrated energy in higher frequencies. This has been found suitable for shaving or planing a silicon wafer in accordance with the present invention.

In one aspect of the invention, the material is removed from the PCD or PcBN compact by electrical discharge machining ("EDM"). In this aspect, the EDM process can utilize one or more electrodes that include diamond. For example, the cathode used in the EDM process can be a boron doped diamond material and the anode used in the EDM process can be the PCD (in this case, the PCD would generally need to be at least partially electrically conductive). As current is applied through the boron doped diamond material, the material of the PCD can be carefully and controllably removed to form various cutting elements from the PCD.

As will be appreciated, the disk 30 is divided into 8 similarly shaped and sized wedges 32. In one embodiment of the invention, the wedges 32 can be attached to a base 12b by way of the solidified organic material layer discussed above. In the embodiment of the invention illustrated in FIG. 3A, the wedges 32 are radially distributed about the face of the cutting device and/or base or substrate. In this manner, the wedges 32 can be arranged so as to each be subject to substantially the same force (and each be substantially as likely to be retained within the organic matrix) when used to abrade or treat a workpiece (not shown). While not so required, in one embodiment of the invention, the PCD blank 30 can be on the order of about 30 mm in diameter, while the base 12b can be on the order of about 100 mm in diameter. Thus, a cutting device with a diameter of around 100 cm can be formed from superhard material taken from a PCD of only about 30 mm.

As shown in FIG. 4, in one aspect of the invention, a longitudinal axis of each of the individual polycrystalline cutting elements (e.g., wedges 32) is aligned along a radius R of the cutting device. In the embodiment shown, the individual polycrystalline cutting elements are distributed on the cutting device in alternating orientations. The manner of arranging the cutting elements across the face of the base or substrate 12b can be varied for particular applications. Due to the consistent shape and size of the individual polycrystalline cutting elements, however, arrangement and attachment of the cutting

elements to the base is made considerably easier. Accordingly, varying the arrangement for particular applications can be more easily and accurately accomplished.

By utilizing a relatively small amount of polycrystalline material (e.g., disk 30), relative to the size of the base 12b which is to be used to treat the workpiece (not shown), the amount polycrystalline material used can be greatly reduced, leading to considerable cost savings. The present inventor has found, however, that cutting devices of the present invention perform equally well, or nearly equally as well, as conventional cutting devices that utilize "full-face" polycrystalline cutting or grinding tools.

As will be appreciated, the blank 30 of FIG. 3A has been divided into 8 equal portions. However, as shown in FIGs. 5 through 12, the disks 30b, 30c and 30d can be divided into twelve equal portions (represented by wedges 32b), sixteen equal portions (represented by wedges 32c), two equal portions (represented by wedges 32d), and so forth. In this manner, the present invention provides additional flexibility for creation and arrangement of the individual polycrystalline cutting elements across the tool. It is contemplated that a variety of other configurations is also possible, including, without limitation, differently sized and shaped individual polycrystalline cutting elements.

Returning to FIG. 3B, in one aspect of the invention, the individual polycrystalline cutting elements 32 can include a series of secondary cutting elements 40 formed on a face of each of the individual polycrystalline cutting elements. The secondary cutting elements can be configured to maintain a sharpness of each of the cutting elements during use of the cutting device. The secondary cutting elements can vary in shape, and can include rectangular-shaped cutting elements, pyramidal-shaped cutting elements, triangular-shaped cutting elements, etc. The secondary cutting elements can also be formed in a truncated pyramidal shape (not shown). By utilizing secondary cutting elements on the primary cutting elements, the total cutting edge length of the cutting element can be extended by as much as 10,000 times.

In accordance with another aspect, the present invention provides a method of forming a cutting device, comprising: obtaining a substrate; arranging on the substrate a plurality of individual polycrystalline cutting elements, each of the plurality of individual polycrystalline cutting elements having a matching geometric configuration; and securing each of the plurality of individual polycrystalline cutting elements to the substrate with a solidified organic material layer.

The method can further comprise aligning at least one cutting tip of each of the plurality of individual polycrystalline cutting elements in a common plane.

Examples

The following examples present various methods for making the cutting tools of the present invention. Such examples are illustrative only, and no limitation on present invention is meant thereby.

Example 1:

Individual sintered polycrystalline diamond cubes with silicon/SiC as the matrix were used as the cutting elements for forming a CMP pad conditioner. Each of the cubes contains about 90 V% of diamond (about 10 microns in grain size) and the remaining phase is either silicon or SiC. A very small amount of titanium is also present to facilitate the sintering process. The cubes were pressed in a graphite mold and were formed in a size of about 1 mm on each side.

An epoxy mold was provided with cavities configured to receive one apex of the PCD cubes. A parting layer was spread on top of the mold. Subsequently, another epoxy is cast on the top in vacuum. After curing, the mold is removed, exposing the apex of each cube. The apexes become the cutting tip of a pad conditioner.

Example 2

A disk of sintered polycrystalline diamond with silicon/SiC as the matrix is divided into a series of wedges of substantially the same volume. The wedges are used as the cutting elements for forming a CMP pad conditioner. Each of the wedges contains about 90 V% of diamond (about 10 microns in grain size) and the remaining phase is either silicon or SiC. A very small amount of titanium is also present to facilitate the sintering process.

An epoxy mold was provided with cavities configured to receive each of the PCD wedges. A parting layer was spread on top of the mold. Subsequently, another epoxy is cast on the top in vacuum. After curing, the mold is removed, exposing the face of each wedge. The faces (and edges of the faces) of the wedges become the cutting elements of a pad conditioner.

Example 3

PCD blanks pressed from a cubic press were trimmed from both sides to remove refractary metal container (e.g. Ta). The outside diameter of the blanks were ground off. The PCD blanks were bonded to a cemented WC base and the PCD layer was EDM shaped to form pyramids distributed in a predetermined pattern. The PCD blanks were subsequently divided into a series of wedge-shaped cutting pieces and the cutting pieces were placed on a flat mold with the cutting pieces leveled with the mold.

The mold was placed in a vacuum chamber and epoxy is poured over the top. Finally, a stainless steel plate was placed on the top of the flowing epoxy and pressed toward the PCD until only a thin layer of epoxy remained between the backing of the PCD and the steel substrate. After curing of the epoxy, the PCD cutting tool was cleaned and mounting structure (e.g., holes) was formed on the back of the steel substrate.

The PCT cutting pieces can be arranged on the stainless steel plate in an annular ring pattern, circular plates, squares, etc. These patterns can be optimized to suit a particular CMP application.

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

CLAIMS

What is claimed is:

1. A cutting device, comprising:

a base having a solidified organic material layer disposed thereon; and

a plurality of individual polycrystalline cutting elements secured in the solidified organic material layer, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration.

2. The cutting device of claim 1, wherein each of the plurality of individual polycrystalline cutting elements includes at least one cutting tip, the tips of the cutting elements being aligned in a common plane.

3. The cutting device of claim 1, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

4. The cutting device of claim 3, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

5. The cutting device of claim 4, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

6. The cutting device of claim 4, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

7. The cutting device of claim 4, wherein the individual polycrystalline cutting elements are radially distributed about the face of the cutting device.

8. The cutting device of claim 7, wherein a longitudinal axis of each of the individual polycrystalline cutting elements is aligned along a radius of the cutting device.

9. The cutting device of claim 8, wherein the individual polycrystalline cutting elements are distributed on the cutting device in alternating orientations.

10. The cutting device of claim 1, further comprising a series of secondary cutting elements formed on a face of each of the individual polycrystalline cutting elements, the secondary cutting elements being configured to maintain a sharpness of each of the cutting elements during use of the cutting device.

11. A cutting device, comprising:

a plurality of individual polycrystalline cutting elements secured in a solidified organic material layer, each of the plurality of individual polycrystalline cutting elements including at least one cutting tip, the tips of the cutting elements being aligned in a common plane.

12. The cutting device of claim 11, wherein arrangement of the individual polycrystalline cutting elements uniformly distributes drag forces across substantially each individual polycrystalline cutting element.

13. The cutting device of claim 11, wherein a majority of each of the individual polycrystalline cutting elements protrudes to a predetermined height above the solidified organic material layer.

14. The cutting device of claim 13, wherein the predetermined height produces a cutting depth of less than about 20 microns when used to abrade a workpiece.

15. The cutting device of claim 11, wherein each of the plurality of individual polycrystalline cutting elements has a substantially matching geometric configuration.

16. The cutting device of claim 11, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

17. The cutting device of claim 16, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

18. The cutting device of claim 17, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

19. The cutting device of claim 17, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

20. The cutting device of claim 17, wherein the individual polycrystalline cutting elements are radially distributed in the organic material layer.

21. The cutting device of claim 11, wherein the individual polycrystalline cutting elements are of substantially the same size and substantially the same shape.

22. The cutting device of claim 11, wherein the individual polycrystalline cutting elements are arranged as a grid.

23. The cutting device of claim 22, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of from about 100 microns to about 800 microns.

24. The cutting device of claim 23, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of about 500 microns.

25. The cutting device of either of claim 1 or claim 11, wherein the solidified organic material layer comprises a member selected from the group consisting of amino resins, acrylate resins, alkyd resins, polyester resins, polyamide resins, polyimide resins, polyurethane resins, phenolic resins, phenolic/latex resins, epoxy resins, isocyanate resins, isocyanurate resins, polysiloxane resins, reactive vinyl resins, polyethylene resins, polypropylene resins, polystyrene resins, phenoxy resins, perylene resins, polysulfone

resins, acrylonitrile-butadiene-styrene resins, acrylic resins, polycarbonate resins, polyimide resins, and mixtures thereof.

26. The cutting device of claim 25, wherein the solidified organic material layer is an epoxy resin.

27. The cutting device of claim 25, wherein the solidified organic material layer is a polyurethane resin.

28. The cutting device of claim 25, wherein the solidified organic material layer is a polyimide resin.

29. The cutting device of claim 25, further comprising a reinforcing material disposed within at least a portion of the solidified organic material layer.

30. The cutting device of claim 29, wherein the reinforcing material is a material selected from the group consisting of ceramics, metals, or combinations thereof.

31. A method of forming a cutting device, comprising:

obtaining a substrate;

arranging on the substrate a plurality of individual polycrystalline cutting elements, each of the plurality of individual polycrystalline cutting elements having a substantially matching geometric configuration; and

securing each of the plurality of individual polycrystalline cutting elements to the substrate with a solidified organic material layer.

32. The method of claim 31, further comprising aligning at least one cutting tip of each of the plurality of individual polycrystalline cutting elements in a common plane.

33. The method of claim 31, wherein each of the individual polycrystalline cutting elements is a divided portion of a polycrystalline blank of material.

34. The method of claim 33, wherein the polycrystalline blank is shaped as a disk, and wherein each of the individual polycrystalline cutting elements is a divided portion of the disk.

35. The method of claim 34, wherein each of the individual polycrystalline cutting elements is an equal portion of the disk.

36. The method of claim 34, wherein each of the individual polycrystalline cutting elements is substantially wedge-shaped.

37. The method of claim 34, wherein the individual polycrystalline cutting elements are radially distributed about the substrate.

38. The method of claim 31, wherein the individual polycrystalline cutting elements are of substantially the same size and substantially the same shape.

39. The method of claim 31, wherein the individual polycrystalline cutting elements are arranged as a grid.

40. The method of claim 39, wherein the individual polycrystalline cutting elements are evenly spaced from one another at a distance of from about 100 microns to about 800 microns.

41. The cutting device of either of claim 1 or claim 11, wherein the polycrystalline cutting elements comprise superhard polycrystalline cutting elements.

42. The cutting device of claim 41, wherein the superhard polycrystalline cutting elements comprise superhard polycrystalline particles.

43. The method of claim 31, where the polycrystalline cutting elements comprise superhard polycrystalline cutting elements.

44. The method of claim 43, wherein the superhard polycrystalline cutting elements comprise superhard polycrystalline particles.

45. The method of claim 43, wherein the superhard polycrystalline cutting elements are selected from the group consisting of: polycrystalline diamond and polycrystalline cubic boron nitride.

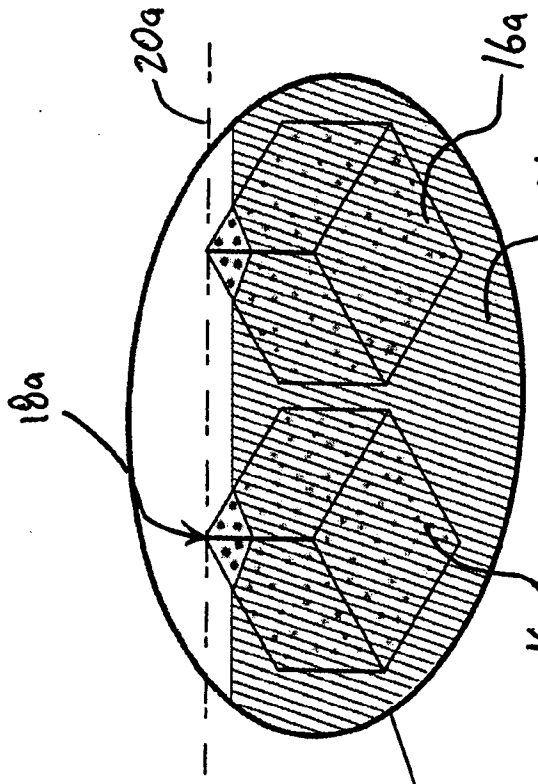


FIG. 1B

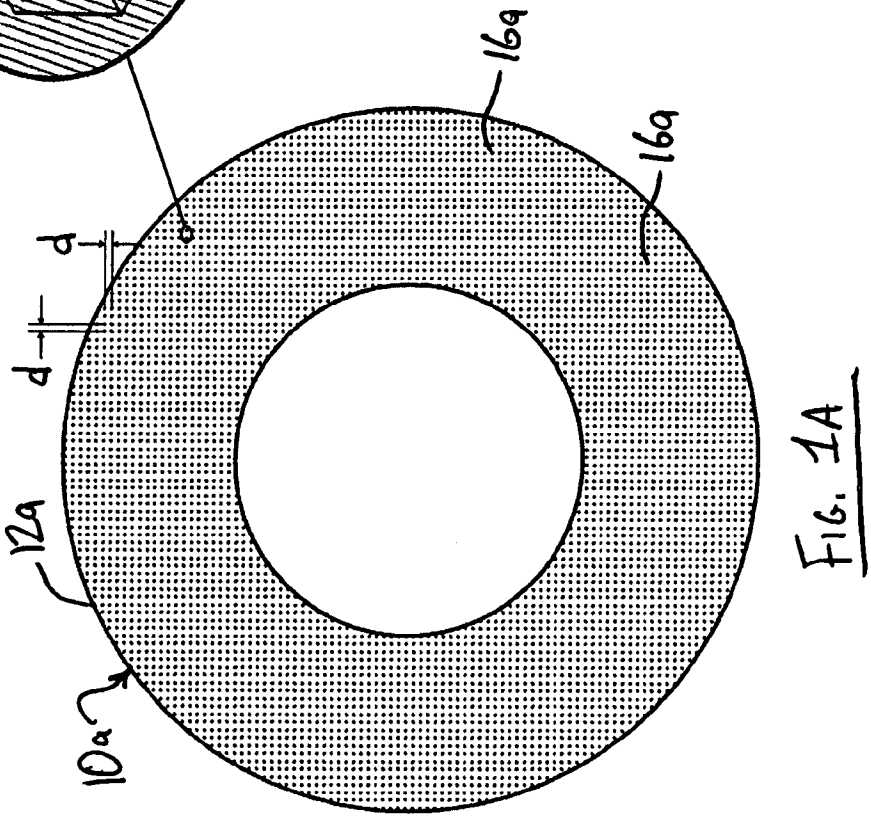


FIG. 1A

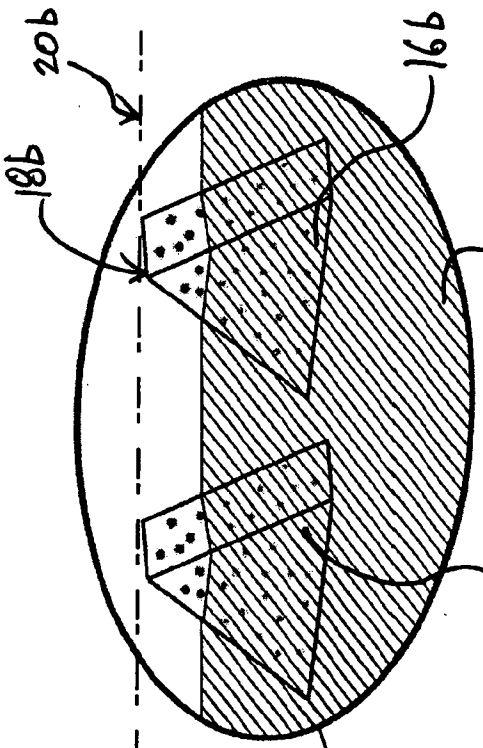


FIG. 2B

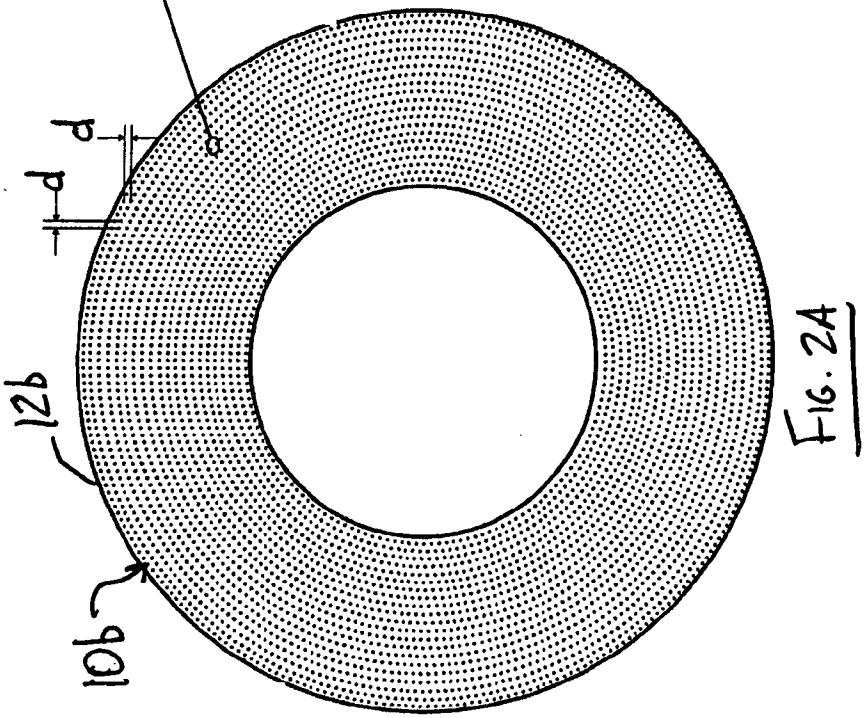


FIG. 2A

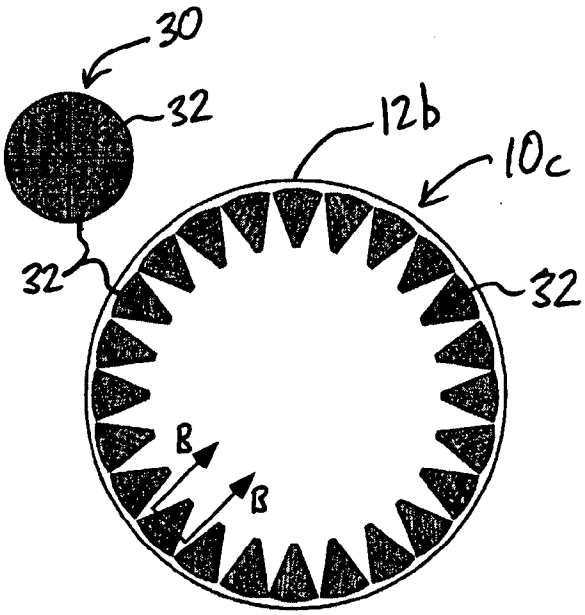


FIG. 3A

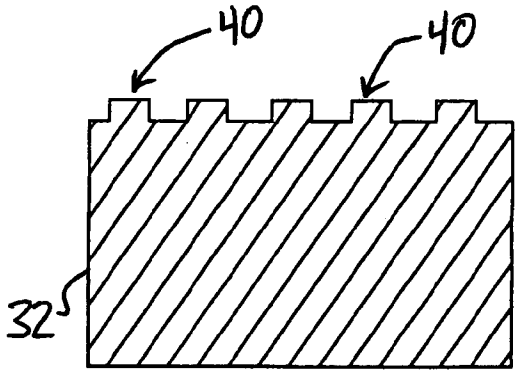


FIG. 3B

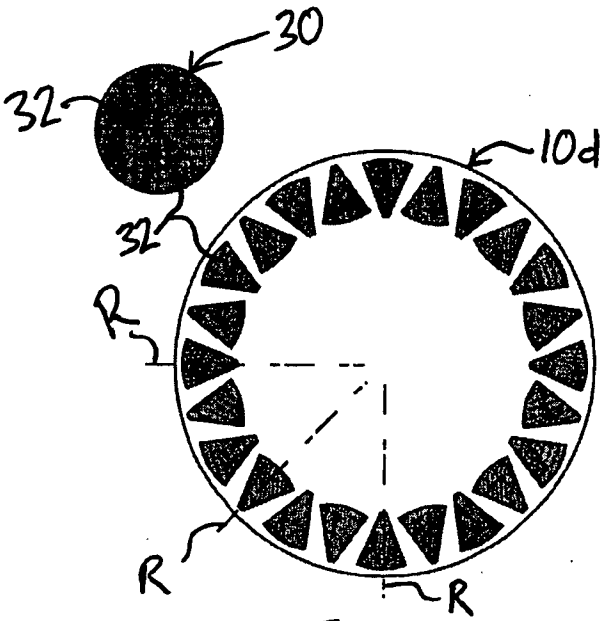


FIG. 4

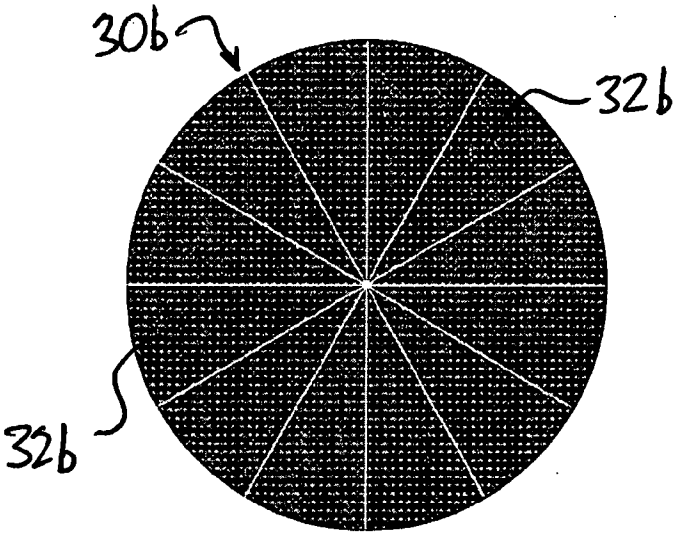


FIG. 5

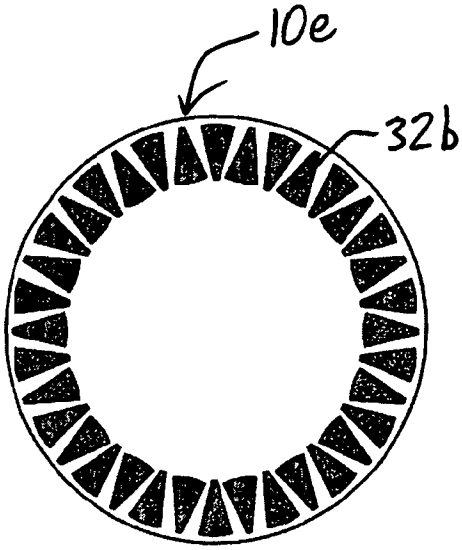


FIG. 6

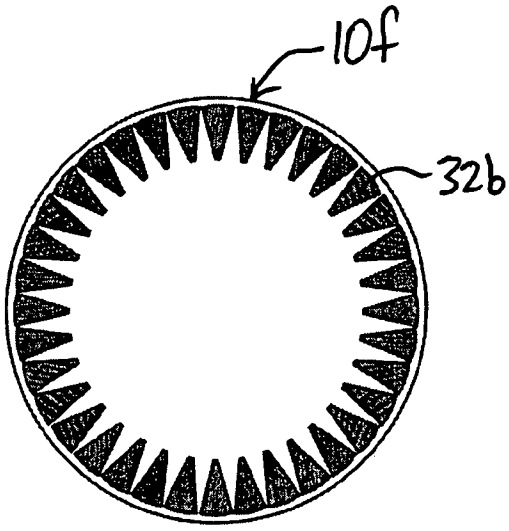


FIG. 7

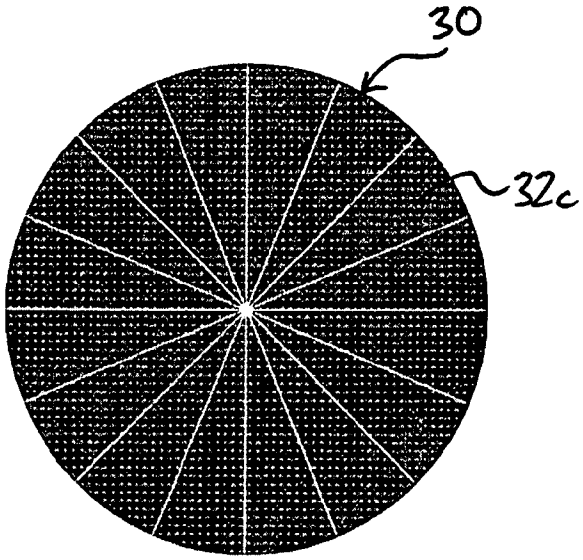


FIG. 8

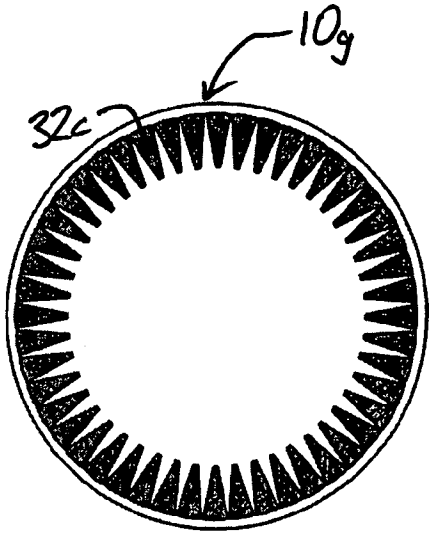


FIG. 9

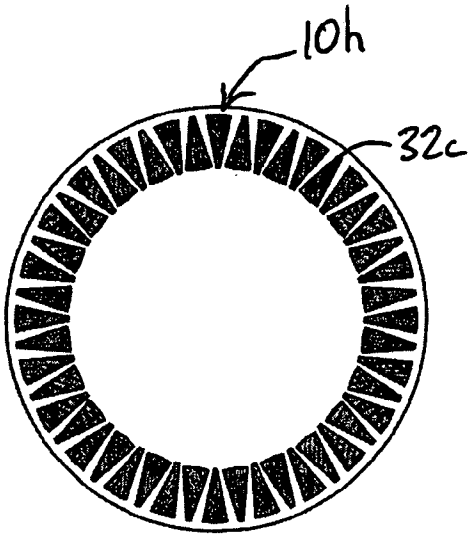


FIG. 10

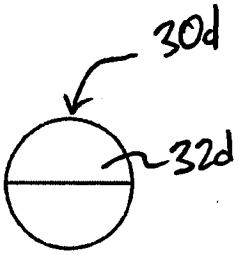


FIG. 11

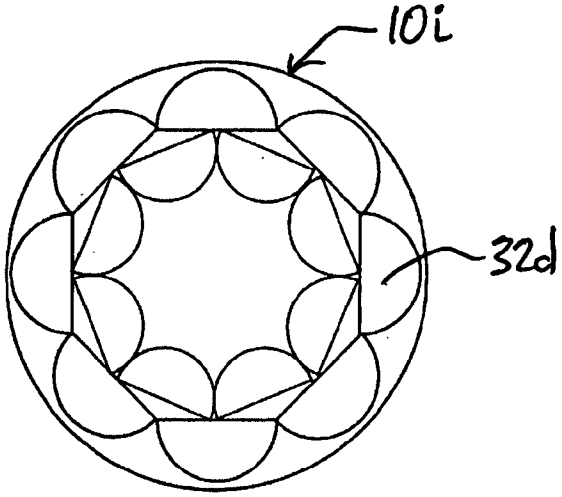


FIG. 12

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

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

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

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

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

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2011/052627

A. CLASSIFICATION OF SUBJECT MATTER

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

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

Korean utility models and applications for utility models

Japanese utility models and applications for utility models

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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

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

☒ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

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

Name and mailing address of the ISA/KR

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

Facsimile No. 82-42-472-7140

Authorized officer

MYUNG Dae Keun

Telephone No. 82-42-481-8417

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2011/052627

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US 2007-0249270 A1	25.10.2007
		US 2007-0264918 A1	15.11.2007

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2008-0028686 A1	07.02.2008
		US 2008-0171503 A1	17.07.2008
		US 2009-0068937 A1	12.03.2009
		US 2009-0093195 A1	09.04.2009
		US 2009-0123705 A1	14.05.2009
		US 2010-0139174 A1	10.06.2010
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		US 7491116 B2	17.02.2009
		US 8043145 B2	25.10.2011
		WO 2006-039413 A2	13.04.2006

PATENT COOPERATION TREATY

From the INTERNATIONAL SEARCHING AUTHORITY

To:

OSBORNE DAVID W.

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

RECEIVED
DEC 26 2012
TROP, PRUNER & HU, P.C.

PCT

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

(PCT Rule 44.1)

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

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

   Filing of amendments and statement under Article 19:

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

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

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

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

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

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

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

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

4. **Reminders**

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

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

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

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

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

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

Form PCT/ISA/220 (July 2010)

(over)

DOCKETED
DEC 30 2012
TNW

* Attention

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

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

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

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

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

PATENT COOPERATION TREATY

PCT

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

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

Applicant

SUNG CHIEN-MIN

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

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

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

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/039199

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/304(2006.01)i

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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

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

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

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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

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

☒ See patent family annex.

* Special categories of cited documents:

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

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

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

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

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

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

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

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

"&" document member of the same patent family

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

Name and mailing address of the ISA/KR

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

Facsimile No. 82-42-472-7140

Authorized officer

Lee, Myoung Jin

Telephone No. 82-42-481-8364

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2012/039199

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

PATENT COOPERATION TREATY

From the
INTERNATIONAL SEARCHING AUTHORITY

To:
OSBORNE DAVID W.

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

PCT

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

(PCT Rule 43bis.1)

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

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

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

H01L 21/304(2006.01)i

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

Applicant

SUNG CHIEN-MIN

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

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

2. **FURTHER ACTION**

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

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

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

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

DOCKETED DEC 30 2012 TNW

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/039199

Box No. I Basis of this opinion

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

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

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

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

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

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

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

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

5. Additional comments:

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.
PCT/US2012/039199

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

1. Statement

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

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

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

1. Novelty and Inventive Step

1.1. Claims [1-9]

1.1.1. Independent Claim [1]

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

1.1.2. Dependent Claims [2-9]

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

Continued on Supplemental Box

WRITTEN OPINION OF THE INTERNATIONAL SEARCHING AUTHORITY

International application No.

PCT/US2012/039199

Box No. VIII Certain observations on the international application

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

Box VIII

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

Supplemental Box

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

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

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

1.2.2. Dependent Claims [11-13]

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

Continued on Supplemental Box

Supplemental Box

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

Supplemental Box

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

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

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

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

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

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

Continued on Supplemental Box

Supplemental Box

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

Supplemental Box

1.5. Claim [27]

1.5.1. Independent Claim [27]

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

2. Industrial Applicability

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

Electronic Acknowledgement Receipt

EFS ID:	19884257
Application Number:	13802112
International Application Number:	
Confirmation Number:	1021
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP.CIP
Receipt Date:	16-AUG-2014
Filing Date:	13-MAR-2013
Time Stamp:	16:32:57
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	79568 bb5800922d16c29117d646c08d0853b6c1cf6bf9	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	145482 d52e87da1199016a2aa497355ef628df6fd8e372	no	2
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	96913 88fd25e68ed69780fb64a7320db3502bee8b7134	no	2
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
4	Foreign Reference	CN1351922.pdf	973793 81e08964602493c30f02c030e80bcd9acf3d3b5e	no	18
Warnings:					
Information:					
5	Foreign Reference	CN1494984.pdf	1166699 de3589c1c90833659c554c1eae81e0ce52a7920f	no	26
Warnings:					
Information:					
6	Foreign Reference	EP0238434A2.pdf	576662 3ea4db1acb5b2cc501f46c9407a066cc2b1c4049	no	8
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Information:					
7	Foreign Reference	EP0264674A2.pdf	2104680 cb312f3c18d88f76743d7bb377f0b6471b60d87f	no	25
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8	Foreign Reference	EP0280657A2.pdf	591306 09c4b96cb7d108c15ec5536360d7326b8f96867e	no	8
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9	Foreign Reference	EP0331344A2.pdf	867235 b4901f96d096569938db0bc342ed03b442616523	no	12
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10	Foreign Reference	EP0712941A1.pdf	5660408 00acdcad4fafb81092ac44fcb6402f6c9e379809	no	86
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11	Foreign Reference	GB2239011A.pdf	635863 ce18e02a32226a762b8f5e3c3cfd31e10f3ad056	no	17
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12	Foreign Reference	JP06182184.pdf	324684 c79877d857de8e021d82f28ba83218c2bc0e7bf3	no	6
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Information:					
13	Foreign Reference	JP10128654.pdf	404129 b4eefa0aa48311199083a62dea720ab022d40e35	no	8
Warnings:					
Information:					
14	Foreign Reference	JP10180618.pdf	333374 09b7988cb325a52ff71deaa2c98c67472bd45292	no	6
Warnings:					
Information:					
15	Foreign Reference	JP11048122.pdf	639852 570c17713f395a3c1e862d1c24c6ace90806892d	no	11
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16	Foreign Reference	JP11077536.pdf	615202 3c2bd3f03d5083c54273995e54cd1439344d519e	no	10
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17	Foreign Reference	JP200034336.pdf	263925 c2baf9893b8576dc427aff8d8bed6842562d3cc9	no	5
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18	Foreign Reference	JP2000167774.pdf	437198 a9e03a765f1033beb84955c305efa0ad87d24224	no	9
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19	Foreign Reference	JP2003071718.pdf	439973 9d17821e1a38acadd1345b030e59c67550011578	no	8
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20	Foreign Reference	JP2004025401.pdf	263413 1110c5dd1ed2dd8cc1d0ace956fc2e1114535857	no	6
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21	Foreign Reference	KR200339181.pdf	329508 447a918bef431deee488a5efb182026e14a779a8	no	8
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22	Foreign Reference	WO9527596A1.pdf	1965492 d424776d1cdca977ea4d8110ccb352cc80867897	no	45
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23	Foreign Reference	WO9427883.pdf	1102237 8cd0d1714b4a1133ad49bb5117794dd047ba2414	no	37
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24	Foreign Reference	WO9606732A1.pdf	2085230 0daff84db27f0d8be217d961e99ca71427a9bdd0	no	47
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25	Foreign Reference	WO9810897A1.pdf	859814 5b94ff9f7704b7f12e4c55f3749b50af04c8aea7	no	20
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27	Foreign Reference	WO9845092A1.pdf	1727338 5ca8155ca1586a9d5c4043182194e8f8d9ea1898	no	52
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Information:					

28	Foreign Reference	WO9851448A1.pdf	1002734 105d9bef179733ed47b6bac307a0d5bfd184e431	no	21
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29	Foreign Reference	WO0231078A2.pdf	536301 a731e953a07be7f967981120354e1fbad622e764	no	15
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Information:					
30	Foreign Reference	WO2004094106A1.pdf	636576 50fb169c81fc992dfa6e4db58bc120210d5bb2a7	no	16
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31	Foreign Reference	WO2006124792A2.pdf	1986978 7b7206213d1c8801ebfad94eea216ab782762857	no	31
Warnings:					
Information:					
32	Foreign Reference	WO2007032946A2.pdf	2336261 3cb52d2488920bdb94705e6cabe06331075d112c	no	40
Warnings:					
Information:					
33	Foreign Reference	WO2008063599A2.pdf	1890215 b5d62b69a9263dcbfee85503db924c9bca4c6e1f	no	38
Warnings:					
Information:					
34	Other Reference-Patent/App/Search documents	PCTUS2011052627searchMay112012.pdf	181061 518d8746fc112643f66c0de5996caa0ac81a0284	no	4
Warnings:					
Information:					
35	Other Reference-Patent/App/Search documents	sr199.pdf	520134 a7944ceee58764dffe1fbff5190b5575cdf2e3c9	no	12
Warnings:					
Information:					
			Total Files Size (in bytes):	35693365	

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/802,112 FILED: 3/13/2013 CONF. NO.: 1021 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP.CIP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: August 16, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

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

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

Dear Sir/Madam:

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

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

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

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

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

SUBMISSIONS

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

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

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

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

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

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

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

☐ because they are substantially cumulative of an enclosed reference.

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

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

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

REMARKS

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

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

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

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

Dated this 16th day of August, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

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

PTO/SB/08A (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		US 6159286	12/2000	Sung	
		US 5919084	07/1999	Powell, et al.	

FOREIGN PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Foreign Patent Document Country Code[3]- Number[4] – Kind Code[5] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear	T[6]
		CN 1351922	06/05/2002	China Emerg Wheel Entpr. Co. Ltd.		
		CN 1494984	05/12/2004	Read Co. Ltd		
		EP 0238434	03/1987	United Tech. Corp.		
		EP 0264674	09/30/1987	Norton Christensen, Inc.		
		EP 0280657	08/31/1988	Diabrasive International		
		EP 0331344	02/1989	Minnesota Mining and Manuf		
		EP 0712941	05/22/1996	Agency of Ind. Sci. & Tec		
		GB 2239011	06/1991	Anthony et al.		
		JP 06182184	07/1994	Sumitomo Electric Industires		
		JP 10128654	05/1998	Toshiba Corp.		
		JP 10180618	07/1998	Nippon Kokan KK		
		JP 11048122	02/1999	Hitachi Ltd.		
		JP 11077536	03/1999	Asahi Diamond Ind.		
		JP 2000343436	12/12/2000	Noritake Diamond Ind. Co. Ltd.		
		JP 2000167774	06/20/2000	Toho Titanium Co. Ltd.		
		JP 2003/071718	03/12/2003	Nippon Steel Corp.		

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

		JP 2004/025401	01/29/2009	Airtec Japan KK		
		KR 200339181	01/31/2004	Jang		
		WO 95/27596	10/1995	Ultimate Abrasive System		
		WO 94/27883	12/08/1994	Zeller Plastik Keehan Graebner DE		
		WO 96/06732	03/07/1996	Roberts		
		WO 98/10897	03/1998	Norton Company		
		WO 98/45091	10/15/1998	Sung		
		WO 98/45092	10/15/1998	Sung		
		WO 98/51448	03/1998	Norton Company		
		WO 02/31078	04/2002	Fries		
		WO 2004/094106	11/04/04	Intel Corporation		
		WO2006/124792	11/23/2006	Sung		
		WO 2007/032946	03/22/2007	Sung		
		WO2008/063599	05/29/20078	Sung		

Examiner Signature		Date Considered	

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

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

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

PTO/SB/08A (08-03)
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Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2002/0182401 A1	12/2002	Lawing	
		2011/0252710 A1	10/2011	Hall et al.	
		7507267 B2	03/2009	Hall et al.	
		7954483 B2	06/2011	Kim et al.	
		8377158 B2	02/2013	Palmgren et al.	

FOREIGN PATENT DOCUMENTS

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

Examiner Signature		Date Considered	

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First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 12/267,172; filed 11/07/2008; Chien-Min Sung; notice of allowance dated 01/07/2013	
		US Application 13/644,790; filing date 10/04/2012; Chien-Min Sung; office action dated 06/17/2014	
		US Application 13/416,201; filing date 03/09/2012; Chien-Min Sung; office action dated 06/18/2014	

Examiner Signature		Date Considered	

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

Electronic Acknowledgement Receipt

EFS ID:	20183804
Application Number:	13802112
International Application Number:	
Confirmation Number:	1021
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP.CIP
Receipt Date:	18-SEP-2014
Filing Date:	13-MAR-2013
Time Stamp:	19:57:32
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	79418 b3ba5a5c0625ae2e0d3d6aa70446c8c69d3b0d4e	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	106087 6583db8df6940fe16a3769074af5f8598576 7078	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	78220 66c5d006d518b854d399515c7cf55a676be 71749	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
			Total Files Size (in bytes):	263725	

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

New Applications Under 35 U.S.C. 111

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

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

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

New International Application Filed with the USPTO as a Receiving Office

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

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/802,112 FILED: 3/13/2013 CONF. NO.: 1021 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP.CIP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: September 18, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

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

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

Dear Sir/Madam:

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

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

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

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

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

SUBMISSIONS

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

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

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

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

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

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

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

☐ because they are substantially cumulative of an enclosed reference.

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

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

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

REMARKS

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

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

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

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

Dated this 18th day of Septembe, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

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

PTO/SB/08A (08-03)
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Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2004/0235406 A1	11/2004	Duescher	
		2006/0213128 A1	09/28/2006	Sung	
		2011/0076925 A1	03/2011	Sung	
		2011/0192652 A1	08/2011	Shen et al.	
		2012/0244790 A1	09/2012	Sung	
		3593382 A	07/20/1971	Miller	
		6299521 B1	10/09/2001	Morimura et al.	
		6372001 B1	04/16/2002	Omar et al.	
		8545583 B2	10/2013	Duescher	

FOREIGN PATENT DOCUMENTS

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

Examiner Signature		Date Considered	

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First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 11/512,755; filing date 08/29/2006; Chien-Min Sung	
		US Application 13/479,148; filing date 05/23/2012; Chien-Min Sung; office action dated 05/15/2014	

Examiner Signature		Date Considered	

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Electronic Acknowledgement Receipt

EFS ID:	20400815
Application Number:	13802112
International Application Number:	
Confirmation Number:	1021
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP.CIP
Receipt Date:	13-OCT-2014
Filing Date:	13-MAR-2013
Time Stamp:	17:35:46
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	79393 aba1ed4ca23ac1e47c6385a751d3a4dcc968956f	no	4
Warnings:					
Information:					

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	110212 3426079b473628642ce09212373ec049e9a26f4c	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	77871 6d50cac746a3da3489552b7eecf3811840fe9594	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
			Total Files Size (in bytes):	267476	

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New Applications Under 35 U.S.C. 111

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New International Application Filed with the USPTO as a Receiving Office

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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/802,112 FILED: 3/13/2013 CONF. NO.: 1021 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP.CIP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: October 13, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

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

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

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

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

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

SUBMISSIONS

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

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

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

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

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

☐ because they are substantially cumulative of an enclosed reference.

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

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

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

REMARKS

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

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

Dated this 13th day of October, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

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

PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it contains a valid OMB control number.

Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet		of	

Complete if Known	
Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 13/153,176; filing date 06/03/2011; Chien-Min Sung; office action dated 07/01/2014	
		US Application 13/113,779; filing date 05/23/2011; Chien-Min Sung; office action dated 07/02/2014	

Examiner Signature		Date Considered	

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

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

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

Electronic Acknowledgement Receipt

EFS ID:	20401013
Application Number:	13802112
International Application Number:	
Confirmation Number:	1021
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP.CIP
Receipt Date:	13-OCT-2014
Filing Date:	13-MAR-2013
Time Stamp:	17:48:30
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	79396 55e6347b37839065a63fe8ea7826cb207d979a26	no	4

Warnings:	
Information:	

2	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	77836 7f5a0546c2e1d0e52b15a2f250df5fc8790b92c8	no	1

Warnings:	
Information:	
This is not an USPTO supplied IDS fillable form	
Total Files Size (in bytes):	157232

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

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

National Stage of an International Application under 35 U.S.C. 371
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New International Application Filed with the USPTO as a Receiving Office
If a new international application is being filed and the international application includes the necessary components for an international filing date (see PCT Article 11 and MPEP 1810), a Notification of the International Application Number and of the International Filing Date (Form PCT/RO/105) will be issued in due course, subject to prescriptions concerning national security, and the date shown on this Acknowledgement Receipt will establish the international filing date of the application.

IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/802,112 FILED: 3/13/2013 CONF. NO.: 1021 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP.CIP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: October 13, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

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

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

Dear Sir/Madam:

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

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

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

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

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

SUBMISSIONS

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☐ because they are substantially cumulative of an enclosed reference.

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

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Dated this 13th day of October, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

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

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of |

Complete if Known	
Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

U.S. PATENT DOCUMENTS

Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
		2008/0014845 A1	01/2008	Yimaz et al.	
		2009/0094902 A1	04/2009	Hou	
		2011/0104989 A1	05/2011	Boutaghou et al.	
		2013/0225052 A1	08/2013	Song et al.	

FOREIGN PATENT DOCUMENTS

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

Examiner Signature		Date Considered	

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

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

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PTO/SB/08B (08-03)
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Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 12/715, 583; filed 03/02/2010; Chien-Min Sung; notice of allowance dated 12/07/2012	
		US Application 13/407,634; filing date 02/28/2012; Chien-Min Sung; office action dated 06/13/2014	
		US Application 11/512,755; filing date 08/29/2006; Chien-Min Sung	

Examiner Signature		Date Considered	

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Electronic Acknowledgement Receipt

EFS ID:	20401155
Application Number:	13802112
International Application Number:	
Confirmation Number:	1021
Title of Invention:	CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS
First Named Inventor/Applicant Name:	Chien-Min Sung
Customer Number:	20551
Filer:	David William Osborne/Warren Archibald
Filer Authorized By:	David William Osborne
Attorney Docket Number:	02074-24012.NP.CIP
Receipt Date:	13-OCT-2014
Filing Date:	13-MAR-2013
Time Stamp:	17:58:22
Application Type:	Utility under 35 USC 111(a)

Payment information:

Submitted with Payment	no

File Listing:

Document Number	Document Description	File Name	File Size(Bytes)/ Message Digest	Multi Part /.zip	Pages (if appl.)
1	Transmittal Letter	transmittal.PDF	79388 100cc34a6a97e474bbe47ebbc990ef59cefeae8e	no	4

Warnings:	
Information:	

2	Information Disclosure Statement (IDS) Form (SB08)	a.PDF	105204 5ccfe6b403134b69a6dd0040cab0aba620ba61d2	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
3	Information Disclosure Statement (IDS) Form (SB08)	b.PDF	78128 e20d1112024cb875ff2eb91f7683e0314babab1	no	1
Warnings:					
Information:					
This is not an USPTO supplied IDS fillable form					
			Total Files Size (in bytes):	262720	

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New International Application Filed with the USPTO as a Receiving Office

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IN THE UNITED STATES PATENT & TRADEMARK OFFICE

ART UNIT: 3723 EXAMINER: FIRST NAMED INVENTOR: Chien-Min Sung SERIAL NO.: 13/802,112 FILED: 3/13/2013 CONF. NO.: 1021 FOR: CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS DOCKET NO.: 02074-24012.NP.CIP	**CERTIFICATE OF MAILING UNDER 37 C.F.R. § 1.8** DATE OF DEPOSIT: October 13, 2014 I hereby certify that this paper or fee (along with any paper or fee referred to as being attached or enclosed) is being submitted on the date indicated above via: ☒ EFS Web ☐ facsimile to _____ ☐ the United States Postal Service with sufficient postage as first class mail addressed to: Mail Stop _____, Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450. /Warren Archibald/ Warren Archibald

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

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

Dear Sir/Madam:

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

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Dated this 13th day of October, 2014.

Respectfully submitted,

/David W. Osborne/

David W. Osborne
Attorney for Applicant
Registration No. 44989

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

PLUS Search Results for S/N 13802112, Searched Wed Oct 22 09:02:59 EDT 2014

The Patent Linguistics Utility System (PLUS) is a USPTO automated search system for U.S. Patents from 1971 to the present PLUS is a query-by-example search system which produces a list of patents that are most closely related linguistically to the application searched. This search was prepared by the staff of the Scientific and Technical Information Center, SIRA.

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7393264 99
7544117 99
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APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
13/802,112	03/13/2013	Chien-Min Sung	02074-24012.NP.CIP	1021

20551 7590 11/06/2014

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

EXAMINER	
NGUYEN, GEORGE BINH MINH	
ART UNIT	PAPER NUMBER
3723	

NOTIFICATION DATE	DELIVERY MODE
11/06/2014	ELECTRONIC

Please find below and/or attached an Office communication concerning this application or proceeding.

The time period for reply, if any, is set in the attached communication.

Notice of the Office communication was sent electronically on above-indicated "Notification Date" to the following e-mail address(es):

patentdocket@tnw.com
rich@tnw.com
laron.lemon@tnw.com

Office Action Summary	Application No. 13/802,112	Applicant(s) SUNG, CHIEN-MIN	
	Examiner GEORGE NGUYEN	Art Unit 3723	AIA (First Inventor to File) Status No

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

Period for Reply

A SHORTENED STATUTORY PERIOD FOR REPLY IS SET TO EXPIRE *3* MONTHS FROM THE MAILING DATE OF THIS COMMUNICATION.

- Extensions of time may be available under the provisions of 37 CFR 1.136(a). In no event, however, may a reply be timely filed after SIX (6) MONTHS from the mailing date of this communication.
- If NO period for reply is specified above, the maximum statutory period will apply and will expire SIX (6) MONTHS from the mailing date of this communication.
- Failure to reply within the set or extended period for reply will, by statute, cause the application to become ABANDONED (35 U.S.C. § 133). Any reply received by the Office later than three months after the mailing date of this communication, even if timely filed, may reduce any earned patent term adjustment. See 37 CFR 1.704(b).

Status

1)☐ Responsive to communication(s) filed on _____.

☐ A declaration(s)/affidavit(s) under **37 CFR 1.130(b)** was/were filed on _____.

2a)☐ This action is **FINAL**. 2b)☒ This action is non-final.

3)☐ An election was made by the applicant in response to a restriction requirement set forth during the interview on _____; the restriction requirement and election have been incorporated into this action.

4)☐ Since this application is in condition for allowance except for formal matters, prosecution as to the merits is closed in accordance with the practice under *Ex parte Quayle*, 1935 C.D. 11, 453 O.G. 213.

Disposition of Claims*

5)☒ Claim(s) *1-20* is/are pending in the application.

5a) Of the above claim(s) _____ is/are withdrawn from consideration.

6)☐ Claim(s) _____ is/are allowed.

7)☒ Claim(s) *1-20* is/are rejected.

8)☐ Claim(s) _____ is/are objected to.

9)☐ Claim(s) _____ are subject to restriction and/or election requirement.

* If any claims have been determined allowable, you may be eligible to benefit from the **Patent Prosecution Highway** program at a participating intellectual property office for the corresponding application. For more information, please see http://www.uspto.gov/patents/init_events/pph/index.jsp or send an inquiry to PPHfeedback@uspto.gov.

Application Papers

10)☐ The specification is objected to by the Examiner.

11)☒ The drawing(s) filed on *3/13/2013* is/are: a)☒ accepted or b)☐ objected to by the Examiner.

Applicant may not request that any objection to the drawing(s) be held in abeyance. See 37 CFR 1.85(a).

Replacement drawing sheet(s) including the correction is required if the drawing(s) is objected to. See 37 CFR 1.121(d).

Priority under 35 U.S.C. § 119

12)☐ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).

Certified copies:

a)☐ All b)☐ Some** c)☐ None of the:

1.☐ Certified copies of the priority documents have been received.

2.☐ Certified copies of the priority documents have been received in Application No. _____.

3.☐ Copies of the certified copies of the priority documents have been received in this National Stage application from the International Bureau (PCT Rule 17.2(a)).

** See the attached detailed Office action for a list of the certified copies not received.

Attachment(s)

1) ☒ Notice of References Cited (PTO-892)

2) ☒ Information Disclosure Statement(s) (PTO/SB/08a and/or PTO/SB/08b) Paper No(s)/Mail Date *10/13/2014;09/18/2014;08/16/2014;06/19/2014;10/04/2013*.

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

4) ☐ Other: _____.

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

DETAILED ACTION

Claims 1-20 are presented for examination.

Receipt is acknowledged of the IDS filed on October 13, 2014, September 18, 2014, August 16,2014, June 19, 2014, and October 4, 2013 which have been considered and placed of record in the file.

This application has been filed with formal drawings which are acceptable to the examiner.

Specification

The disclosure is objected to because of the following informalities: in page 3, line 10, Fig. 3 should have been about “a method of polishing a semiconductor wafer”.

Appropriate correction is required.

Claim Rejections - 35 USC § 103

The following is a quotation of pre-AIA 35 U.S.C. 103(a) which forms the basis for all obviousness rejections set forth in this Office action:

> (a) A patent may not be obtained though the invention is not identically disclosed or described as set forth in section 102 of this title, if the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious at the time the invention was made to a person having ordinary skill in the art to which said subject matter pertains. Patentability shall not be negatived by the manner in which the invention was made.

The factual inquiries set forth in *Graham v. John Deere Co.*, 383 U.S. 1, 148 USPQ 459 (1966), that are applied for establishing a background for determining obviousness under pre-AIA 35 U.S.C. 103(a) are summarized as follows:

1. Determining the scope and contents of the prior art.

2. Ascertaining the differences between the prior art and the claims at issue.

3. Resolving the level of ordinary skill in the pertinent art.

4. Considering objective evidence present in the application indicating obviousness or nonobviousness.

Claims 1-20 are rejected under pre-AIA 35 U.S.C. 103(a) as being unpatentable over Dinh-Ngoc et al.'2010/0248595 in view of Sung'2008/0292869.

In re claim 1, Dinh-Ngoc et al.'595 discloses **a method of conditioning a CMP pad, comprising: pressing a CMP pad dresser #200 against a CMP pad** ([0007])**, the dresser including a monolayer of a plurality of superabrasive particles #221 protruding from a matrix layer #201, wherein the difference in protrusion distance #215 between the highest protruding tip #213 and the second highest protruding tip of the monolayer of superabrasive particles is less than or equal to about 50 microns** ([0075-0076], Fig. 2A, flatness even not greater than 0.005cm or 50 microns).

However, Dinh-Ngoc et al.'595 does not disclose **the difference in protrusion distance between the highest 10 protruding tips of the monolayer of superabrasive particles are within about 20 microns or less; and rotating the dresser against the CMP pad such that asperities are cut into the CMP pad having a maximum cutting depth of about 60 microns.**

Nevertheless, Sung'869 discloses a superabrasive tool for conditioning a polishing pad. Sung'869 discloses that superabrasive particles #24 protruding to a predetermined height may produce a [redacted] of less than about 20 microns when used to abrade

a work piece ([0010]). Sung'869 further discloses that It may also be beneficial for the superabrasive particles to protrude from the solidified organic material layer to a predetermined height or series of heights that is/are along a designated profile. **Numerous configurations for designated profiles are possible, depending on the particular use of the abrading tool** ([0057-0059]).

Thus, it would have been obvious to one skilled in the art at the time the invention was made to have modified Dinh-Ngoc et al.'869 conditioner tool with a designated profile as taught by Sung'869 as set forth in the claim in order to achieve a desired cutting depth.

In re claims 2-4, regarding to the tip range set forth in the claims, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have utilized the range set forth in the claims, since it has been held that where the general conditions of a claim are discloses in the prior art, discovering the optimum or workable ranges involves only routine skill in the art.

In re claims 5-8, the claimed limitations are disclosed in ([0062]). Regarding to the percentage of dresser radius range set forth in the claims, it would have been obvious to one having ordinary skill in the art at the time the invention was made to have utilized the range set forth in the claims, since it has been held that where the general conditions of a claim are discloses in the prior art, discovering the optimum or workable ranges involves only routine skill in the art.

In re claims 9 -10, Sung'869 discloses superabrasive particles in different locations of the dresser ([0061]). Official Notice is taken that peripherally located particles is a

conventional or well-known feature or method for the purpose of saving material in the dresser . Therefore, it would have been obvious to a person having ordinary skill in the art at the time the invention was made to have attached the abrasive particles in the peripheral region in order to save material cost.

In re claims 11-13, the claimed limitations are apparently disclosed in [0002] of Sung'869.

In re claims 14-16, the claimed limitations are not given any patentable weight because it has been held that to be entitled to weight in method claims, the recited structure limitations therein must affect the method in a manipulative sense, and not to amount to the mere claiming of a use of a particular structure. Ex Parte Pfeiffer, 1962 C.D. 408 (1961) . Please note that in [0005] Sung'869 discloses polishing ULSI wafer with size reduction. Therefore, Sung'869 method would obviously be able to polish semiconductor device with such node size, line width, and wafer size as set forth in the claim.

In re claims 17-20, in [0002], Sung'869 discloses a CMP process using slurry and polyurethane pad. Official Notice is taken that slurry with silica abrasive, oxidative compound, and hydrogen peroxide is a conventional or well-known feature or method for the purpose of providing dual chemical and mechanical forces exerted on the wafer to cause it to be polished in a desired manner . Therefore, it would have been obvious to a person having ordinary skill in the art at the time the invention was made to have utilized slurry with silica abrasive, oxidative compound, and hydrogen peroxide in order

providing dual chemical and mechanical forces exerted on the wafer to cause it to be polished in a desired manner.

Conclusion

The prior art made of record and not relied upon is considered pertinent to applicant's disclosure. Please see PTO-892.

Any inquiry concerning this communication or earlier communications from the examiner should be directed to GEORGE NGUYEN whose telephone number is (571)272-4491. The examiner can normally be reached on Monday -Friday from 8 AM-4 PM.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Hail Joseph can be reached on 571-272-4485. The fax phone number for the organization where this application or proceeding is assigned is 571-273-8300.

Information regarding the status of an application may be obtained from the Patent Application Information Retrieval (PAIR) system. Status information for published applications may be obtained from either Private PAIR or Public PAIR. Status information for unpublished applications is available through Private PAIR only. For more information about the PAIR system, see http://pair-direct.uspto.gov. Should you have questions on access to the Private PAIR system, contact the Electronic Business Center (EBC) at 866-217-9197 (toll-free). If you would like assistance from a USPTO Customer Service Representative or access to the automated information system, call 800-786-9199 (IN USA OR CANADA) or 571-272-1000.

George Nguyen

Primary Examiner
Art Unit 3723

/GEORGE NGUYEN/
Primary Examiner, Art Unit 3723

Notice of References Cited	Application/Control No. 13/802,112	Applicant(s)/Patent Under Reexamination SUNG, CHIEN-MIN	
	Examiner GEORGE NGUYEN	Art Unit 3723	Page 1 of 2

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*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
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*	C	US-5,030,276 A	07-1991	Sung et al.	75/237
*	D	US-5,380,390 A	01-1995	Tselesin, Naum N.	156/230
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*	F	US-6,299,521 B1	10-2001	Morimura et al.	451/533
*	G	US-2001/0046835 A1	11-2001	Wielonski et al.	451/533
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	N					
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NON-PATENT DOCUMENTS

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	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
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	Examiner GEORGE NGUYEN	Art Unit 3723	Page 2 of 2

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*	E	US-7,404,857 B2	07-2008	Sung, Chien-Min	117/79
*	F	US-2008/0292869 A1	11-2008	Sung, Chien-Min	428/323
*	G	US-7,494,404 B2	02-2009	Sung, Chien-Min	451/527
*	H	US-2010/0022174 A1	01-2010	Chou et al.	451/548
*	I	US-2011/0076925 A1	03-2011	Sung, Chien-Min	451/8
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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Sheet | | of |

Complete if Known	
Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

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Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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Examiner Signature	/George Nguyen/ (10/30/2014)	Date Considered	

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		US Application 13/153,176; filing date 06/03/2011; Chien-Min Sung; office action dated 07/01/2014	
		US Application 13/113,779; filing date 05/23/2011; Chien-Min Sung; office action dated 07/02/2014	

Examiner Signature	/George Nguyen/ (10/30/2014)	Date Considered	

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		2008/0014845 A1	01/2008	Yimaz et al.	
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FOREIGN PATENT DOCUMENTS

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

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BIB DATA SHEET

CONFIRMATION NO. 1021

SERIAL NUMBER	FILING or 371(c) DATE RULE	CLASS	GROUP ART UNIT	ATTORNEY DOCKET NO.
13/802,112	03/13/2013	451	3723	02074-24012.NP.CIP

APPLICANTS

INVENTORS

Chien-Min Sung, Tansui, TAIWAN;

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

This application is a CIP of 13/479,148 05/23/2012
which claims benefit of 61/489,074 05/23/2011

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

**** IF REQUIRED, FOREIGN FILING LICENSE GRANTED **** ** SMALL ENTITY **
04/16/2013

Foreign Priority claimed ☐ Yes ☑ No 35 USC 119(a-d) conditions met ☐ Yes ☐ No Verified and Acknowledged /GEORGE BINH MINH NGUYEN/ Examiner's Signature	☐ Met after Allowance Initials	STATE OR COUNTRY	SHEETS DRAWINGS	TOTAL CLAIMS	INDEPENDENT CLAIMS
		TAIWAN	7	20	1

ADDRESS

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

TITLE

CMP PAD DRESSER HAVING LEVELED TIPS AND ASSOCIATED METHODS

FILING FEE RECEIVED		
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EAST Search History

EAST Search History (Prior Art)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S1	48	(US-20120244790-$ or US-20120302146-$ or US-20130165023-$ or US-20010046835-$ or US-20070066194-$ or US-20020139680-$ or US-20070175765-$ or US-20030084894-$ or US-20040112359-$ or US-20070051354-$ or US-20070051355-$ or US-20090283089-$ or US-20110296766-$ or US-20120192499-$ or US-20120220208-$ or US-20120260582-$ or US-20020173234-$ or US-20050095959-$ or US-20060068691-$ or US-20060073774-$).did. or (US-6517424-$ or US-7300338-$ or US-5492771-$ or US-5511718-$ or US-5976205-$ or US-7124753-$ or US-7771498-$ or US-8104464-$ or US-6884155-$ or US-7201645-$ or US-7241206-$ or US-7258708-$ or US-7285039-$ or US-7393264-$ or US-7473162-$ or US-7491116-$ or US-7494404-$ or US-7544117-$ or US-7651386-$ or US-7690971-$ or US-7749050-$ or US-7901272-$ or US-8043145-$ or US-8142261-$ or US-8298043-$ or US-8298048-$).did. or (US-8414362-$ or US-8449357-$).did.	US-PGPUB; USPAT	OR	OFF	2013/07/09 08:32
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S9	4663	51/309.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/09 10:46
S10	180	S9 and (flatness warping)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	OFF	2013/07/09 10:47

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S20	341	sung-chien-min.in.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2013/07/16 11:47
S24	655	b24b53/07.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:04
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S27	331	451/444.ccls.	USPAT	OR	OFF	2014/02/24 11:34
S28	912	451/548.ccls.	USPAT	OR	OFF	2014/02/24

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S29	1838	b24b53/12.cpc.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/02/24 11:40
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S42	8	S40 and S41	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 11:43
S43	14761	"51"/$.ccls.	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 12:52
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S47	59	protrusion adj difference	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO;	OR	OFF	2014/05/07 13:42

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S53	1160	adhesive near2 transfer near2 sheet	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 15:46
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S55	971	aperture near2 template	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/07 16:09
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S62	126	warping adj (reducing reduction minimizing mininized)	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:51
S63	0	S62 and S60	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/05/09 08:51
S64	113048	"451"/$.ccls.	US-PGPUB; USPAT;	OR	OFF	2014/05/09 08:51

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S79	434842	dresser conditioner	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/31 09:58
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S91	2031	node adj size	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/31 10:50
S92	61	S91 same semiconductor	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/31 10:50
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			IBM_TDB			
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S96	52	S94 and S95	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/31 11:00
S97	198	oxidative adj compound	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/31 11:39
S98	1	S97 same slurry	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/31 11:40
S99	1	S95 and S97	US-PGPUB; USPAT; USOCR; FPRS; EPO; JPO; DERWENT; IBM_TDB	OR	OFF	2014/10/31 11:41

EAST Search History (Interference)

Ref #	Hits	Search Query	DBs	Default Operator	Plurals	Time Stamp
S21	608	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S22	53464	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S23	1	S21 same S22	US-PGPUB; USPAT; UPAD	OR	OFF	2013/07/16 11:56
S30	635	first near2 monolayer near2 second	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38
S31	55259	rigid near2 support	US-PGPUB; USPAT; UPAD	OR	OFF	2014/02/24 11:38
S32	19881	(superabrasive abrasive) adj	US-PGPUB; USPAT;	OR	OFF	2014/02/24

		particles	UPAD			11:39
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11/ 3/ 2014 9:00:03 AM
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PTO/SB/08B (08-03)
Approved for use through 07/31/2006. OMB 0651-0031
U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE
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Substitute for form 1449/PTO

INFORMATION DISCLOSURE STATEMENT BY APPLICANT

(Use as many sheets as necessary)

Sheet | | of | |

Complete if Known	
Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

NON PATENT LITERATURE DOCUMENTS

Examiner Initials*	Cite No.[1]	Include name of author (in CAPITAL LETTERS), title of the article (when appropriate), title of the item (book, magazine, journal, serial, symposium, catalog, etc.), date, page(s), volume-issue number(s), publisher, city and/or country where published.	T[2]
		US Application 12/267,172; filed 11/07/2008; Chien-Min Sung; notice of allowance dated 01/07/2013	
		US Application 13/644,790; filing date 10/04/2012; Chien-Min Sung; office action dated 06/17/2014	
		US Application 13/416,201; filing date 03/09/2012; Chien-Min Sung; office action dated 06/18/2014	

Examiner Signature	/George Nguyen/ (10/30/2014)	Date Considered	

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INFORMATION DISCLOSURE STATEMENT BY APPLICANT

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Complete if Known	
Application Number	13/802,112
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First Named Inventor	Chien-Min Sung
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Search Notes	Application/Control No.	Applicant(s)/Patent Under Reexamination
	13802112	SUNG, CHIEN-MIN
	Examiner	Art Unit
	GEORGE NGUYEN	3723

CPC- SEARCHED		
Symbol	Date	Examiner
b24b53/07;53/017;3/125	11/3/2014	GN

CPC COMBINATION SETS - SEARCHED		
Symbol	Date	Examiner

US CLASSIFICATION SEARCHED			
Class	Subclass	Date	Examiner
451	443,444,548,56	11/3/2014	GN
51	295,309	11/3/2014	GN

SEARCH NOTES		
Search Notes	Date	Examiner
updated parent search 13/479,148	11/3/2014	GN
Inventor search	11/3/2014	GN

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

	/GEORGE NGUYEN/ Primary Examiner.Art Unit 3723

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		US Application 11/512,755; filing date 08/29/2006; Chien-Min Sung	

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Examiner Initials*	Cite No.[1]	Document Number Number-Kind Code[2] (if known)	Publication Date MM-DD-YYYY	Name of Patentee or Applicant of Cited Document	Pages, Columns, Lines, Where Relevant Passages or Relevant Figures Appear
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Application Number	13/802,112
Filing Date	3/13/2013
First Named Inventor	Chien-Min Sung
Art Unit	3723
Examiner Name	
Attorney Docket Number	02074-24012.NP.CIP

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(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 075 898 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
14.02.2001 Bulletin 2001/07

(51) Int. Cl.[7]: **B24B 37/04**, B24B 53/007, B24B 53/12

(21) Application number: **00116133.0**

(22) Date of filing: **31.07.2000**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **13.08.1999 JP 22949599**
24.09.1999 JP 27117699
28.04.2000 JP 2000131784
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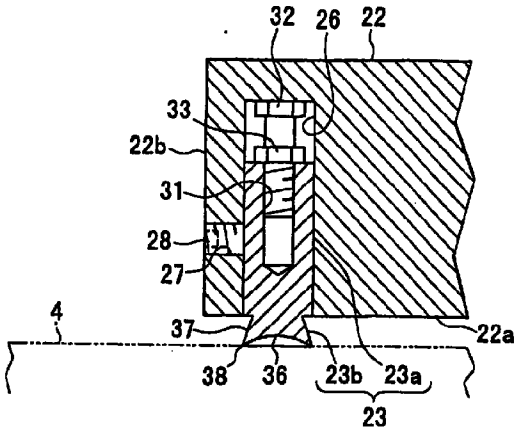
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(54) Dresser and dressing apparatus

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

FIG. 2



EP 1 075 898 A2

Description

BACKGROUND OF THE INVENTION

Field of the invention:

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

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

Description of the Related Art:

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

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

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

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

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

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

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

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

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

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

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

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

Ex. 1003, Page 947

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Ex. 1003, Page 948

SUMMARY OF THE INVENTION

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

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

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

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

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

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

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

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

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

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

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

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

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

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

[0043] Still further object of the present invention is

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

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

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

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

BRIEF DESCRIPTION OF THE DRAWINGS

[0047]

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

DESCRIPTION OF PREFERRED EMBODIMENTS

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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against the surface of the polishing pad 4.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Example 2:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Example 3:

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

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

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

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

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

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

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

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

Example 4:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Example 5:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Claims

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

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

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

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

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

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portion.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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FIG. 1

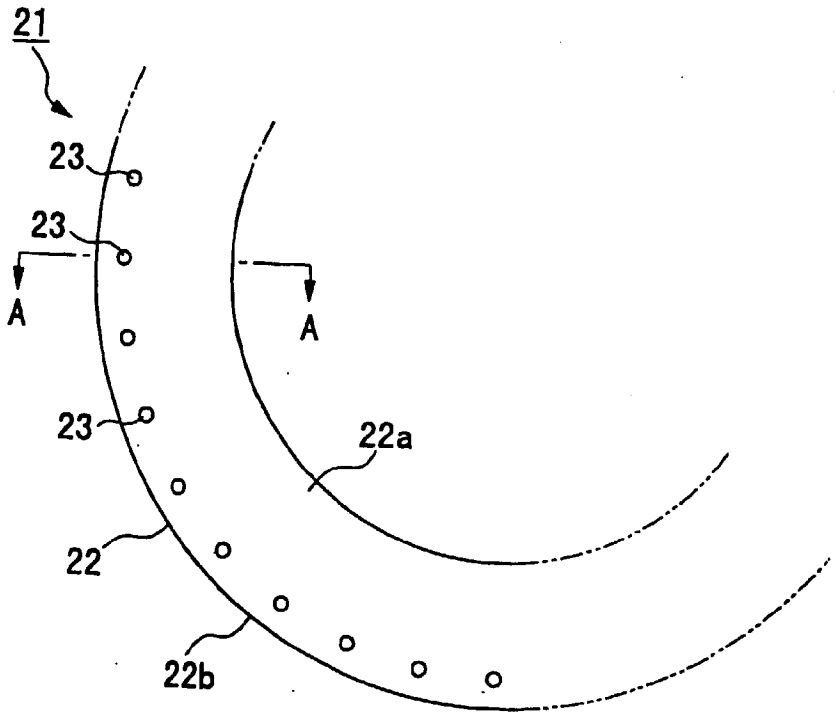


FIG. 2

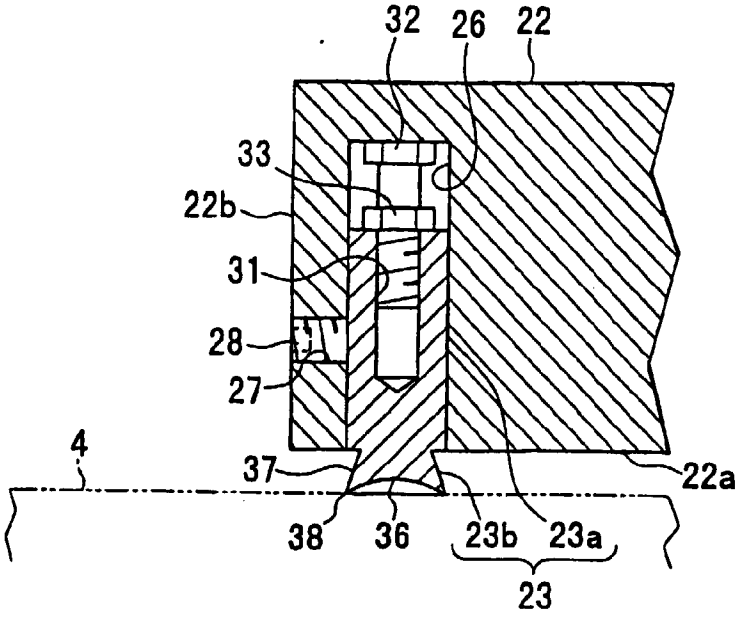

32
26
22
33
22b
31
28
27
4
37
22a
38
36
23b
23a
23

FIG. 3

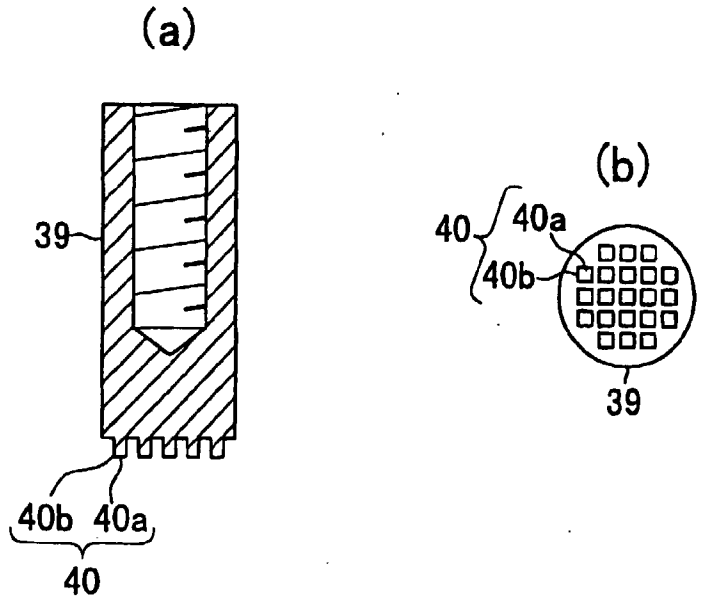

(a)
39
40b
40a
40
(b)
40
40a
40b
39

FIG. 4

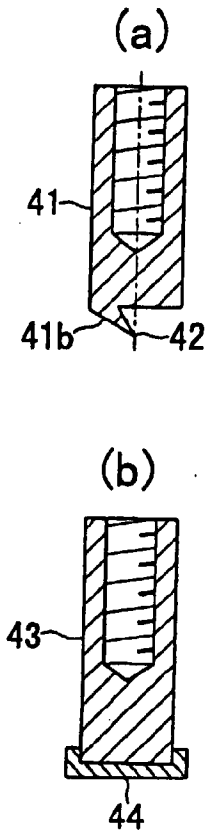


FIG. 5

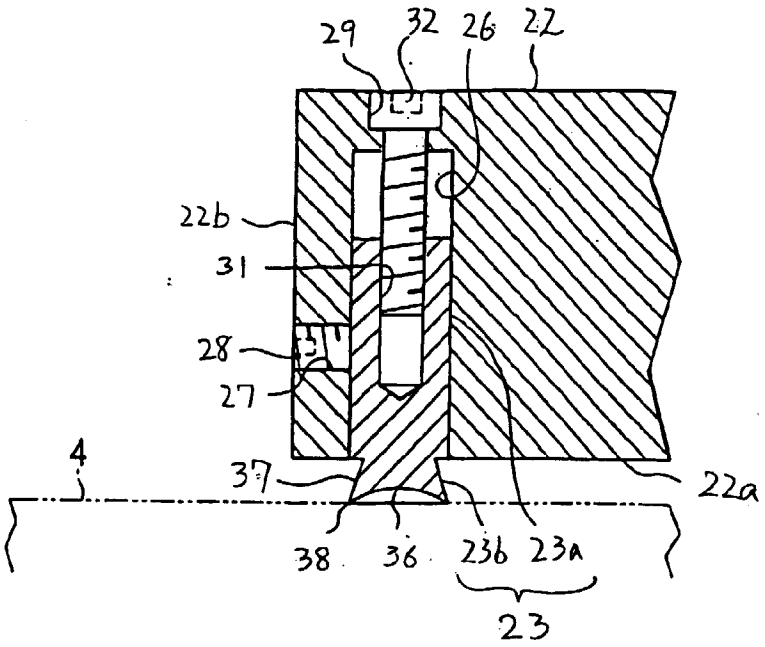


FIG. 6

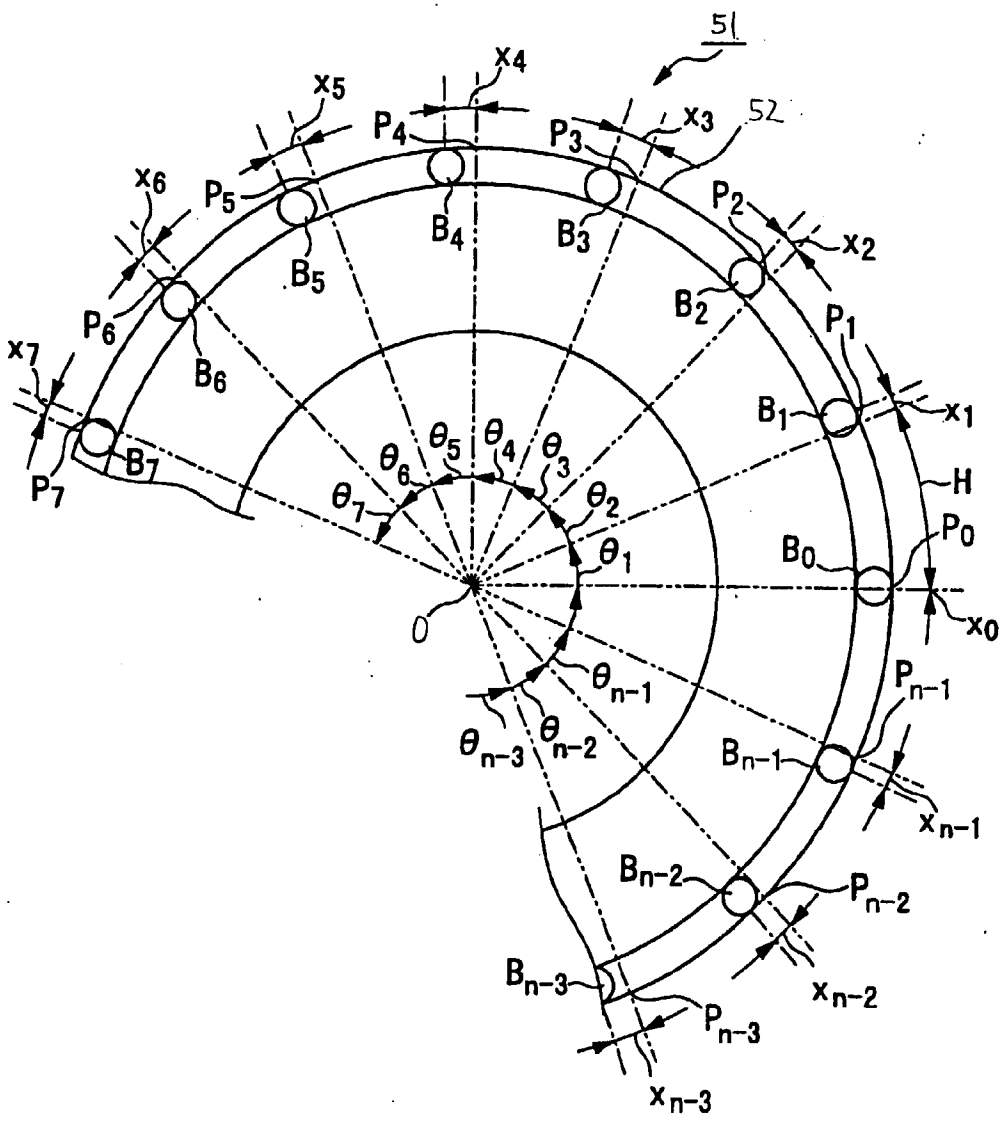

51
52
x_4
x_5
P_4
P_3
x_3
x_6
P_5
P_2
x_2
B_4
B_3
B_5
B_2
P_1
P_6
B_6
x_7
B_1
x_1
P_7
B_7
θ_5
θ_4
θ_3
θ_6
θ_2
H
θ_7
θ_1
P_0
B_0
x_0
0
θ_{n-1}
P_{n-1}
θ_{n-3}
θ_{n-2}
B_{n-1}
x_{n-1}
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x_{n-2}
P_{n-3}
x_{n-3}

FIG. 7

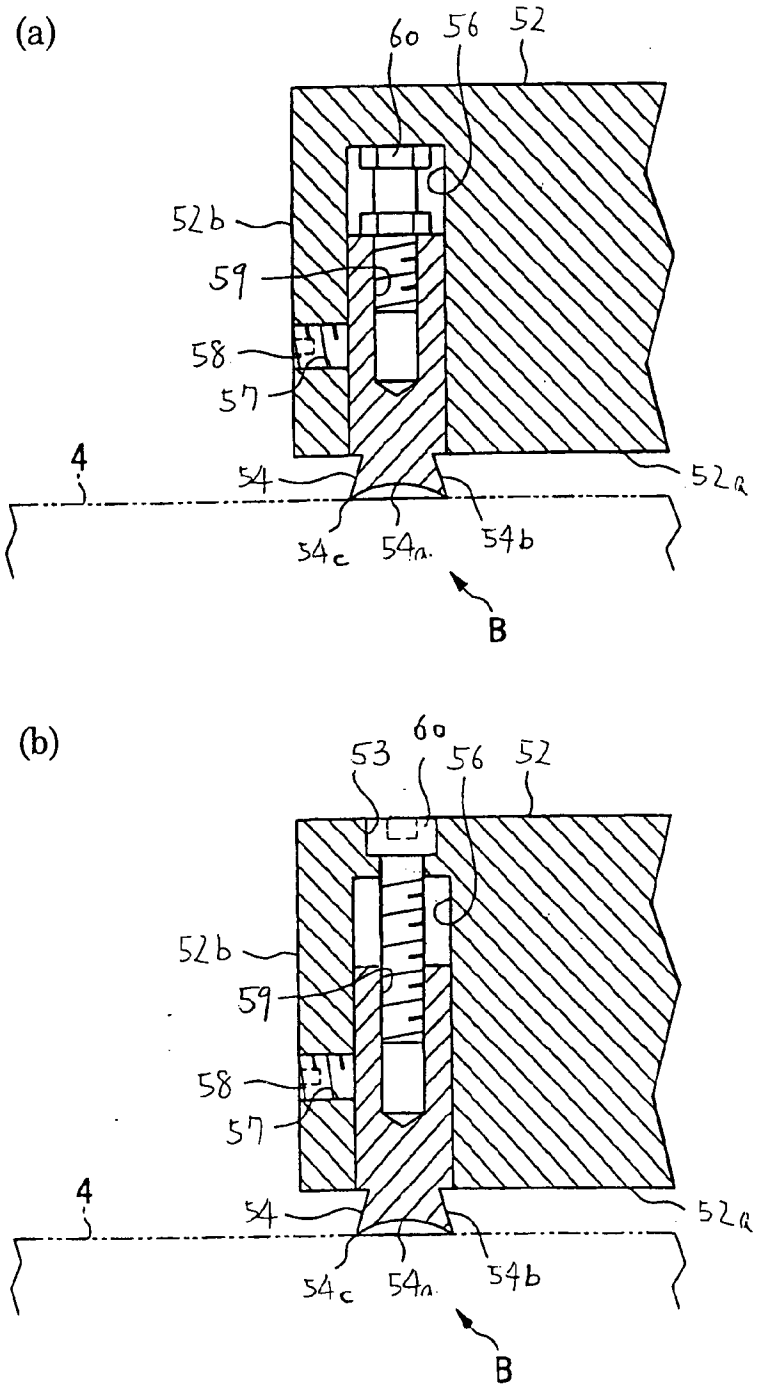

(a)
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B
(b)
53
60
56
52
52b
59
58
57
4
54
52a
54c
54a
54b
B

FIG. 8

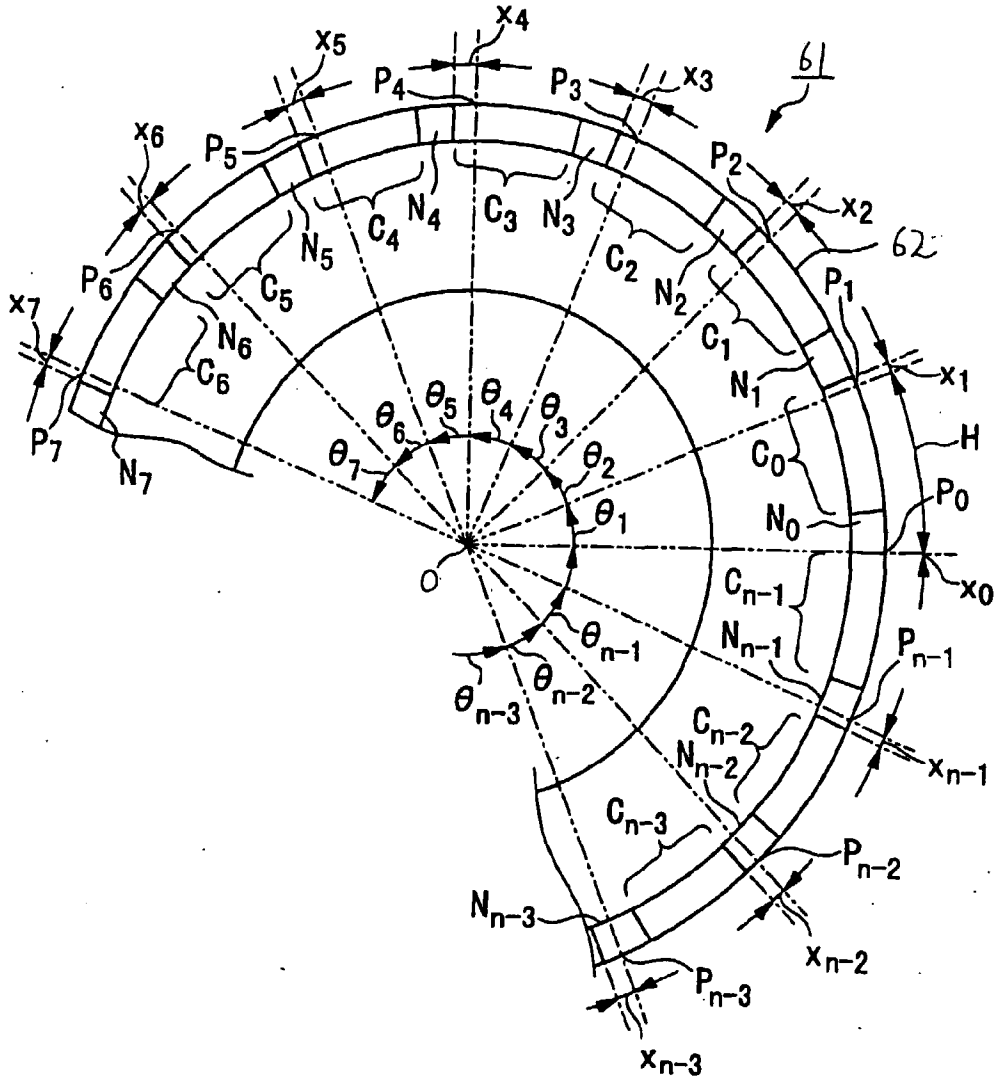

61
62
O
H
x_0
x_1
x_2
x_3
x_4
x_5
x_6
x_7
x_{n-1}
x_{n-2}
x_{n-3}
P_0
P_1
P_2
P_3
P_4
P_5
P_6
P_7
P_{n-1}
P_{n-2}
P_{n-3}
N_0
N_1
N_2
N_3
N_4
N_5
N_6
N_7
N_{n-1}
N_{n-2}
N_{n-3}
C_0
C_1
C_2
C_3
C_4
C_5
C_6
C_{n-1}
C_{n-2}
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θ_1
θ_2
θ_3
θ_4
θ_5
θ_6
θ_7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

FIG. 9

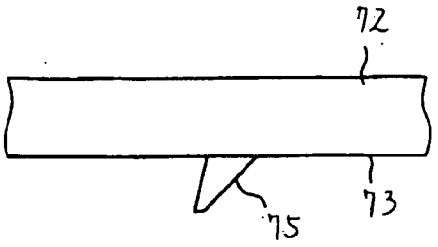


FIG. 10

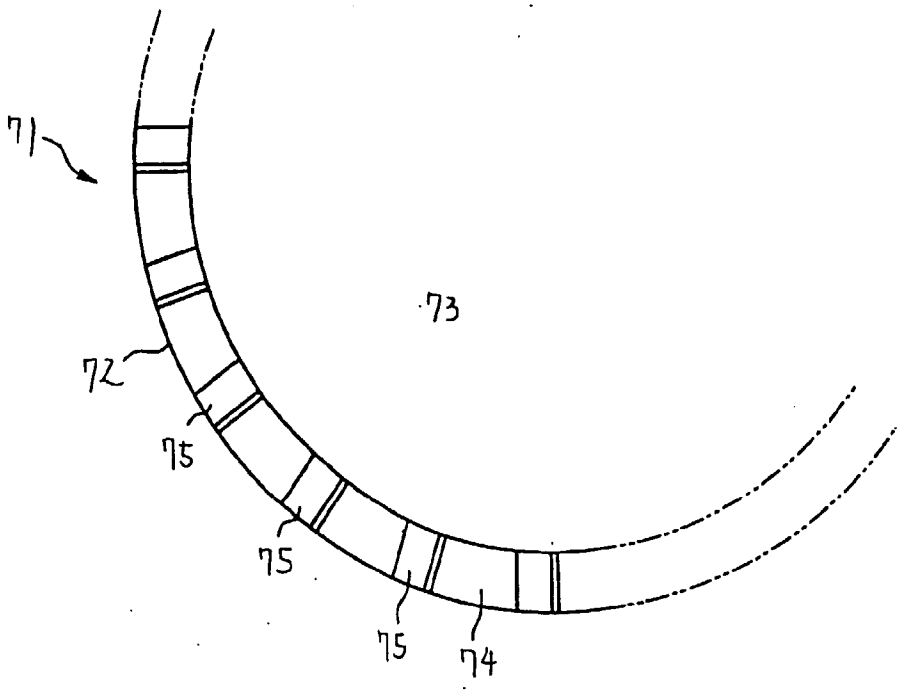


FIG. 11

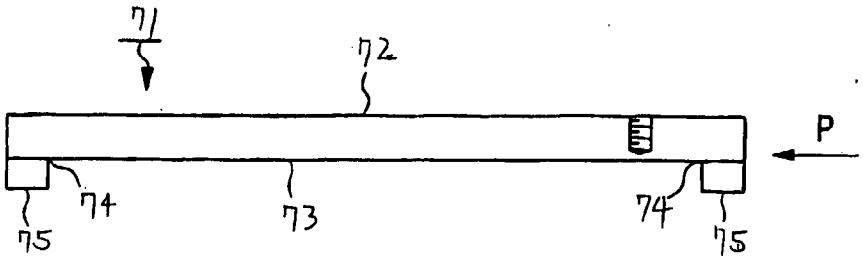


FIG. 12

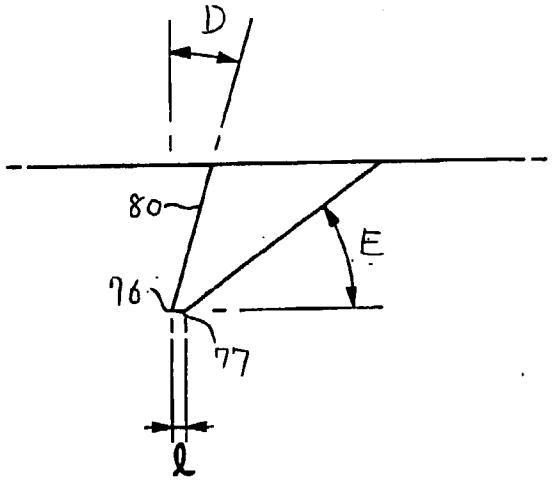


FIG. 13

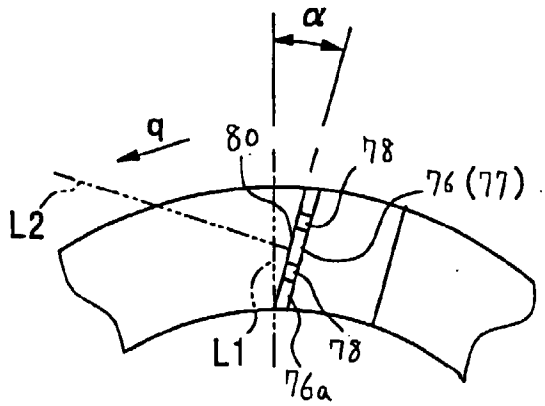


FIG. 14

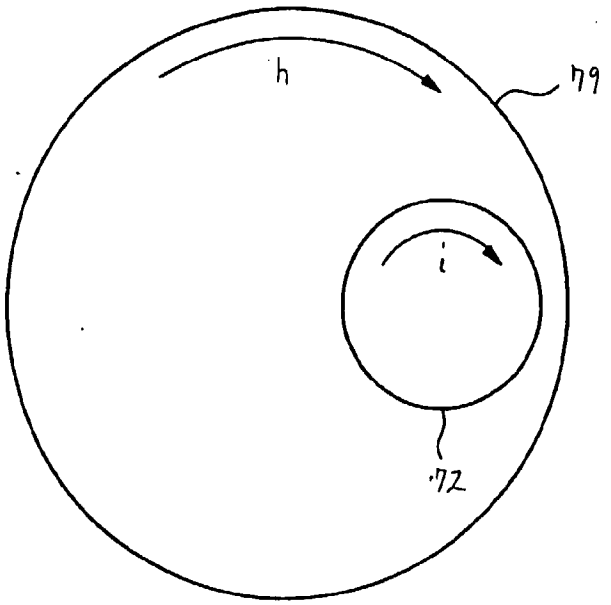


FIG. 15

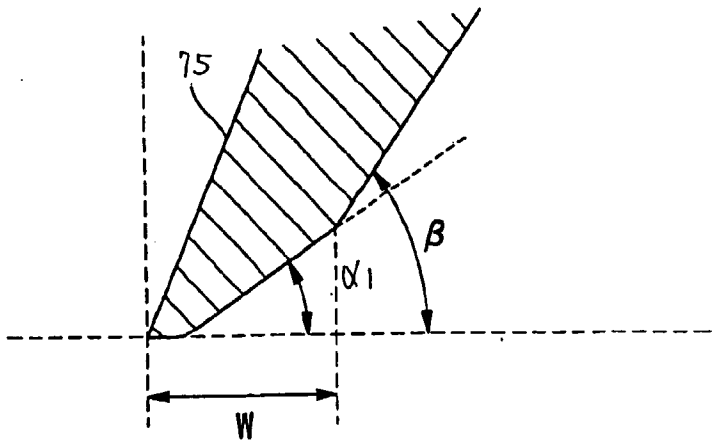


FIG. 16

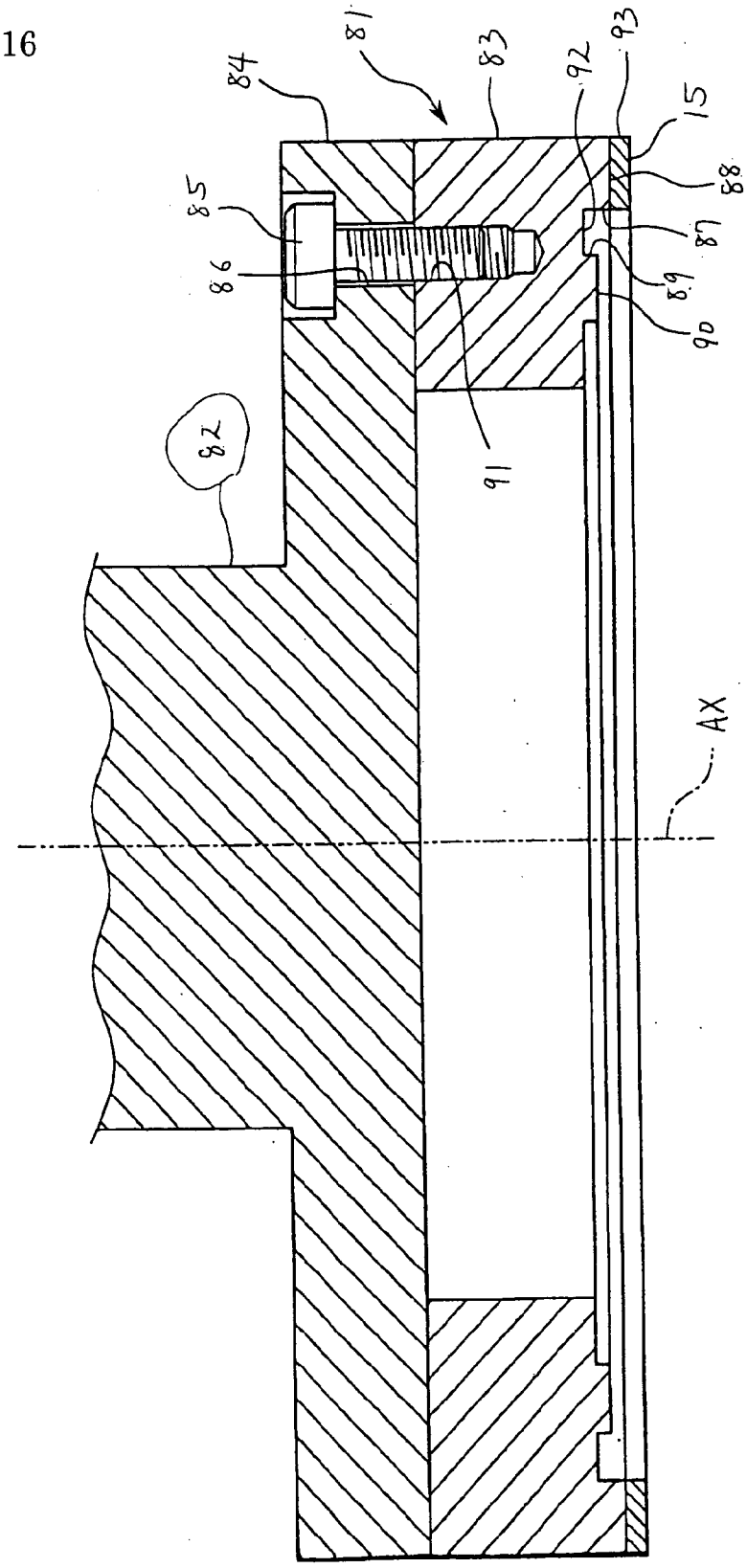


FIG. 17

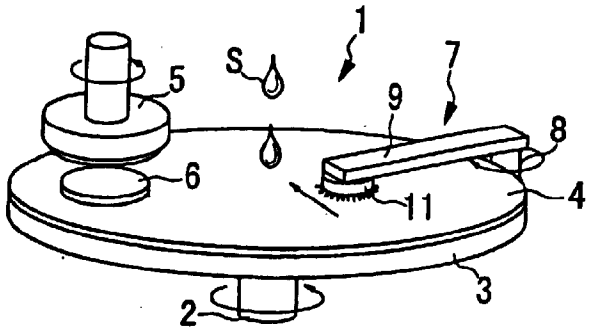


FIG. 18

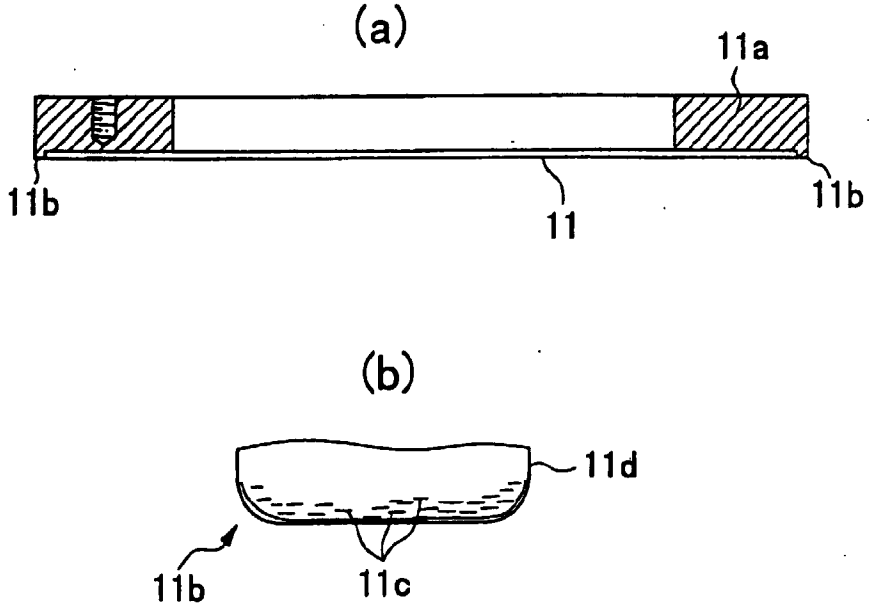


FIG. 19

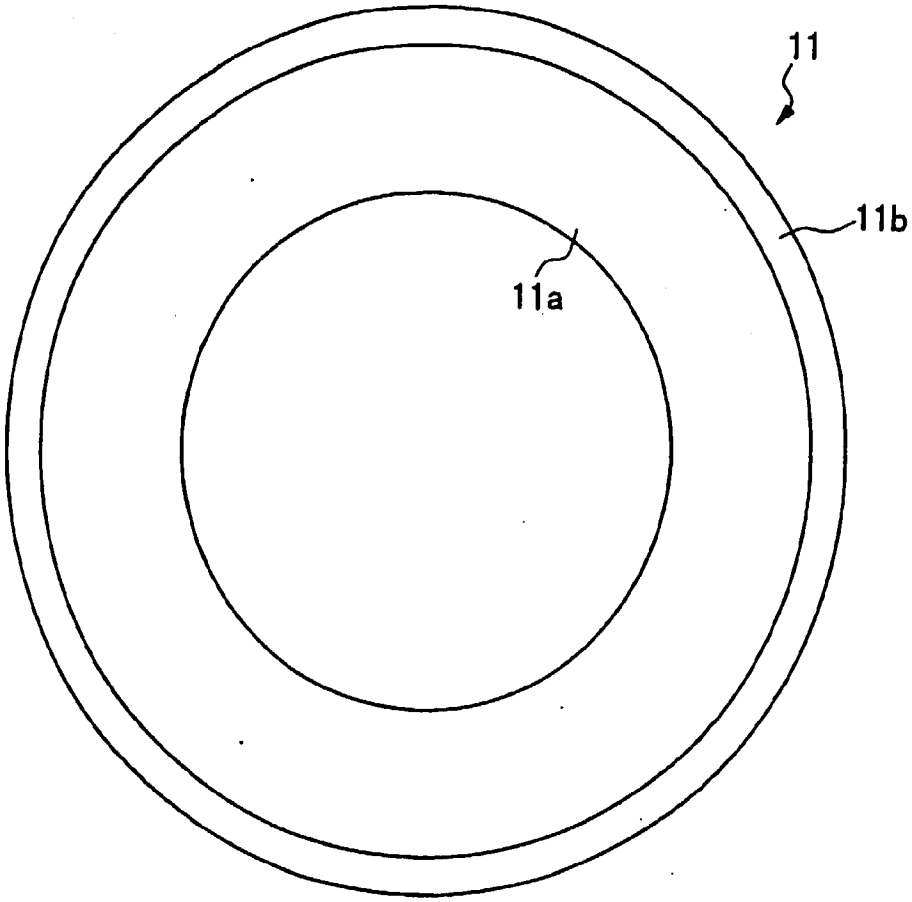


FIG. 20

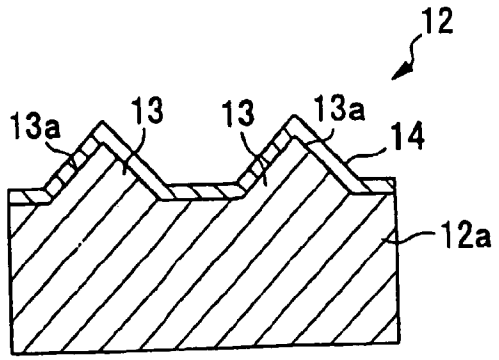
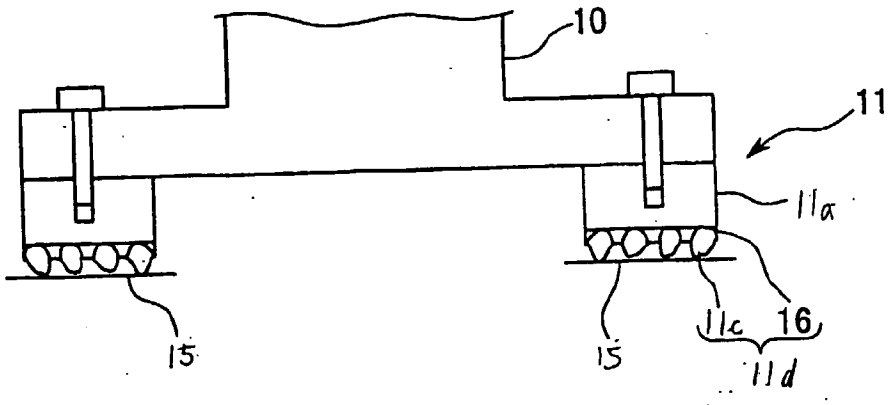


FIG. 21



(12) UK Patent Application (19) GB (11) 2 366 804 (13) A

(43) Date of A Publication 20.03.2002

(21) Application No 0022947.6

(22) Date of Filing 19.09.2000

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(51) INT CL[7]
C23C 16/44 , B22F 7/04 , B24B 53/12 , C23C 16/00 16/27

(52) UK CL (Edition T)
C7F FHE FP861 FP862 FP864 FR902
B3D DMN
C7D DB704
U1S S1578 S1645 S1652 S1660

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JP020256464 & WPI Accession no 90-357429
JP580090465 A & Japio abstract of JP580090465 A

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

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

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

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FIG. 1a

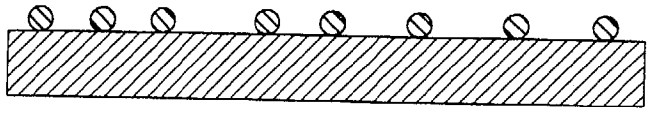


FIG. 1b

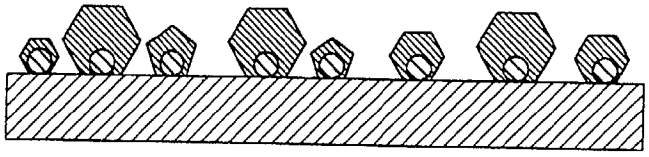
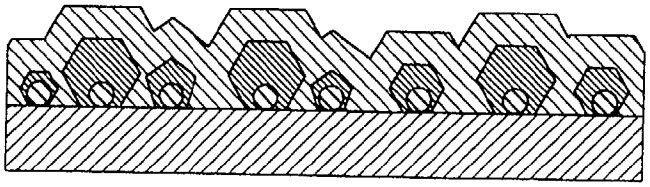


FIG. 1c



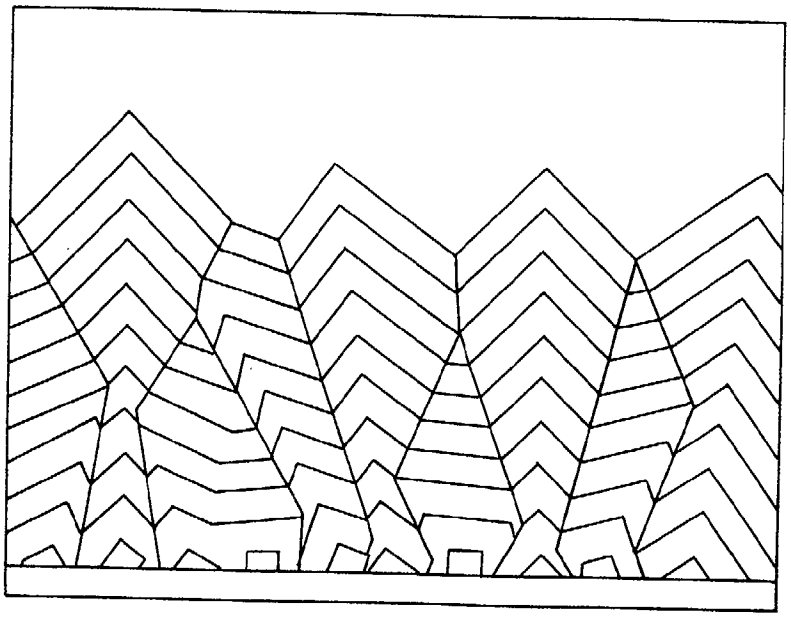


FIG. 1d

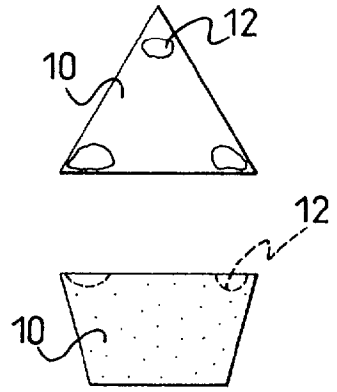


FIG. 2
PRIOR ART

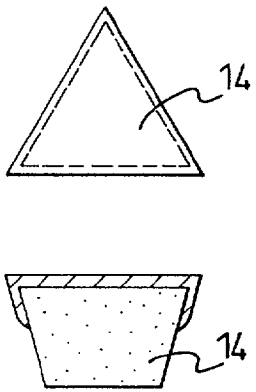


FIG. 3
PRIOR ART

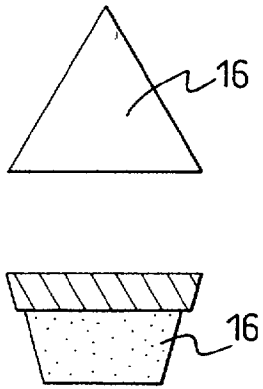


FIG. 4
PRIOR ART

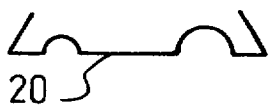


FIG. 5

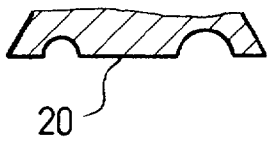


FIG. 6

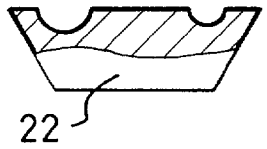


FIG. 7

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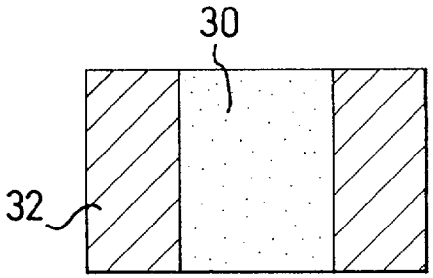


FIG. 8
PRIOR ART

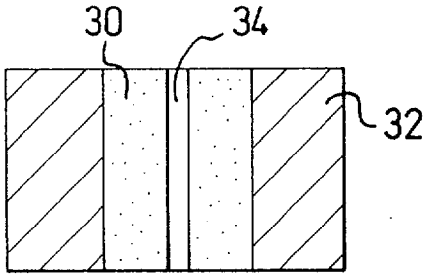


FIG. 9
PRIOR ART

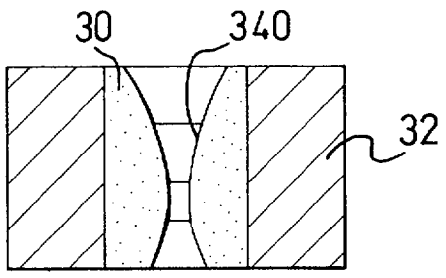


FIG.10
PRIOR ART

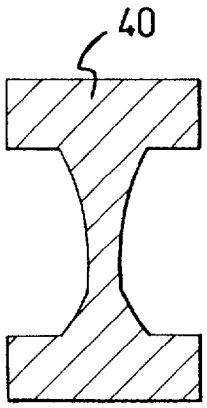


FIG.11

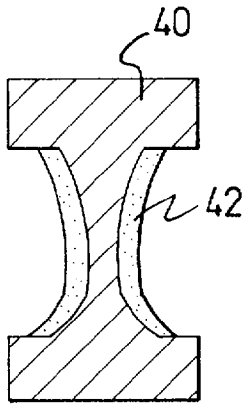


FIG.12

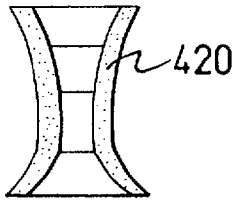


FIG.13

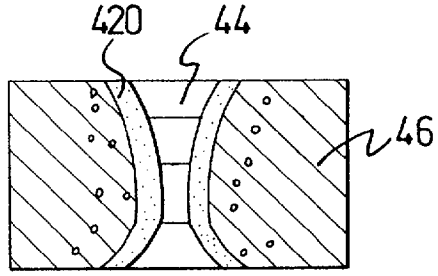


FIG.14

Ex. 1003, Page 977

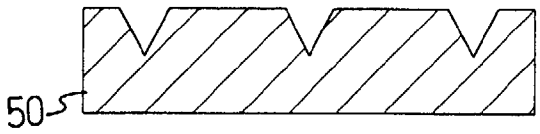


FIG. 15

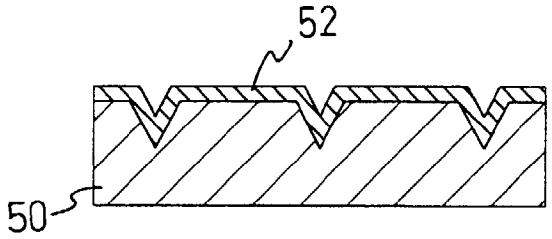


FIG. 16

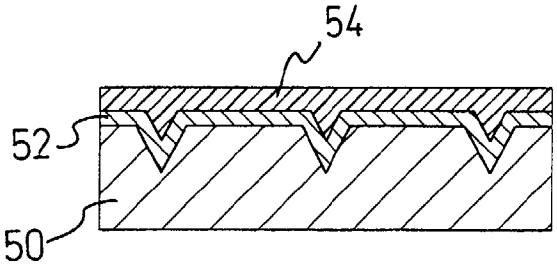


FIG. 17

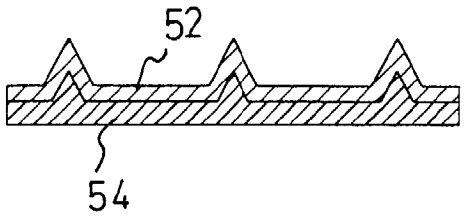


FIG. 18

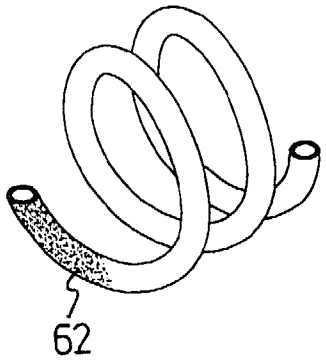


FIG. 21

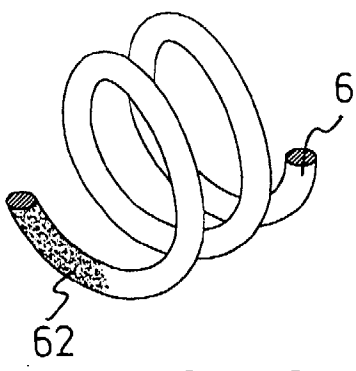


FIG. 20

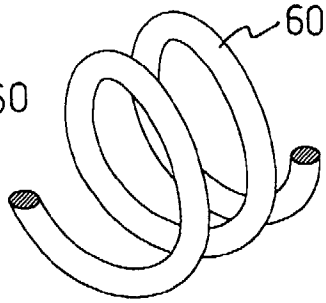


FIG. 19

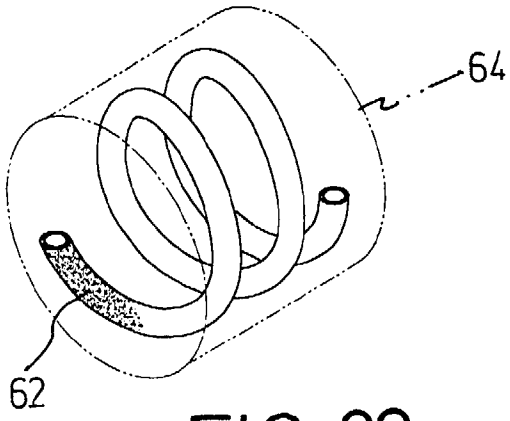


FIG. 22

CAST DIAMOND TOOLS AND THEIR FORMATION BY CHEMICAL VAPOR DEPOSITION

1. Field of the Invention

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

2. Description of Related Art

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

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

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

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

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

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

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

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

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

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

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

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

Example 1- Cutting Inserts Made of Diamond

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

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

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

Example 2 - Wire Drawing Dies Made of Diamond

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

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

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

Example 3 - Pad Conditioners Made of Diamond

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

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

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

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

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

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

In the drawings

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

Fig. 2 shows a conventional tungsten carbide tool insert;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

silicon has been dissolved away;

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

compression force is.

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

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

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

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

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

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

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

Diamond Hose

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

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

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

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

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

CLAIMS:

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

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

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

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

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

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

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

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

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

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

cutting tool contains chip breakers.

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

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

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

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

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

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

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

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

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

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

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): C7F (FHB, FHE, FHX); B5A (AB18, AB19, ANA, AT3P, ATXP); C7D (DB702, DB704, DB706, DB708); B3D (DEN, DMN)

Int Cl (Ed.7): C23C (16/00, 16/27, 16/44); B29C (33/42, 39/02, 39/10, 41/08, 41/20, 45/37); B29D 31/00; B22F 7/04; B24B 53/12

Other: Online: WPI, EPODOC, JAPIO

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : H01L 23/48, 21/76 — A1

(11) International Publication Number: **WO 95/31006**

(43) International Publication Date: 16 November 1995 (16.11.95)

(21) International Application Number: PCT/US95/05217

(22) International Filing Date: 4 May 1995 (04.05.95)

(30) Priority Data:

238,552	5 May 1994 (05.05.94)	US
321,937	12 October 1994 (12.10.94)	US

(81) Designated States: AM, AT, AU, BB, BG, BR, BY, CA, CH, CN, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IS, JP, KE, KG, KP, KR, KZ, LK, LR, LT, LU, LV, MD, MG, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TT, UA, UG, UZ, VN, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG), ARIPO patent (KE, MW, SD, SZ, UG).

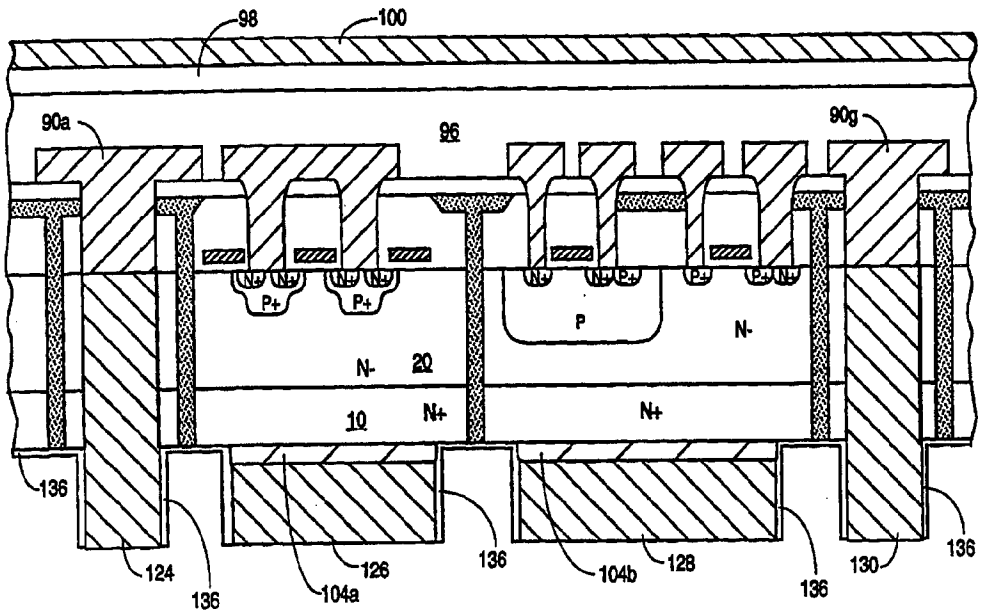
Published
With international search report.
With amended claims.

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(54) Title: SURFACE MOUNT AND FLIP CHIP TECHNOLOGY



(57) Abstract

An integrated circuit chip has full trench dielectric isolation of each portion of the chip. A heat sink cap (100) is attached to a diamond passivation layer (96) on the substrate front side surface. The passivation layer is a CVD diamond film which provides both electrical insulation and thermal conductivity. In a flip chip version, frontside electrical contacts (174a, 174b) extend through the frontside passivation layer to the heat sink cap. In a surface mount version, vias are etched through the substrate, with surface mount posts (90a, 90g) formed on the vias, to contact the frontside electrical contacts and provide all electrical contacts on the substrate backside surface. The wafer is then scribed into die in both versions without need for further packaging.

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SURFACE MOUNT AND FLIP CHIP TECHNOLOGY

BACKGROUND OF THE INVENTION

Field of the Invention

This invention relates to integrated circuit electrical isolation, and more specifically to integrated circuit total isolation using both surface mount and flip chip fabrication technologies with a diamond film passivation layer.

Description of the Prior Art

Dielectric isolation for integrated circuits is well known. A trench or groove is formed in the semiconductor chip substrate and is lined or filled with an insulative material, to electrically isolate various portions of the chip. For instance, a particular portion of the chip such as power (high voltage) transistors is surrounded by an insulated trench, thereby electrically isolating the power transistors from logic type (low voltage) transistors.

This prior art trench isolation has the significant disadvantage that the bottom of each trench is an area of substantial mechanical stress in the silicon substrate, thereby being detrimental to chip functionality. Such trenches thus reduce yield (increase cost). This deficiency is sometimes overcome by using "round hole" techniques to form the bottom of

each trench (providing a U-shaped rather than a rectangular cross-section) which however, also tends to increase cost.

Another method for achieving isolation uses two wafers, with an oxide layer formed on a surface of one wafer which is then bonded to the second wafer; the oxide layer provides the isolation. After bonding the two wafers, the backside of one of the wafers is polished away down to the oxide layer to isolate a portion of the remaining substrate. However, this is very expensive because there can be no defects in the bond between the two wafers. Defects are often induced by particles in the bond between the two wafers, causing low production yield and hence high cost. Also, oxidation induced stacking faults (OISF) due to processing temperature cycles are undesirably more pronounced in such a bond than in bulk silicon.

Therefore, the prior art is deficient in not providing practical and inexpensive dielectric isolation, especially for use with power transistors but also for other types of integrated circuits.

SUMMARY OF THE INVENTION

An integrated circuit structure and a fabrication method use trench dielectric isolation. This trench dielectric isolation is part of a chip fabrication process which allows the packaging for each chip to be formed on the wafer, thereby eliminating the prior art separate step of packaging a semiconductor die after the wafer is scribed into multiple die. Therefore the disclosed process is the equivalent of assembly or packaging the integrated circuit die at "waferscale", since each die is already packaged before the wafer is scribed.

In accordance with the invention, transistors (or other semiconductor devices) are conventionally

fabricated on a semiconductor substrate. Some of these devices may be power transistors (operating at high voltage) and others may be lower voltage logic-type transistors formed in another portion of the substrate. In one embodiment, the devices are field effect transistors having gate electrodes formed in an insulated layer overlying the principal surface of the semiconductor substrate. Alternatively, the transistors are IGBT's (insulated gate bipolar transistors), or bipolar transistors, or other semiconductor devices. The fabrication process technology may be a CMOS, NMOS, PMOS, DMOS, BiCMOS, or bipolar technology, for example. Then an interconnect pattern is conventionally formed overlying and interconnecting the gate electrodes (or other transistor elements), and for contacting the semiconductor regions (e.g. source and drain) formed in the substrate.

A plurality of insulated trenches are then formed penetrating the principal surface of the substrate into the depth thereof, and surrounding (in a top view) various portions of the substrate. The trenches are conventionally insulated by filling or lining them with an insulative material followed by a planarization. This step may be prior to metallization. Then a portion of the backside of the substrate is removed by conventional machining or chemical processes, exposing the bottom portion of each of the trenches, and thereby achieving full (total) electrical isolation of the various substrate portions surrounded by each trench.

Prior to the step of removing the backside portion of the substrate, the frontside surface is bonded to a heat sink cap or plate (made for instance of silicon) using epoxy or similar bonding materials. This heat sink cap also provides the needed mechanical support for the substrate, which is otherwise quite thin

following the substrate removal step.

Electrical contact is achieved in two different embodiments. In a surface mount embodiment, vias penetrate from the backside surface of the substrate to its principal (frontside) surface, allowing electrically conductive material formed in the vias to contact an interconnect structure already formed on the substrate frontside surface. Extensions of the vias on the substrate backside define posts for surface mount electrical contacts. Other similar posts formed on the backside surface of the substrate make contact to the bulk substrate. The heat sink cap attached to the frontside substrate surface has a mechanical and heat dissipation function, with no electrical connections provided thereby.

In a flip chip type embodiment, the heat sink cap also carries on it an electrical interconnect, making electrical contact to the conventional interconnect on the substrate frontside surface. This heat sink cap may be attached to a conventional flip chip backplate. In this embodiment the electrical contacts formed on the substrate backside surface are the conventional drain or collector contacts for e.g. power integrated circuits.

In both embodiments, the individual integrated circuits are packaged while still being part of a single wafer, by the application of the heat sink cap which is attached (by epoxy or other adhesive) to the wafer frontside surface. This cap replaces the conventional plastic or ceramic packaging which in the prior art is applied only after the wafer is scribed into individual die. In the present case the full trench isolation between the die allows the die to be scribed adjacent to the isolation trenches, together with attached front end mechanical support plate (cap), so no further packaging is needed.

Typically, the thickness of the substrate after the substrate removal step is less than about 50 micrometers. This very thin substrate is free of heat induced mechanical stresses, due to its mechanical flexibility. Advantageously, integrated circuit chips in accordance with the invention are inexpensively fabricated using essentially conventional steps which provide a high yield, thus reducing cost.

The dielectric isolation trenches may conventionally be lined, for instance with silicon dioxide (formed from the silicon trench walls), or may be completely filled with silicon dioxide, or may be lined with silicon dioxide and then filled with another material such as CVD (chemical vapor deposition) nitride, polysilicon or oxide. In another embodiment, the trenches are filled with conventional spun on glass. Other insulating materials may be used for the trench dielectric.

The heat sink cap (plate) is typically silicon, silicon carbide, silicon nitride, aluminum nitride, molybdenum, or other material which provides sufficient heat transfer and is conveniently fabricated. The removal of the backside of the substrate advantageously eliminates mechanical stresses normally present at the bottom of a trench formed in silicon. Thus the principal problem with prior art trench isolation is overcome, resulting in a thin, flexible substrate.

Also, the prior art requirement for a semiconductor buried layer in the substrate is eliminated, due to the very thin substrate and formation of a layer of conductive material on selective areas of the substrate backside surface. Thus the processing problems associated in the prior art with establishing an effective buried layer are avoided, and the parasitic bipolar transistor effects typically present in prior art integrated circuits

(especially for power integrated circuits) are eliminated by a backside contact which is a metal plate or metallization layer rather than a buried semiconductor layer.

The metallized drain (or collector) contact on the backside surface, which is in relatively close proximity to the active transistors (due to the thinness of the substrate), increases current carrying capability over that of the prior art chips which require either the buried layer or current being transmitted through the relatively thick bulk of the semiconductor substrate. Thus advantageously the actual thickness of the final substrate itself is the minimum necessary to support (mechanically and electrically) the active transistor regions. This thickness may be as little as 10 microns, in contrast to prior art integrated circuits typically having a 400 micron die thickness needed for mechanical support for the integrated circuit.

Additionally, the step of removing the backside portion of the substrate after trench formation means that the initial trench depth need not be precisely determined. In the prior art, formation of trenches of precise depth is a significant processing limitation. In the present case, since the bottom portion of each trench is removed, exact trench depth is not critical.

Also, the fabrication process in accordance with the invention advantageously allows for an isolated backside contact structure which is not a single contact but a plurality of individual backside contacts, each contact associated with a particular portion of the die. This allows for instance a first backside contact to a power transistor portion of the integrated circuit, and a second backside contact associated with a low voltage transistor portion of the integrated circuit. Thus the backside contacts are

selectable for a particular portion of the integrated circuit, and various portions of the chip need not share a common collector or common drain.

In another embodiment, the passivation layer which serves as an isolation layer and an attachment layer to bond the IC wafer (substrate) to the heat sink cap or plate is a CVD (Chemical Vapor Deposition) diamond film. Such material advantageously has high thermal conductivity and high electric resistivity. The diamond film is deposited on top of the substrate after the final front side surface metal patterning. A thermally conductive adhesive (such as silver epoxy) is applied to the exposed surface of the deposited diamond film to attach the substrate to the plate. This use of diamond film is compatible both with the surface mount and flip chip embodiments described above. In accordance with the invention the diamond layer may be patterned so that particular portions of the metal contact or bonding pads are connected to and through the support plate to external leads from the front side of the wafer, in the flip chip embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

Figs. 1 to 12 illustrate exemplary fabrication steps of the surface mount embodiment of the invention.

Figs. 13 to 17 illustrate exemplary fabrication steps of the flip chip type embodiment of the invention.

DETAILED DESCRIPTION OF THE INVENTION

Surface Mount Embodiment

Figs. 1 to 12 illustrate steps to fabricate a surface mount integrated circuit chip in accordance with the invention. It is understood that these are conventionally drawn cross sections of an integrated

circuit showing only a small portion of the circuit, i.e. a small portion of a wafer. No topside views are provided, since the top side geometry of the integrated circuit is conventional, as will be understood by one of ordinary skill in the art from the following description. Also, this is only an illustration of the surface mount approach, which is not limited to semiconductor devices of the type shown.

Fig. 1 shows initial steps in fabrication of this embodiment. Fig. 1 is conventional both in structure and fabrication as typically used for integrated circuits which include both power transistors and low voltage transistors on one chip. See U.S. Patent Application No. 07/948,276, filed 9/21/92, Hamza Yilmaz et al., entitled "BiCDMOS Process Technology and Structure", incorporated by reference, for an example of such a fabrication process. Shown in Fig. 1 is silicon (or other material) substrate 10 which is conventionally N+ doped, having formed on an upper portion thereof in one embodiment an epitaxial (silicon) layer 20 which is conventionally N- doped. The epitaxial layer is an option but is not a necessary part of the invention; the active portions of the transistors may be formed in the substrate. (It is to be understood that materials, dimensions, transistor structure, conductivity types, and other elements disclosed herein are illustrative only and not limiting.)

Substrate 10 is approximately 500 micrometers thick, and silicon layer 20 is 1 to 50 micrometers thick. Conventionally formed (in this illustrative embodiment) in silicon layer 20 are two "deep body" conventionally doped P+ regions 22 and 24. Formed respectively in body regions 22 and 24 are N+ source regions 26, 28, 30 and 32 each of which is conventionally doped. It is to be appreciated that in

this embodiment P+ body regions 22 and 24 and the associated other doped regions are a part of a power portion of the integrated circuit, i.e. power transistors.

Formed adjacent to regions 22 and 24 is P tub 38 which is conventionally doped. Formed in P tub 38 are N+ doped regions 40 and 42. Also formed in silicon layer 20 are P+ regions 46 and 48 which are similar in their doping level and structure to region 44, and N+ region 50 which is similar to regions 40 and 42. Formed immediately overlying the upper surface of silicon layer 20 is a conventional gate oxide layer 60 of e.g. silicon dioxide.

Formed conventionally overlying oxide gate layer 60 is a doped polysilicon gate electrode layer 54 including (as a result of a masking step) portions 54a, 54b, 54c and 54d and 54e which in this embodiment form the gate electrodes of various transistors.

Overlying gate electrode layer 54 is a second overlying (upper) insulative layer 62 formed of silicon dioxide and also covering the respective side edges of the gate electrodes 54a, ..., 54e.

Overlying upper oxide layer 62 is a BPSG layer 64 (borophosphorsilicate glass) formed to a thickness of 0.5 to 1.5 micrometers and then conventionally reflowed to completely cover gate electrodes 54a, ..., 54e.

Fig. 2 shows subsequent processing with a conventional masking layer 70 formed overlying BPSG layer 64. Masking layer 70 is conventionally patterned and the underlying structure etched, with the etchant penetrating through silicon layer 20 and into substrate 10 to define trenches 72a, 72b, 72c, 72d, and 72e. These trenches are 0.5 to 5 micrometers in width and 5 to 50 micrometers in depth. (The depth is relatively arbitrary for reasons discussed later and the width dimension is also not critical.) The trench etch is a

conventional anisotropic process. It is to be understood that trenches 72a, ..., 72e as shown here in cross-section, would in a topside view interconnect so as to surround various portions of the integrated circuit, i.e. so as to surround the power transistor portion 22, 24 thereby separating this portion from the portion including P tub 38.

Then (not shown) the remaining portions of masking layer 70 are conventionally stripped off.

Next in Fig. 3, a glass layer 76 is formed conventionally such as by being spun on in each of trenches 72a, ..., 72e thereby filling each of these trenches, and also overlying the upper surface of BPSG layer 64, to a thickness of 1 to 2 micrometers. Alternatives to SOG for layer 76 are CVD formed materials or plasma enhanced CVD formed materials. After formation of spun on glass layer 76, this material is cured. Spun on glass 76 here is the trench dielectric insulating material. In other embodiments, the trenches e.g. are lined with a layer of grown silicon dioxide and then filled with another material such as CVD oxide, or nitride, or polysilicon. (These are conventional processes for forming dielectric layers.)

Next in Fig. 4, first an etch back (planarization) step using for instance CMP of the spun on glass layer 76 effectively removes those parts of layer 76 overlying the gate electrodes 54a, ..., 54e. An alternative to CMP is to apply a layer of photoresist then etch back using a dry etch.

Following the etch back step, an LTO (low temperature oxide) layer 80 is deposited over the upper surface of the structure to a thickness of 0.5 to 2.0 micrometers. Following the LTO layer 80 deposition, an electrical contact mask layer (not shown) is applied overlying LTO layer 80. The contact mask layer is then

conventionally patterned and the underlying layers etched, with the etch extending through LTO layer 80, through the remaining portions of spun on glass layer 76, and down to the principal surface of the silicon layer 20, thus exposing portions of the principal surface of the silicon layer 20 and defining contact openings 84a, ..., 84g.

Next in Fig. 5, a layer of conductive material 90 (such as aluminum) is conventionally deposited over the surface of the substrate, filling the various contact openings 84a, ..., 84g and making contact with the underlying semiconductor regions formed in silicon layer 20. Then conductive layer 90 is conventionally masked, the masking layer is patterned, and layer 90 is etched to define electrical contacts 90a, ..., 90g.

Then in Fig. 6 a conventional passivation layer of e.g. plasma nitride material is formed overlying electrical contacts 90a, ..., 90g. Passivation layer 96 is 0.5 to 2.5 micrometers thick.

Overlying passivation layer 96, an epoxy material layer 98 is conventionally deposited 25 to 250 micrometers thick. This epoxy material 98 is e.g. a high performance epoxy resin composition that is thermally conductive (such as silver epoxy).

Next a "cap" (plate) 100 is affixed to epoxy layer 98 which is then cured, bonding cap 100 to passivation layer 96. Cap 100 is about 500 micrometers thick and is e.g. undoped silicon. A single cap 100 covers the entire wafer which includes substrate 10 and silicon layer 20. Other bonding materials and processes other than epoxy may be used to affix cap 100. Cap 100 achieves thermal conductivity through epoxy layer 98 and also provides sufficient mechanical support for the substrate 10, silicon layer 20, and the active transistor regions and interconnect formed thereon.

Next in Fig. 7, the backside surface of substrate

10 is partially removed by grinding, etching, or CMP (chemical-mechanical polishing) so that the total thickness of substrate 10 and/or silicon layer 20 is in the range of 5 to 100 microns. This is in contrast to the original total thickness of structures 10 and 20 of about 500 microns. (Again, these dimensions are illustrative and not limiting.) The goal is to reduce the thickness of substrate 10 and silicon layer 20 to a minimum necessary for electrical functioning of the transistors formed therein. The removing step reduces the thickness of substrate 10 so that the bottom portion of each of trenches 72a, ..., 72e is exposed, and thereby the insulative material formed in each of these trenches is exposed at the backside surface of substrate 10. This achieves full electrical isolation of each portion of substrate 10. It is to be understood that in this case the attachment of heat sink cap 100 is done prior to the removing step to ensure that the substrate, after the removing step, remains in one integrated piece. Conventional masking, implantation, and annealing steps may be added to this process, as desired to form N+ or P+ contacts on the backside surface of substrate 10 for subsequent metal layer 104.

Next in Fig. 8, the backside surface of substrate 10 is metallized by a conventional sputtering or evaporative process to form a metal layer 104 (aluminum) thereon having a thickness of e.g. 0.15 to 1.5 micrometers. Then metal layer 104 is conventionally covered with a mask layer, the mask layer is patterned, and metal layer 104 then etched to define backside contact pads 104a, 104b on the backside surface of substrate 10. Each of contact pads 104a, 104b is associated with a selected portion of the integrated circuit die as defined by the trenches 72a, ..., 72e. Of course each portion of the die need not

have a contact pad; contact pads 104a, 104b are only provided to those portions of the die which require same. (It is to be understood that conventionally some types of transistors do not require backside contacts.)

Next in Fig. 9, a protective/passivation layer 110 is deposited on the backside surface of substrate 10 overlying contact pads 104a and 104b. Then layer 110 is conventionally patterned to define openings 112a and 112b. Each opening 112a and 112b is associated with a particular electrical contact 90a, 90g on the upper side surface of silicon layer 20, as shown.

Next in Fig. 10, a deep silicon etch is undertaken through openings 112a and 112b to define vias 116a, 116b extending through substrate 10 and/or silicon layer 20 to expose the underside portions of electrical contacts 90a, 90g. This deep silicon etching step uses a wet or wet/dry or dry etching technique.

Vias 116a, 116b need only be wide enough to establish good electrical paths to contacts 90a, 90g and otherwise their dimensions in terms of width are not critical; neither is their cross-sectional shape critical. Then as shown in Fig. 10 the remaining portions of layer 110 may be conventionally stripped off or kept as a passivation layer.

Next in Fig. 11 by a plating step (electrodeposition), vias 116a and 116b are filled with a solderable metal (e.g. nickel, gold, copper) to define posts 124, 130 extending therefrom. In the same electrodeposition step, metal posts 126, 128 are deposited on metal contacts 104a, 104b.

Alternatively, posts 126, 128 are formed by screen printing the desired type of metal on respectively the backside 104, 104b interconnection leads to establish the desired thickness for the surface mount posts. The diameter of the surface mount posts may vary, depending on the particular application.

Next in Fig. 12, an (optional) passivation layer 136 is deposited over all exposed surfaces of the surface mount posts 124, 126, 128 and 130 to a thickness of 0.8 to 1.2 micrometers. Passivation layer 136 is e.g. polyamide or low temperature oxide.

Then portions of passivation layer 136 are removed (by masking and etching or other means, for instance CMP) from the bottom surfaces of each surface mount post 124, 126, 128, 130, so as to leave the post bottom surfaces exposed for soldering, such as to a printed circuit board. The height of the surface mount posts extending from the lower backside surface of substrate 10 is conventionally 10 to 300 micrometers, or any other height as needed depending on the mounting application.

In Fig. 12 all of the electrical interconnections to outside of the chip are provided on the backside surface of substrate 10 by the surface mount posts 124, 126, 128 and 130.

Subsequently (not shown) the wafer is scribed into individual integrated circuit die along predescribed scribe lines which are for instance adjacent to dielectrically filled trenches. Thus as a result of the scribing step, the various integrated circuit die are already packaged by the top side cap 100 and the bottom side passivation layer 136; hence no further packaging is needed.

Flip Chip Embodiment

In the flip chip embodiment, the initial processing steps are identical to those shown in Figs. 1 to 5 for the surface mount embodiment, resulting in the structure of Fig. 13. Again, the flip chip embodiment is not limited to semiconductor devices of the type shown. The structure of Fig. 13 is identical to that of Fig. 5, except that in Fig. 13 the next step is that passivation layer 160 (which is similar in

material and thickness to passivation layer 96 in Fig. 6) is masked using a mask layer (not shown) which is patterned, with subsequent etching to define contact openings 164a, 164b, therethrough. Contact openings 164a, 164b, expose a portion of the underlying electrical contacts 90a, 90g. The goal in this embodiment is to define both substrate frontside and backside electrical contacts; openings 164a, 164b define the frontside contact openings.

Next in Fig. 14, silicon (or other suitable material) heat sink cap 172 is provided, having formed thereon (prior to assembly to the substrate 10) metal (aluminum or a solderable material) interconnect structures 176a, 176b. Interconnect structures 176a, 176b include interconnect lines on the surface of cap 172 which faces contacts 90a, 90b; these interconnect lines have a thickness of e.g. 10 to 50 micrometers. Cap 172 is electrically insulated on all surfaces by e.g. oxide dielectric layer 175. Interconnect structures 176a, 176b are then conventionally soldered or sintered to underlying contacts 90a, 90g. This electrical contact can be provided by any other conventional method.

Cap 172 is attached to the underlying structure by a high performance thermally conductive (and electrically insulative) epoxy resin layer 168 (or other high performance adhesive) formed on passivation layer 160 to a thickness of 25 to 250 micrometers. Adhesive layer 168 is prevented from fouling the electrical interconnections (between elements 176a, 176b and 90a, 90b) by masking and etching the adhesive layer 168 or by polishing it away from the interconnections. For instance, adhesive layer 168 is initially formed in a thick layer covering structures 176a, 176b, then etched back to expose the ends of structures 176a, 176b using a wet or dry etch.

It is to be understood that cap 172 serves as a heat sink and supports contact structures 176a, 176b which connect through vias extending through cap 172 to form interconnect contacts 174a, 174b on the opposite surface of cap 172. These interconnect contacts 174a, 174b are suitable for attachment to an underlying supporting conventional flip chip-type back plate (not shown) providing mechanical support and electrical bonds thereto.

Next in Fig. 15, (similar to Fig. 7) the backside surface of substrate 10 is polished or etched away to expose the lower portions of dielectrically insulated trenches 72a, ..., 72e. Again, the total thickness of substrate 10 and silicon layer 20 is minimized by this removing step to that needed for proper electrical functioning. Next in Fig. 16, backside contacts 178a, 178b are formed, similar to contacts 104a, 104b in Fig. 8. Next in Fig. 17, backside passivation layer 186 is deposited to a thickness of e.g. 0.5 to 2.5 micrometers using oxide or nitride or an oxide-nitride "sandwich" material over the backside surface of substrate 10 and initially over contact areas 178a and 178b, but is then removed from the exposed surfaces by use of a mask which is then patterned, and etching away of the unneeded portions of passivation layer 186. This exposes the bonding area of the power device drain contact 178a and a collector type drain contact 178b if desired. (Again the use of the backside contact depends on the nature of the associated semiconductor devices). Thus the flip chip configuration of Fig. 17 provides both frontside substrate electrical contacts 174a, 174b through cap 172 and also backside contacts 178a, 178b. The frontside leads are beam or tunnel lead structures or types to the transistors.

Again, after the steps of Fig. 17, the entire wafer is conventionally scribed along predetermined

scribe lines (not shown); thus as a result of scribing the chip is complete (packaged), advantageously without any need for further packaging steps.

Diamond Film Passivation Layer Embodiment

The above-described flip chip type and surface mount embodiments use conventional silicon dioxide or nitride as the dielectric insulation and passivation layer between the semiconductor wafer itself and the heat sink plate. These materials are known to provide relatively poor heat conduction, due to for instance the very low thermal conductivity of silicon dioxide of approximately 2 W/mK. In contrast, diamond film (which is also a good dielectric insulating material) provides thermal conductivities of about 2,000 W/mK. Also diamond is well known to be chemically inert, and due to its having the densest crystal lattice of any known material, the diffusion of other elements into diamond is very low. Thus diamond is not only a good dielectric insulator with excellent thermal conductivity but it is also a material which serves effectively as a passivation layer, providing good corrosion protection.

It has been determined in accordance with invention that diamond film has the best combination of thermal conductivity and electrical resistivity of available materials. Other materials such as aluminum nitride, aluminum oxide, or silicon carbide also provide high dielectric insulation but much less thermal conductivity than diamond. The only materials providing thermal conductivity similar to that of diamond film are electrically conductive metals such as copper and silver, which are not useful for passivation.

It is well known to provide chemical vapor deposition (CVD) of diamond film deposited at

temperatures of 600° to 950°C and at sub-atmospheric pressures. Typically methane or acetylene is used as the carbon source with significant partial pressure of atomic hydrogen. Excitation sources used include microwave and radio frequency plasmas, hot filament and thermal plasmas and combustion flames.

It has also been known to achieve a diamond deposition at temperatures below 600°C, for instance by using other process gas mixtures such as adding rare gases to the commonly utilized mixtures of carbon containing gases and hydrogen, mixtures of alcohols and water, halogenated gases and other gaseous combination. Typically growth rates of about 0.2 micrometers per hour have been achieved at deposition temperatures of about 400°C.

Methods for depositing diamond film in accordance with the present invention include low temperature microwave plasma assisted CVD. An alternative is an arc jet CVD process. It is known to pattern diamond films using conventional oxygen-based RIE (reactive ion etching) processes, as are well known in semi-conductor fabrication.

Thus in accordance with the invention for the above-described surface mount embodiment, a diamond film formed by one of the above described processes (or any other process) is substituted for passivation layer 96. The diamond film is formed to be a layer e.g. approximately 0.5 to 10 micrometers thick (but this is not limiting). Then the next substitution is, instead of using an ordinary epoxy material layer 98, a thermally conductive adhesive such as commercially available silver epoxy is used to bond the plate 100 to the diamond film. All other processing steps are as described above for this embodiment.

Similarly, for the above-described flip chip type embodiment, passivation layer 160 is a CVD (or other