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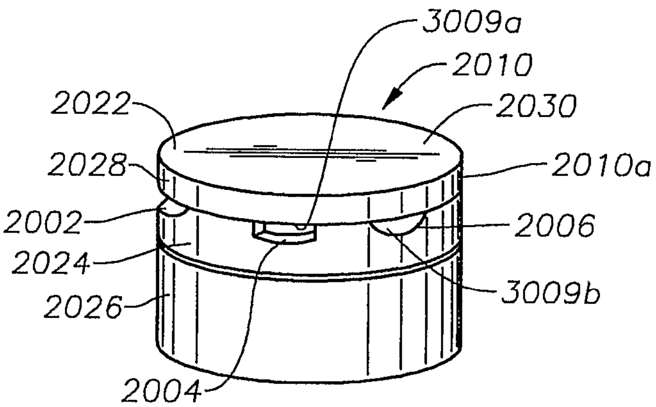
(54) **Title:** PCD CUTTERS WITH ENHANCED WORKING SURFACES ADJACENT A CAVIT



(57) **Abstract:** A PCD cutting element (2010) having a table of superhard material (2022) bonded to a substrate (2024). The superhard material has a first end working surface and an intermediate peripheral working surface (2028) adjacent the substrate. A cavity (2002, 2004, 2006) is formed in the substrate in an area immediately adjacent the peripheral working surface to expose a second end working surface. One particularly advantageous use of this new PCD cutting element is as cutting elements for earth boring drill bits.

WO 2007/148060 A1

"PDC Cutters with Enhanced Working Surfaces Adjacent a Cavity"

BACKGROUND OF THE INVENTION

The invention relates to superhard polycrystalline material elements for earth drilling, cutting, and other applications where engineered superhard surfaces are needed. The invention particularly relates to polycrystalline diamond and polycrystalline diamond-like (collectively called PCD) elements with enhanced impact toughness.

Polycrystalline diamond and polycrystalline diamond-like elements are known, for the purposes of this specification, as PCD elements. PCD elements are formed from carbon based materials with exceptionally short inter-atomic distances between neighboring atoms. One type of diamond-like material similar to PCD is known as carbonitride (CN) described in U.S Patent No. 5,776,615. In general, PCD elements are formed from a mix of materials processed under high-temperature and high-pressure into a polycrystalline matrix of inter-bonded superhard carbon based crystals. A common trait of PCD elements is the use of catalyzing materials during their formation, the residue from which often imposes a limit upon the maximum useful operating temperature of the element while in service.

A well known, manufactured form of PCD element is a two-layer or multi-layer PCD element where a facing table of polycrystalline diamond is integrally bonded to a substrate of less hard material, such as tungsten carbide. The PCD element may be in the form of a circular or part-circular tablet, or may be formed into other shapes, suitable for applications such as hollow dies, heat sinks, friction bearings, valve surfaces, indentors, tool mandrels, etc. PCD elements of this type may be used in almost any application where a hard wear and erosion resistant material is required. The substrate of the PCD element may be brazed to a carrier, often also of cemented tungsten carbide. This is a common configuration for PCD's used as cutting elements, for example in fixed cutter or rolling cutter earth boring bits when received in a socket of the drill bit, or when fixed to a post in a machine tool for machining.

PCD elements are most often formed by sintering diamond powder with a suitable binder-catalyzing material in a high-pressure, high-temperature press. One particular method of forming this polycrystalline diamond is disclosed in U.S. Patent No. 3,141,746 herein incorporated by reference for all it discloses. In one common process for manufacturing PCD elements, diamond powder is applied to the surface of a preformed tungsten carbide substrate incorporating cobalt. The assembly is then subjected to very high temperature and pressure in a press. During this process, cobalt migrates from the substrate into the diamond layer and acts as a binder-catalyzing material, causing the diamond particles to bond to one another with diamond-to-diamond bonding, and also causing the diamond layer to bond to the substrate.

The completed PCD element has at least one body with a matrix of diamond crystals bonded to each other with many interstices containing a binder-catalyzing material as described above. The diamond crystals comprise a first continuous matrix of diamond, and the interstices form a second continuous matrix of interstices containing the binder-catalyzing material. In addition, there are necessarily a relatively few areas where the diamond-to-diamond growth has encapsulated some of the binder-catalyzing material. These 'islands' are not part of the continuous interstitial matrix of binder-catalyzing material.

In one common form, the diamond body constitutes 85% to 95% by volume and the binder-catalyzing material the other 5% to 15%. Such an element may be subject to thermal degradation due to differential thermal expansion between the interstitial cobalt binder-catalyzing material and diamond matrix beginning at temperatures of about 400 degrees C. Upon sufficient expansion the diamond-to-diamond bonding may be ruptured and cracks and chips may occur.

A common problem with these PCD elements, especially when used in highly abrasive cutting application, such as in drill bits, has been the limitation imposed between wear resistance and impact strength. This relationship has been attributed to the fact that the catalyzing material remaining in the interstitial regions among the bonded diamond crystals contributes to the degradation of the diamond layer.

It has become well known in the art to preferentially remove this catalyzing material from a portion of the working surface in order to form a surface with much higher abrasion resistance without substantially reducing its impact strength. This new type of PCD element is described in U.S. Patent Nos. 6,601,662; 6,592,985 and

6,544,308 - all these U.S. patents are incorporated by reference herein for all they disclose.

PCD elements made in accordance with these and in other related patents have become widely used in the oilfield drilling industry. One surprising observation resulting from this usage, however, has been an increase in the cutting efficiency of these cutters, which has been manifested in higher drilling rates of penetration – typically by 40%, but occasionally by as much as a factor of two to four times.

US 4976324 describes an arrangement in which a vapor deposition technique is used to apply a catalyst free diamond layer to a surface of a cutting element, but it will be appreciated that the vapor deposition technique used does not bond the diamond layer to the underlying diamond table. US 6068913 and US 4766040 both describe multi-layered elements, and US 6187068 describes providing the element with concentric ring shaped regions of different abrasion resistance.

An arrangement is described in US 6189634 in which, when worn, part of the substrate of a cutting element becomes exposed at the working surface.

BRIEF SUMMARY OF THE INVENTION

The present invention is a PCD cutting element, in which a cavity is formed in the substrate in an area immediately adjacent the peripheral working surface and treating the PCD exposed in this cavity to render it and at least part of each of the end working surfaces and the peripheral working surface of the cutting element more abrasion resistant without substantially reducing its impact strength.

One particularly advantageous use of this new PDC cutting element is as cutting elements for earth boring drill bits.

According to the present invention there is provided a cutting element having a table of superhard material bonded to a substrate of less hard material. The table of superhard material defines a plurality of interstices containing a catalyzing material. The table of superhard material also defines a first end working surface and a peripheral working surface extending to the substrate, at least part of the first end working surface and at least a portion of the peripheral working surface are substantially free of catalyzing material. The peripheral working surface is substantially free of catalyzing material to a second end working surface of the table of superhard material which is exposed by a cavity formed in the substrate.

The catalyst free or substantially free parts may extend along the peripheral working surface from the face of the table all the way to a second end working surface of the table of superhard material which is exposed by the cavity formed in the substrate.

The element may have an edge of the part of the first end working surface which is substantially free of catalyzing material which defines a first protruding lip, and an edge of the part of the peripheral working surface which is substantially free of catalyzing material defining a second protruding lip. The first end working surface may be substantially planar, and the peripheral working surface may be substantially perpendicular thereto. The superhard material may be polycrystalline diamond, and may incorporate regions of different abrasion resistance, for example arranged in a series of layers, or in a series of concentric rings. The table of superhard material may incorporate encapsulated diamond material, for example made using powdery carbonate. A region of superhard material containing catalyzing material may be exposed between the parts of the peripheral working surface and the first end working surface which are substantially free of catalyzing material. The first protruding lip may be formed adjacent said region at an edge of the part of the first end working surface which is substantially free of catalyzing material and the second protruding lip may be formed adjacent said region at an edge of the part of the peripheral working surface which is substantially free of catalyzing material.

The element may be used as a cutting element for an earth boring drill bit.

The invention also relates to a method of manufacturing a cutting element comprising forming a table of superhard material bonded to a less hard substrate, the table of superhard material defining a plurality of interstices containing a catalyzing material, the table defining two end working surfaces and an intervening peripheral working surface, forming a cavity in the substrate in an area immediately adjacent the peripheral working surface and treating at least part of each of the end working surfaces and the peripheral working surface to remove the catalyzing material therefrom.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of a PCD element of an embodiment of the present invention in the form of a planar-face cutting element.

Figure 2 is a perspective view of a fixed cutter drill bit suitable for using the PCD elements of the present invention.

Figure 3 is a perspective view of a PCD element of the present invention in the form of a domed-face cutting element.

Figure 4 is a perspective view of a rolling cutter drill bit suitable for using the PCD elements of the present invention.

Figure 5 is a section view of a prior art PCD cutting element.

Figure 6 is a perspective view of a prior art planar face PCD cutting element drilling into the earth.

Figure 7 is a section view of a planar face PCD cutting element of the prior art.

Figure 8 is a diagrammatic sectional view of the prior art cutter of figure 7 in a worn condition.

Figure 9 is a diagrammatic view illustrating the structure of part of a cutter.

Figure 10 is a sectional view of another embodiment of a cutter of the present invention showing a cavity formed in the substrate.

Figure 11 is a perspective view of another PCD element of another embodiment of the present invention in the form of a planar-face cutting element showing cavities formed in the substrate.

Figure 12 is a perspective view of still another PCD element of another embodiment of the present invention in the form of a planar-face cutting element showing a single cavity formed in the substrate.

DETAILED DESCRIPTION OF THE INVENTION AND THE PREFERRED EMBODIMENT

Referring now to Figures 1-4, the polycrystalline diamond or polycrystalline diamond-like (PCD) element 1010, 2122 (in Fig. 10), 2010 (in Fig. 11), 3010 (in Fig. 12), of the present invention may be a preform cutting element 1010, 2122 (in Fig. 10), 2010 (in Fig. 11), 3010 (in Fig. 12), for a fixed cutter rotary drill bit 1012 (as shown in Figure 2). The bit body 1014 of the drill bit is formed with a plurality of blades 1016 extending generally outwardly away from the central longitudinal axis of rotation 1018 of the drill bit. Spaced apart side-by-side along the leading face 1020 of each blade is a plurality of the PCD cutting elements 1010, 2122 (in Fig. 10), 2010 (in Fig. 11), 3010 (in Fig. 12) of the present invention.

Typically, the PCD cutting element 1010, 2010, 2122, 3010 has a body 1010a, 2010a, 2122a, 3010a in the form of a circular tablet having a relatively thin front facing table 1022, 2022 (in Figs. 10 and 11), 3022 (in Fig. 12) of diamond or diamond-like (PCD) superhard material, bonded in a high-pressure high-temperature press to a substrate 1024, 2024 (in Figs. 10 and 11), 3024 (in Fig. 12), of less hard material such as cemented tungsten carbide or other metallic material. The cutting element 1010, 2010, 2122, 3010 is preformed and then typically bonded on a generally cylindrical carrier 1026, 2026 (in Fig. 11), 3026 (in Fig. 12) which is also formed from cemented tungsten carbide, or may alternatively be attached directly to the blade 1016. The PCD cutting element 1010, 2010 (in Fig. 11), 2122 (in Fig. 10), 3010 (in Fig. 12) has peripheral and end working surfaces 1028, 2028 (in Figs. 10 and 11), 3028 (in Fig. 12) and 1030, 2030 (in Figs. 10 and 11), 3030 (in Fig. 12) which, as illustrated, are substantially perpendicular to one another.

The cylindrical carrier 1026, 2026, 3026 is received within a correspondingly shaped socket or recess in the blade 1016. The carrier 1026, 2026, 3026 will usually be brazed, shrink fit or press fit in the socket. Where brazed, the braze joint may extend over the carrier 1026, 2026, 3026 and part of the substrate 1024, 2024, 3024. In operation the fixed cutter drill bit 1012 is rotated and weight is applied. This forces the cutting elements 1010, 2010, 2122, 3010 into the earth being drilled, effecting a cutting and/or drilling action.

In a second embodiment, a shaped cutting element 1032 (as shown in Figure 3) is provided on a rolling cutter type drill bit 1034, shown in Figure 4. A rolling cutter drill bit 1034 typically has one or more truncated rolling cone cutters 1036, 1038, 1040 assembled on a bearing spindle on the leg 1042 of the bit body 1044. The cutting elements 1032 may be mounted, for example by press fitting as one or more of a plurality of cutting inserts arranged in rows on rolling cutters 1036, 1038, 1040, or alternatively the PCD cutting elements 1032 may be arranged along the leg 1042 of the bit 1034. The PCD cutting element 1032 has a body in the form of a facing table 1046 of diamond or diamond like material bonded to a less hard substrate 1048. The facing table 1046 in this embodiment is in the form of a convex surface 1050 and has peripheral and end working surfaces 1052 and 1054. Typically, there may be a number of transitional layers between the facing table 1046 and the substrate 1048 to help more evenly distribute the stresses generated during fabrication, as is well known to those skilled in the art. The end working surface 1052 is of domed or part-spherical form whilst the peripheral working surface 1054 is of frusto-conical form.

In operation the rolling cutter drill bit 1034 is rotated and weight is applied. This forces the cutting inserts 1032 in the rows of the rolling cone cutters 1036, 1038, 1040 into the earth, and as the bit 1034 is rotated the rolling cutters 1036, 1038, 1040 turn, effecting a drilling action.

As illustrated in Figure 9, the structure of the table 1046 defines a series of interstices 1046a between the diamond crystals 1046b, the interstices 1046a containing binder catalyst material 1046c used during the synthesis of the table 1046.

The remaining discussion and description of the present invention will be drawn, by way of example, to the planar face type of cutting element 1010, 2010, 2122, and 3010 shown in Figures 1, 11, & 12. It is understood, however, that the same general principals and outcomes will apply as well to the domed type cutting element 1032, as shown in Figure 3.

A cross section view of a preform cutting element of the prior art 1100 is shown in Figure 5 and a view of the prior art cutting element 1100, in use, is shown in Figure 6 to illustrate and contrast the present invention. The prior art cutting element 1100 shares many elements in common with the PCD cutting element 1010, 2010, 2122, and 3010 of the present invention, such as having a relatively thin front facing table 1022, 2022(in Fig. 11), 3022 (in Fig. 12) of diamond, bonded to a substrate 1024, 2024, 3024 of cemented tungsten carbide. All the cutting elements 1010, 2010, 2122, and 3010 have peripheral and end working surfaces 1028, 2028, 3028, and 1030, 2030, 3030. A layer 1102, 2102 of the facing table 1022, 2022, and 3022 in many of these cutting elements is treated in a manner such that the catalyzing material is substantially removed from a relatively thin layer adjacent to the end working surface 1030, 2030, 3030. Removal of the catalyzing material in this manner had been found to greatly increase the wear resistance of the cutting element, and to surprisingly increase its drilling rate.

Note, however, that the peripheral working surface 1028, 2028, and 3028 on the outside periphery 1104 on the prior art cutting element 1100 was initially not treated to remove the catalyzing material. The cutting element 1100 is operated in a manner as illustrated in Fig. 6. This is a typical representation in which the cutting element 1100 is operated at a backrake angle 1106 of from typically 10 to 45 degrees. When operated in this manner, the treated layer 1102 of the facing table 1102, 2022, and 3022 is presented to the earth formation 1108.

In the prior art cutter 1100, as shown in Figures 5 and 6, a single lip 1109 would often form as the cutter 1100 began to wear when drilling. The inventors believed that this lip 1109 formed because the layer 1102 had higher abrasion resistance than the other diamond material. What was not appreciated at the time of that invention was that this lip tended to increase the drilling rate of penetration by a factor of two and often more. The mechanism behind this increase in rate of penetration is believed to be the interaction of the lip 1109 with the earth formation 1108 during drilling. As drilling progresses, the underlying diamond wears from beneath the lip 1109 causing ever further protrusion. Once this protrusion reaches a critical amount the lip fractures. This changes the cutting geometry of the cutter 1100 in a manner that tends to make it self-sharpening – as when the lip fractures, the lines of stress cause a cup-shaped or crescent-shaped portion of the facing table to be lost. Until the lip re-forms, however, the cutters 1100 will not be as sharp, and at least for a period of time will not drill as efficiently. However, there are typically many of these cutters 1100 on a drill bit 1012 so the average drilling rate of penetration remains relatively stable. This is overall a more efficient cutting shape than the flats that tend to wear onto diamond tables of untreated cutters, however. As shown in Figures 5-7, the treated surface layer 1102 ended at the edge 1103 of the prior art cutter 1100, and it is at this edge 1103 that the lip 1109 forms.

It is further believed that the impact toughness of the cutter 1010, 2010, 2122, and 3010 is improved by providing a cavity 2000 (in Fig 10), 2002, 2004, 2006 (in Fig. 11), 3008 (in Fig. 12) which allows the treated portion of the cutter to extend to a second end working surface 2009, 3009A, 3009B, 3009C of the table of superhard material 1022, 2022, 3022, as will be described later. These are illustrated in Figs 10, 11 and 12.

In Figure 7, a cutter 1116 in later developed prior art has a layer 1030, 2030, 3030 which is treated in much the same manner as in the prior art cutters 1100 shown in Figures 5 and 6. However, in this cutter 1116 the treatment is applied additionally to the outside periphery 1124 of cutter 1116. It is preferred that this layer 1030, 2030, 3030 may be continuous across the face and periphery of the cutter, as shown. However, it is also possible to make a discontinuous layer as is known in the art. As shown in Figure 8, the representation of this cutter 1116 after drilling for a period of time, as the cutter wears, two lips 1110 form. This configuration had been shown to increase the drilling rate of penetration by as much as another 40% over the earlier the prior art cutter 1100— but otherwise similar in shape and mode of operation.

As mentioned hereinbefore, the treatment forms a relatively thin layer 1102, 2102 which is free of or substantially free of catalyzing material. The depth or thickness 1102a of the layer 1102, 2102 conveniently falls within the range of about 0.02 to about 0.70 mm, preferably about 0.15 to about 0.25 mm.

In this specification, when the term 'substantially free' is used referring to catalyzing material 1046c in the interstices 1046a, or in a volume of the body 1010a, 2010a, 2122a, 3010a, it should be understood that many, if not all, the surfaces of the adjacent diamond crystals 1046b may still have a coating of the catalyzing material 1046c. Likewise, when the term 'substantially free' is used referring to catalyzing material 1046c on the surfaces of the diamond crystals 1046b, there may still be catalyzing material 1046c present in the adjacent interstices 1046a.

In time, however, as shown in Figure 8, the prior art cutter 1116 wears until only a small part of the working surface 1028 has the lip 1110. The lifetime of this cutter 1116 is dependent, therefore upon the how far down the outside periphery 1124 the treatment extends, and the wear angle 1126. It is also dependent upon other factors including the rate of penetration and the interaction of the cutter with radially adjacent cutters. Wear angle 1126 is generally an angle complimentary to the backrake 1106 of the cutter, but may also be profoundly related to the type of formation drilled, the manner in which the drill bit is operated, and the thickness of the wear resistant layer.

There are numerous ways of producing wear resistant layers which produce lips 1110, as is now well known in the prior art – and as described for instance in pending GB Patent application No. GB 0423597.4 filed on October 23, 2004, and its corresponding U.S. Patent application serial No. 11/163,323 filed on October 14, 2005 both entitled "Dual-Edge Working Surfaces for Polycrystalline Diamond Cutting Elements" and both incorporated by referenced herein for all they disclose.

The PCD cutting elements 1010, 2010, 2122, 3010 may be also made incorporating encapsulated diamond material made using powdery carbonates and many other means, as are well known.

In the present invention – as represented by Figures 10, 11 and 12, a cavity 2000, 2002, 2004, 2006 and 3008 is formed into the substrate 2024, 3024. This facilitates extending the treated layer 1102, 2102, which is substantially free of the catalyzing material, from the facing surface 1030, 2030, 3030 along at least a portion of the peripheral working surface 1028, 2028, and 3028 to the second end working surface 2009, 3009A, 3009B, 3009C of the table of superhard material 1022, 2022, 3022. Extending the surface 1030, 2030, 3030, 1028, 2028, 3028 in this manner further enhances the improvement in impact toughness of the cutter as previously described.

The method of manufacturing this cutting element starts by forming a table of superhard material bonded to a less hard substrate so that the table of superhard material defining a plurality of interstices containing a catalyzing material. The table also defines a first end working surface and a peripheral working surface.

A cavity is formed in the substrate in an area immediately adjacent the peripheral working surface and at least part of each of the end working surface and the peripheral working surface of the cutting element is treated to remove the catalyzing material therefrom to form a second end working surface of the table of superhard material which is exposed by the cavity formed in the substrate.

The cavity allows the peripheral working surface 1028, 2028, and 3028 to be treated to remove the catalyzing material therefrom all the way down the peripheral working surface 1028, 2028, and 3028 and around to the end surface 2009, 3009B, 3009C without interruption.

The invention encompasses, as well as the cutting element, a method of manufacture thereof. The method comprises forming a table of superhard material bonded to a substrate of a less hard material. The table defines a plurality of interstices containing a catalyzing material. The end and peripheral working surfaces are defined by the table. The method involves treating at least part of the end working surface and at least part of the peripheral working surface to remove the catalyzing material therefrom. The treatment may comprise a leaching operation.

Whereas the present invention has been described in particular relation to the drawings attached hereto, it should be understood that other and further modifications apart from those shown or suggested herein, may be made within the scope and spirit of the present invention.

CLAIMS

1. A cutting element comprising a table of superhard material bonded to a substrate of less hard material, the table of superhard material defining a plurality of interstices containing a catalyzing material, the table of superhard material defining a first end working surface and a peripheral working surface extending to the substrate, at least part of the first end working surface and at least a portion of the peripheral working surface are substantially free of catalyzing material, wherein the peripheral working surface is substantially free of catalyzing material to a second end working surface of the table of superhard material which is exposed by a cavity formed in the substrate.

2. The cutting element of Claim 1, wherein a plurality of cavities are formed in the substrate.

3. The cutting element of claim 1, wherein a single cavity is formed about the entire periphery of the substrate.

4. The cutting element of any of the preceding claims, wherein the cavity is formed when the working surfaces are rendered substantially free of the catalyzing material.

5. The cutting element of any of the preceding claims, wherein the end working surface is substantially planar, and the peripheral working surface is substantially perpendicular thereto.

6. The cutting element of any of the preceding claims, wherein the peripheral working surface is of substantially frusto-conical form.

7. The cutting element of any of the preceding claims, wherein the superhard material is polycrystalline diamond.

8. The cutting element of any of the preceding claims, wherein the table of superhard material comprises regions of different abrasion resistance.

9. The cutting element of Claim 8, wherein the regions comprise a series of layers.

10. The cutting element of Claim 9, wherein the layers are continuous.

11. The cutting element of any of the preceding claims, wherein the table of superhard material incorporates encapsulated diamond material.

12. The cutting element of Claim 11, wherein the encapsulated diamond material is made with powdery carbonates.

13. The cutting element of any of the preceding claims, wherein a region of superhard material containing catalyzing material is exposed between the parts of the peripheral working surface and the end working surface which are substantially free of catalyzing material.

14. The cutting element of Claim 13, wherein a first protruding lip is formed adjacent said region at an edge of the part of the end working surface which is substantially free of catalyzing material and a second protruding lip is formed

adjacent said region at an edge of the part of the peripheral working surface which is substantially free of catalyzing material.

15. The cutting element of Claim 13, wherein said region is formed by machining away of material.

16. The cutting element of Claim 13, wherein said region is formed, in use, by part of the cutting element wearing.

17. The cutting element of Claim 13, wherein the said parts of the working surface which are substantially free of catalyzing material extend to a depth in the range of about 0.02 mm to about 0.70 mm.

18. The cutting element of Claim 17, wherein the said parts extend to a depth in the range of about 0.15 mm to about 0.25 mm.

19. A method of manufacturing a cutting element comprising forming a table of superhard material bonded to a less hard substrate, the table of superhard material defining a plurality of interstices containing a catalyzing material, the table defining first and second end working surfaces and an intermediate peripheral working surface, and treating at least part of each end and peripheral working surfaces to remove the catalyzing material therefrom to an area immediately adjacent the substrate.

20. A method of manufacturing a cutting element comprising forming a table of superhard material bonded to a less hard substrate, the table of superhard material

defining a plurality of interstices containing a catalyzing material, the table defining a first end working surface and a peripheral working surface, forming a cavity in the substrate in an area immediately adjacent the peripheral working surface and treating at least part of each of the end working surface and the peripheral working surface to remove the catalyzing material therefrom to form a second end working surface of the table of superhard material which is exposed by the cavity formed in the substrate.

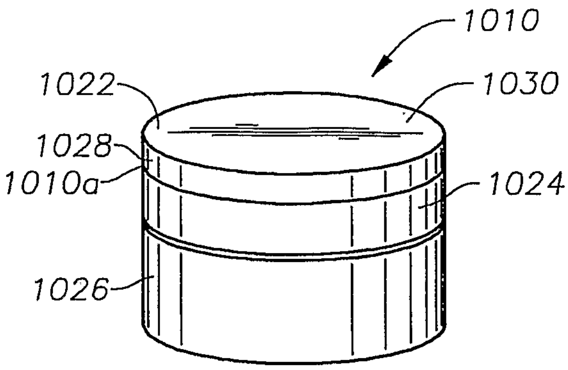


Fig. 1

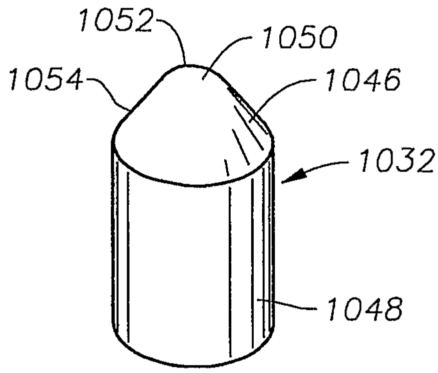


Fig. 3

Fig. 2

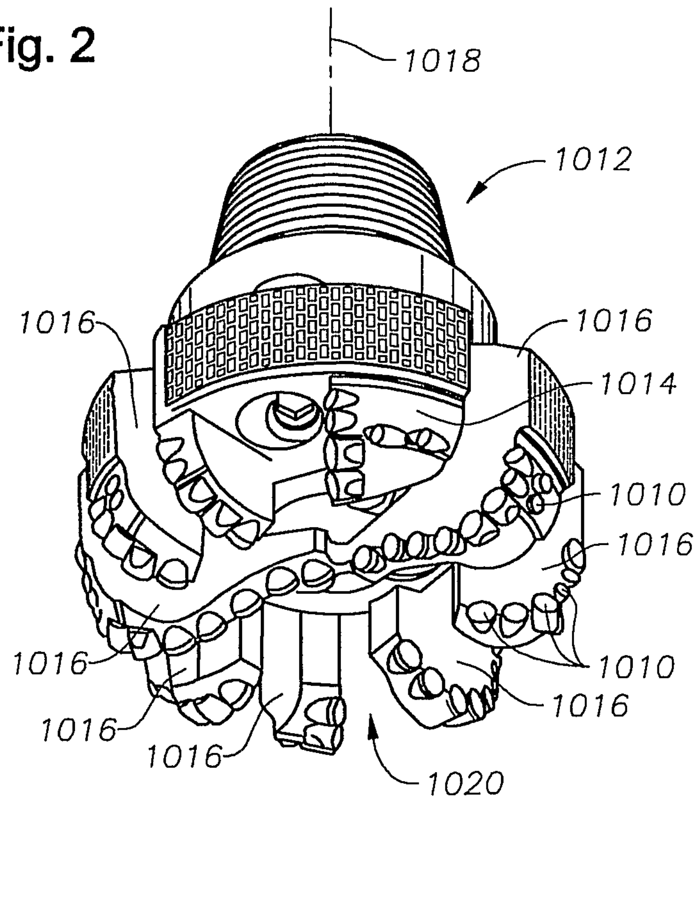
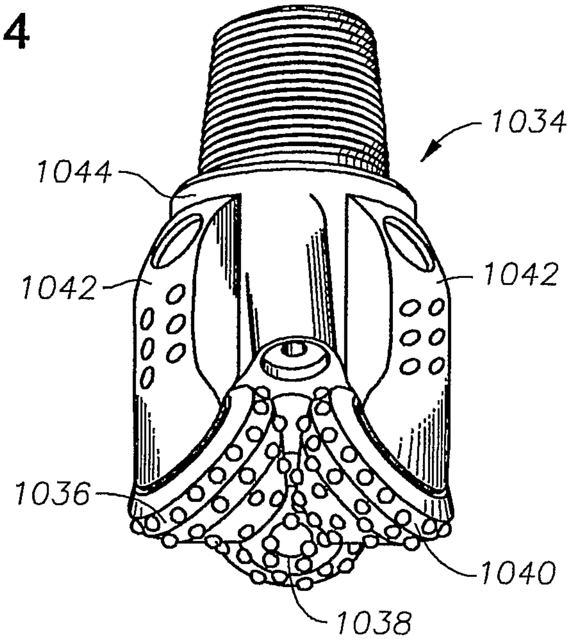


Fig. 4



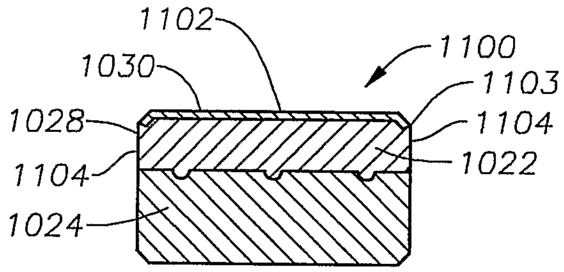


Fig. 5
(Prior Art)

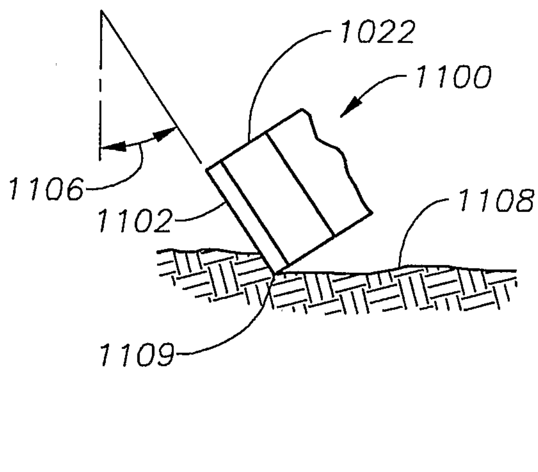


Fig. 6
(Prior Art)

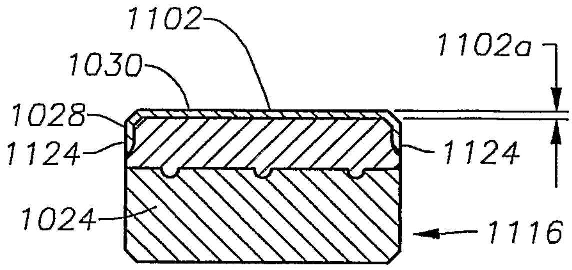


Fig. 7
(Prior Art)

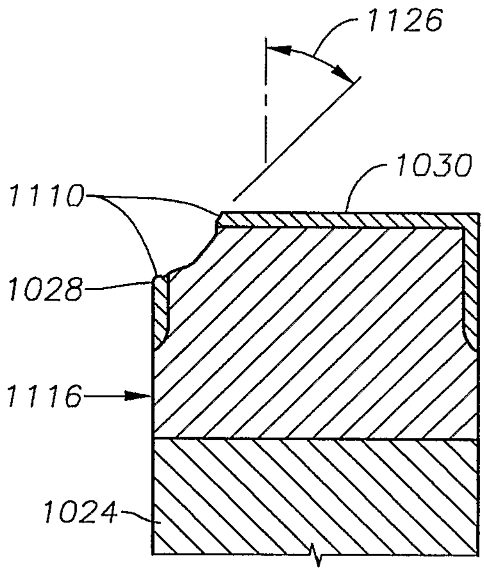


Fig. 8
(Prior Art)

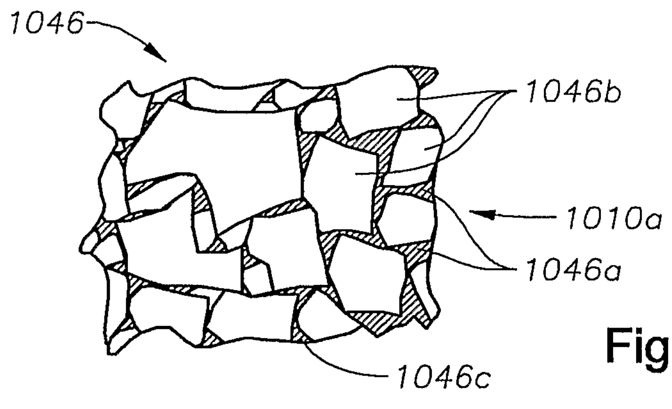


Fig. 9

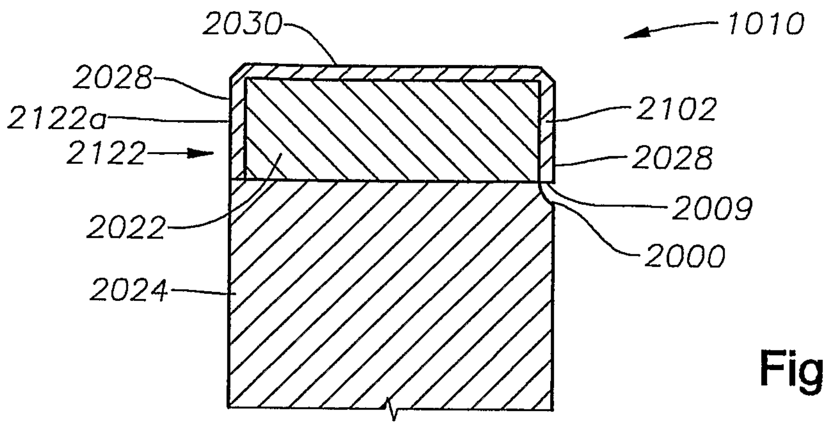


Fig. 10

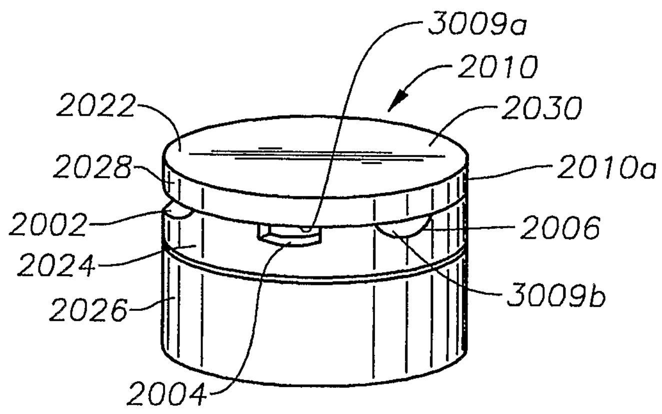


Fig. 11

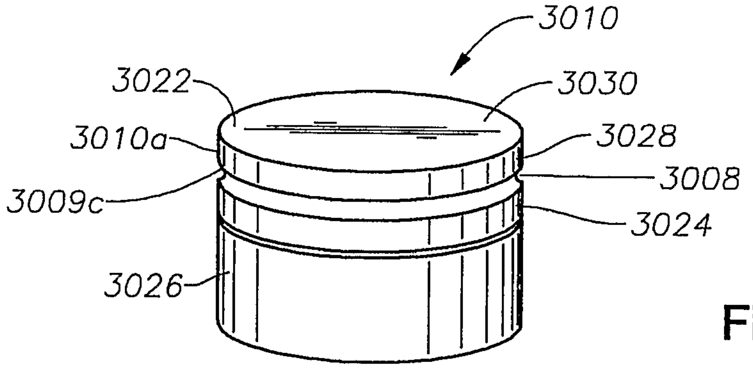


Fig. 12

INTERNATIONAL SEARCH REPORT

International application No
PCT/GB2007/002263

A. CLASSIFICATION OF SUBJECT MATTER
INV. E21B10/573

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)
E21B

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

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

[X] See patent family 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
5 September 2007	19/09/2007

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	van Berlo, André

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International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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