(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
31 May 2012 (31.05.2012)

WIPO | PCT

(10) International Publication Number
WO 2012/071246 A2

(51) International Patent Classification: *B22F 5/00* (2006.01)

(21) International Application Number: PCT/US2011/061268

(22) International Filing Date: 17 November 2011 (17.11.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
12/951,193 22 November 2010 (22.11.2010) US

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(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CL, 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, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, 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 (Rule 48.2(g))*

(54) **Title**: SACRIFICIAL CATALYST POLYCRYSTALLINE DIAMOND ELEMENT

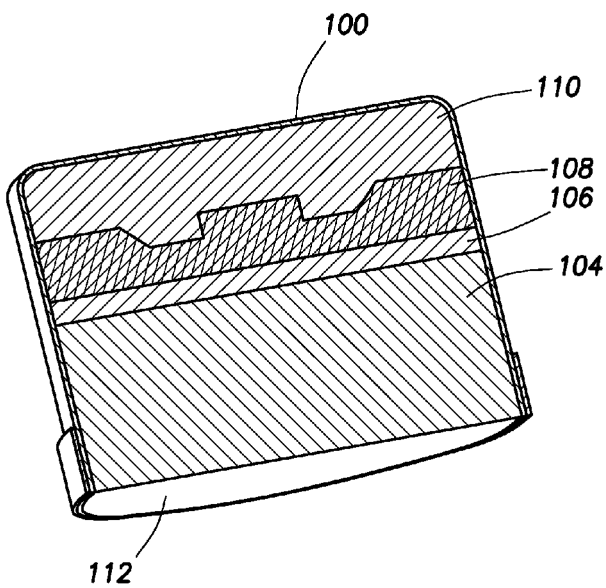

FIG.5

(57) **Abstract**: A superhard composite material comprising a polycrystallme diamond cutter (PDC) having a cutting surface and cutting edges having a polycrystallme diamond thickness of about 3 mm is integrally formed with a sacrificial catalyst source that is removed later in the processing of the cutter.

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SACRIFICIAL CATALYST POLYCRYSTALLINE DIAMOND ELEMENT

BACKGROUND OF THE INVENTION

1. Field of the Invention

Disclosed herein are elements of superhard polycrystalline material synthesized in a high-temperature, high-pressure process and used for wear, cutting, drawing, and other applications. These elements have specifically placed superhard surfaces at locations where wear resistance is required. In particular, these elements are polycrystalline diamond and polycrystalline diamond-like (collectively called PCD) elements with tailored wear and impact resistance and methods of manufacturing them.

2. Description of the Related Art

U.S. Pat. No. 4,534,773 discloses a method of producing an abrasive body of diamond particles in diamond-to-diamond bond with second phase of Ni and/or Si under condition of a High Temperature, High Pressure (HTHP) apparatus.

U.S. Pat. No. 6,861,098 discloses known methods for fabrication of PDC cutter, inserts and tools. 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 polycrystalline diamond-like material is known as carbonitride (CN) described in U.S. Pat. No. 5,776,615. Another, more commonly used form of PCD is described in more detail below. 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 diamond 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 with a substrate of less hard material, such as cemented 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 friction bearings, valve surfaces, indenters, bearing elements, earth boring drill bits and the like. PCD elements of this type may be used in almost any application where a hard abrasive 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. These types of PCD elements are typically called polycrystalline diamond cutters or PDC's.

PCD elements may be 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. Pat. 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 matrix of diamond crystals bonded to each other with many interstices containing a binder-catalyzing material metal 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 element constitutes 85% to 95% by volume and the binder-catalyzing material the other 5% to 15% by volume. Although cobalt is most commonly used as the binder-catalyzing material, any group VIII element, including cobalt, nickel, iron, and alloys thereof, may be employed.

U.S. Pat. No. 7,588,108 describes the fabrication of a high impact resistant tool that has a sintered body of diamond or diamond-like particles in a metal matrix bonded to cemented metal carbide substrate at a non planar interface. The catalyst for enabling diamond-diamond sintering is provided by the substrate. Based on known art, the general manufacture of a PDC cutter or insert or cutting still typically uses a cemented carbide substrate to provide catalyst to aid in the sintering of the diamond particles.

Published U.S Patent Application No. 2005/0044800, describes the use of a meltable sealant barrier to cleanse the PDC constituent assembly via vacuum thermal reduction followed by melting the sealant to provide a hermetic seal for the further HTHP processing. The sealing of the can used to process the PDC cutter is required to limit contamination from the catalyst from the cemented WC substrate to the un-sintered Diamond particle bed during HTHP processing. HTHP can assemblies to prevent contamination of the PCD table may also use processes such as EB welding, as is known for standard production of cutters and inserts.

U.S. Pat. No. 5,127,923 describes an abrasive compact that is subjected to two distinct HTHP operations, the first operation to produce a PDC cutting element with the use of a solvent catalyst sintering aid, and the second pressing operation with the use of a non-solvent catalyst sintering aid.

U.S. Pat. No. 6,045,440 describes an oriented PDC cutter where formation chips and debris are funneled away from the cutting edge via the use of raised top surfaces on the PCD. The redirection of the debris is achieved by creation of high and low surfaces on the PCD cutting surface. Although not described in detail, in the method used to form the protrusion on the PCD, it is assumed that the surface texture and geometry in this case is limited to its ability to extrude/form can surfaces that are a negative of the desired PCD front face extrusions; alternatively post HTHP processing such as EDM and Laser cutting may be necessary to form these surfaces on the cutter face. The geometries in this case are limited to the protruding feature size, pattern and distribution. The art is, in general, silent about the use of sacrificial substrates to generate such surfaces on the as formed PCD table.

BRIEF SUMMARY OF THE INVENTION

A super hard material composite is described which has an in-situ formed PCD complex face optimized for aggressive cutting of formation, low contamination levels in the PCD working surface, and an integrally bonded substrate that can be optimized for wear and impact strength. The composite material has a plurality of hard-phase (Diamond, CBN) particles integrally bonded to plurality of catalyst-free (W, Mo, V, etc) C particles via temperature and pressure. Sintering and densification of the composite layer is aided by catalyst which may be one or more of Co, Ni, and Fe. These elements may be released from a sacrificial substrate that is removed by mechanical or chemical methods after composite manufacture.

The resultant composite may have features including: a premixed or mechanically blended diamond/metallic interface to reduce residual stress, a PCD surface that is the negative of the substrate, and low residual contamination in the diamond and metal carbide particles to be moved to the bottom of the post-sintered PCD substrate. The catalyst flow (sweep) occurs through the diamond layer, causing a physical action that in essence mechanically bonds and blends the interface layer and substrate particle bed during processing. The catalyst sweeps from the substrate toward the sacrificial substrate, thus pushing the impurities toward the PCD layer/sacrificial substrate interface and allowing much of the impurities to be removed while sacrificial substrate is removed.

The present invention addresses manufacturing issues with current PDC cutters and inserts fabrication by including:

A less stringent requirement for diamond particle purity.

EB or vacuum brazed sealing of can/container may be used to lower contamination levels prior to HTHP sintering to inhibit impurity migration to the PCD surface.

Lapping of wear element face to remove PCD material that may have a higher impurity concentration levels (Blemish) due to the catalyst melt flow and surface interaction with the diamond particles.

The post HTHP toughness/wear resistance of the sintered substrate that is used as the catalyst source is controlled by selection of in-situ sintered substrate grain size.

The infiltration rate and direction of catalyst is limited by the sintered particle size and volume % binder in the cemented carbide substrate.

The texture of the PCD working surface limited to the can geometry.

Protrusions with hills or valleys on the tool faces for aggressive cutting are difficult to form with the prior art cell configuration.

In at least one aspect, the disclosure relates to a superhard composite material including a polycrystalline diamond cutting element having a cutting surface with a finished polycrystalline diamond thickness of between about 2 mm and about 5 mm and a high-temperature, high-pressure in-situ formed cemented carbide substrate that is integrally bonded to the PCD. A can and a lid may be provided for the HTHP component assembly with a shrink factor of about 1.10 for minimal OD grinding, and the thickness of the in-situ formed cemented carbide substrate is between about 6 and 20 mm. A cobalt catalyst for Diamond-Diamond particle sintering and WC-WC cementation may be supplied by a sacrificial cemented carbide substrate with an average grain size of 20 μm and cobalt of 35 wt %. The finished cutter may be about 1613 mm in diameter. The sacrificial substrate in contact with the diamond particle may form a conic bevel at an outside diameter to form an in-situ chamfer on the PCD after HTHP processing. The diamond feed stock may have a mono modal size of about 50 μm. The WC particle size in contact with the diamond particle may be a mono modal size of about 50 μm. A transition Diamond--WC layer may be formed by using a probing tool that is used to selectively transfer WC particle into the diamond particle bed to a depth of about 1 mm. The can and lid may be mechanically sealed. The can may be exposed to a HTHP process to enable composite densification aided via a catalyst infiltration from the cemented carbide substrate into the diamond and WC particle bed, wherein the cemented carbide substrate is a sacrificial substrate, and wherein the HTHP processing is at least 40 kbar pressures and the temperature is at least 1000°C.

The sweep or movement of the catalyst during HTHP processing may occur from the top of the PCD surface to the bottom of the in-situ formed substrate. After HTHP processing, the super hard composite may be finished by removal of the can/sacrificial substrate and OD grinding. The sacrificial substrate may be formed of a metal carbide selected from the group consisting of a tungsten carbide, titanium carbide, tantalum carbide, and mixtures thereof. The sacrificial substrate may be formed of a carbide from the group of IVB, VB, or VIB metals which is pressed and sintered in the presence of a binder of cobalt, nickel, iron, and alloys thereof, and further comprises: an average carbide particle size greater than >3 μm, a weight % Binder >3, a binder comprising Co, Ni, or Fe with at least 5 wt % Co in the sacrificial binder phase. The WC may be replaced with MC comprising M=V, Mo, Ti, Ta and mixes thereof with a WC content of at least 5 wt %. The sacrificial binder substrate may have M, C, Co (Fe, Ni) a eutectic composition forming 100% melt at the eutectic temperature; W, C, Co--Ni eutectic temperate is about 1270 °C. A surface texture of the sacrificial substrate may be in contact with the diamond particle. The surface texture on the substrate may be the negative of the desired roughness on the cutting element face, with the texture formed by pressing the grade mix or post sintered operations including laser, EDM or other methods for providing the texture. The texture can have chip breaker geometries used for milling and turning inserts to aid with chipping of formation.

The diamond particles may have a multi-modal size distribution for optimal packing with a size range of 1 nm to 100 μm, and the diamond particles have a carbon phase additive >5 wt %

that is amorphous or nano structure fullerenes. The diamond particles may be replaced with CBN particles. A mixture of diamond and CBN particles may include at least 0.5 wt % diamond particles. The interface probing depth may be 100% of the PCD layer with a low WC concentration near a sacrificial substrate and a high concentration near the WC-diamond interface. The WC content in diamond particle bed ranges at the preformed interface may range from 1 wt % to 80 wt %. The carbide particles may be formed of a metal carbide selected from the group consisting of tungsten carbide, titanium carbide, tantalum carbide, and mixtures thereof from the group of IVB, VB, or VIB metals, and include a multi modal particle size distribution for optimal packing with a size range of 1 nm to 100 μm, wherein at least 5 wt % of the particles are >50 μm to ensure adequate erosion resistance of the HTHP in-situ formed substrate.

The diamond particles, interface and WC particle bed may be preforms manufactured using a fugitive binder like PEG, mineral oil and methyl cellulose to limit segregation during transfer to the can, wherein, a moldable diamond mix is pressed in the can to conform to the sacrificial substrate texture, an interface is formed by using a probing tool to transfer a given amount of WC mix into the diamond mix, a WC mix is pressed into the can above the interface, and the fugitive binder is removed in the presence of hydrogen. A sink for a catalyst abridging the WC bed may be used to reduce catalyst content in the densified PCD/substrate wherein the sink comprises loose Zirconia ceramic particles and the like, that have greater resistance to HTHP sintering than WC particles in the presence of said catalyst, and wherein the sink is removed after HTHP processing via a EDM, laser or abrasive cutting. The substrate removal may be by a mechanical dry/wet abrasives grinding or chemical leaching or a combination of both methods. The PCD face may be coated with a nano coating diamond or diamond like coating. The cutter shape may have an irregular cross section or symmetric cross section such as an oval, triangular, or a trapezoidal shape. The composite tool may have a typical geometry for cutting and milling inserts. The composite tool may have a typical geometry of inserts used for rolling cutter earth boring drill bits.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is an illustrative view of a typical drill rig in operation.

FIG. 2 is a view of a PCD cutting element typical for those of the present invention.

FIG. 3 is a perspective view drill bit which may utilize the PCD cutting elements of the present invention.

FIG. 4 is a modified cross section view of a prior art PCD cutting element in a can ready for HTHP processing.

FIG. 5 is a perspective view of one embodiment of a PCD cutting element of the present invention in a suitable can and ready for HTHP processing.

FIG. 6A shows one preferred non-planar interface pattern on a sacrificial substrate used to make a PDC cutting element of the present invention and FIG. 6B shows a perspective view of the pattern as it is formed on the finished cutter.

FIG. 7A shows another preferred non-planar interface pattern on a sacrificial substrate for a PDC cutting element in the present invention, and FIG. 7B shows a perspective view of the pattern as it is formed on the resulting cutter interface.

FIG. 8A shows still another preferred non-planar interface pattern on a sacrificial substrate for a PDC cutting element in the present invention, and FIG. 8B shows a perspective view of the pattern as it is formed on the resulting cutter interface.

FIG. 9 is a cross section view a PDC element of the present invention after HTHP processing and before finishing.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, it is understood that the composite described hereafter as formed of polycrystalline diamond, PCD, or sintered diamond as the material is often referred to in the industry, but can also be any of the super hard abrasive materials, including, but not limited to, synthetic or natural diamond, cubic boron nitride, and related materials.

Polycrystalline diamond cutters are well known and used as cutting elements in drilling bits used to form boreholes into the earth, and are primarily used for, but not limited to, drilling tools for exploration and production of hydrocarbon minerals from the earth.

For illustrative purposes only, a typical drilling operation is shown in FIG. 1. FIG. 1 shows in schematic form a representation of a drill string 2 suspended by a derrick 4 for drilling a borehole 6 into the earth for minerals exploration and recovery, and in particular petroleum. A bottom-hole assembly (BHA) 8 is located at the bottom of the borehole 6. Oftentimes, the BHA 8 may have a downhole drilling motor 9 to rotate an earth boring drill bit 1.

As the drill bit 1 is rotated from the surface or by the downhole motor 9, it drills into the earth allowing the drill string 2 to advance, forming the borehole 6. For the purpose of understanding how these systems may be operated, for the type of drilling system illustrated in FIG. 1, the drill bit 1 may be any one of numerous types well known to those skilled in the oil and gas exploration business. This is just one of many types and configurations of bottom hole assemblies 8, however, and is shown only for illustration. There are numerous arrangements and equipment configurations possible for use for drilling boreholes into the earth, and the present disclosure is not limited to the particular configurations as described herein.

As illustrated in FIG. 4, a cross section view of a prior art cutting element 50 is typically made up of only a polycrystalline diamond table 55 integrally formed with a substrate 60 of tungsten carbide-cobalt (or other suitable hard metallic material). There are numerous known variations in configurations, sizes, shapes and materials for these prior art cutting elements 50.

A more detailed view of the earth boring drill bit 1 that may use the cutting elements 10 of the present invention is shown in FIG. 3. Referring now to FIGS. 2 and 3, a superhard composite material polycrystalline diamond cutting element 10 of the present invention may be a preform cutting element 10 for a fixed cutter rotary drill bit 1 (as shown in FIG. 3). The bit body 14 of the drill bit may be formed with a plurality of blades 16 extending generally outwardly away from the central longitudinal axis of rotation 18 of the drill bit. Spaced apart side-by-side along the leading face 20 of each blade 16 are a plurality of the PCD cutting elements 10 of the present invention.

A typical PCD cutting element 10 may have a body in the form of a circular tablet having a thin front facing table 22 of diamond bonded in a high-pressure high-temperature press to a substrate 24 of less hard material such as cemented tungsten carbide or other metallic material. The cutting element 10 may be preformed as will be described in detail and then may be bonded on a generally cylindrical carrier 26 which may also be formed from cemented tungsten carbide, or it may alternatively be attached directly to the blade 16. The PCD cutting element 10 has peripheral and end working surfaces 28, 30 which, as illustrated, are substantially perpendicular to one another.

When a cylindrical carrier 26 is utilized, it may be received within a correspondingly shaped socket or recess in the blade 16. The carrier 26 may be brazed, shrink fit or press fit into the socket (not shown) in a drill bit 12. Where brazed, the braze joint may extend over the carrier 26 and part of the substrate 24. In operation the fixed cutter drill bit 12 is rotated and weight is applied. This forces the cutting elements 10 into the earth being drilled, effecting a cutting and/or drilling action.

These cutting elements 10 are typically made in a very high temperature and high pressure pressing operation (which is well known in the industry) and then finished machined into the cylindrical shapes shown.

The typical process for making these PCD cutting elements 10 typically involves combining mixtures of various sized diamond crystals, which are mixed together, and processed into the PDC elements 10 as previously described.

In various embodiments of the invention, a superhard composite material comprises a polycrystalline diamond cutter (PDC) having a flat cutting surface having a polycrystalline diamond thickness ranging from about 1 to 5 mm or greater--but typically about 3 mm and a high-temperature, high-pressure (HTHP) in-situ cemented carbide substrate of about 10 mm thickness that is integrally formed with the PCD.

These PDC cutting elements 10 may be made in a manufacturing process with a preformed can 100 (Figure 5) that has at the bottom (or lid) 112 a material forming a base substrate 104. An in-situ high-temperature, high-pressure sacrificial substrate 110 may be placed on top of the base substrate 104. In a preferred embodiment, the base substrate 104 may be domed whereby the thickness at the center is much greater than the thickness at the sides, as shown in FIG. 9. On top of the base substrate 104 may be a layer of fine PCD diamond material 108 which may typically have a range of particle sizes. This diamond layer 108 will fill the can 100 to a level higher than the in-situ substrate 106. Because the in-situ substrate 106 may be domed shaped, (as shown by numeral 114 in FIG. 9) the thickness of the diamond layer 108 will be less at the center than at the periphery (as shown). A generally cylindrical sacrificial substrate 110 may be placed on top of the diamond layer 108. Thereafter a lid 112 is placed upon the preformed can 100. The can 100 with the above described mixture is then processed to remove impurities; the can 100 may be welded or otherwise hermetically sealed, and then subjected to a high pressure, high temperature process as is well known in the industry.

What results is a superhard composite material that has a base substrate 104 and a sacrificial substrate 110 that allows simultaneous infiltration of the diamond layer 108 from both the top and the bottom. This process moves the impurities that tend to be pushed ahead of the liquid front as the sintering process proceeds toward the center of the sintered diamond material 108, instead of accumulating at the working surfaces, as is the case in prior art PDC elements.

The sacrificial substrate 110 may have various geometrical surface configurations 120A, 122A, and 124A, as shown in FIGS. 6A, 7A and 8A. Although only three geometrical arrangements are shown, it is understood that a great variety of specific geometrical patters may be useful, and the present invention is not intended to be limited only to those shown. When the PDC elements are formed with these sacrificial substrates, a negative (or mirror image) of the pattern forms in the PCD layer 108 as the PDC elements is being formed in the HTHP process.

In the three specific geometries of the sacrificial substrates, as represented in perspective views by numeral 120A in FIG. 6A, 122A in FIG. 7A, and 124A in FIG. 8A, it can be seen that a negative pattern of the non-planar surface geometry will be produced on the working surface of the finished cutting as shown in the perspective views of finished cutters 120B, 122B and 124B in FIGS. 6B, 7B, and 8B. These cutting elements 120B, 122B and 124B of the present invention have the geometrical patterns that were formed by the patterns on the sacrificial substrate material 110. Even though the sacrificial substrate 110 is removed (that is why it is called sacrificial) during processing, a negative of the pattern is left behind of the finished cutting element, as shown in perspective in FIGS. 6B, 7B and 8B.

The end result is a new type of PDC cutting element 10 with superior physical/mechanical properties as compared to the prior art. Furthermore, various geometrical patterns may be integrally formed on the face of the cutting element in the formation process, providing an integrally formed surface geometry on the \`as pressed\` cutter--yielding a PDC cutting element with superior physical and mechanical properties.

As part of the manufacturing process, another advantage of the superhard composite material described above is that it may further utilize a can 100 with a lid 112 for the HTHP component assembly with a shrink factor of about 1.10 for minimal OD grinding.

The superhard composite material may have a cobalt catalyst for diamond-diamond particle sintering aid and WC-WC cementation is supplied by a sacrificial cemented carbide substrate (as will be described in detail) that may have an average grain size of 20 μm and cobalt of 35 Wt. %, and the finished cutter may be about 1613 mm in diameter.

Also, the sacrificial substrate 110 in contact with the diamond particles may form a conic bevel at an outside diameter to form an in-situ chamfer on the PCD after HTHP processing, and further, the diamond feed stock may have a mono modal size of about 50 μm. Furthermore, a transition Diamond--WC-Co layer is formed by using a probing tool that is used to selectively transfer WC-Co particle into the diamond particle bed to a depth of about 1 mm. The can 100 and lid 112 may be mechanically sealed and the can 100 is exposed to an HTHP process to enable composite densification aided via a catalyst infiltration from the cemented carbide substrate into the diamond and WC-Co particle bed. The cemented carbide substrate is a sacrificial substrate, and the HTHP processing may require at least 40 k bar pressures and a temperature of at least 1000°C.

The sweep or movement of the catalyst during HTHP processing may occur from the top of the PCD surface to the bottom of the in-situ formed substrate and after HTHP processing, the super hard composite is finished by removal of the can 100 and substrate 110 and OD grinding.

The sacrificial substrate 110 may be separately formed of a metal carbide selected from the group including a tungsten carbide, titanium carbide, tantalum carbide, and mixtures thereof, and the sacrificial substrate 110 may be formed of a carbide from the group of IVB, VB, or VIB metals which is pressed and sintered in the presence of a binder of cobalt, nickel, iron, and alloys thereof, and may further have:

an average carbide particle size greater than >3 μm,

a weight % of binder material >3%,

a binder of Co, Ni, or Fe with at least 5 wt % Co in the sacrificial binder phase,

The WC may be replaced with MC comprising M=V, Mo, Ti, Ta) and mixes thereof with a WC content of at least 5 wt %, and also the sacrificial binder substrate that has M, C, Co (Fe, Ni) a eutectic composition forming 100% melt at the eutectic temperature; W-C--Co or W-C--Ni eutectic temperate is about 1270 degrees C. There may also be a surface texture of the sacrificial substrate 110 in contact with the diamond particle which has a surface texture on the substrate that is the negative of the desired roughness on the cutting element face, and the texture is formed by pressing the grade mix or post sintered operations including laser, EDM or other methods for providing the texture.

The above superhard composite material may also have a texture supporting chip breaker geometries used for milling and turning inserts to aid with chipping of formation, and may have diamond particles with a multi-modal size distribution for optimal packing with a size range of 1 nm to 100 μm, and, the diamond particles have a carbon phase additive >5 wt % that is amorphous or nano structure fullerenes.

In addition, the superhard composite may have diamond particles which are replaced with CBN particles, and may further have a mixture of Diamond and CBN particles with at least 0.5 wt % diamond particles with an interface, with the interface probing depth 100% of the PCD layer with a low WC concentration near a sacrificial substrate 110 and a high concentration near the WC-diamond interface.

The WC content in diamond particle bed ranges at the preformed interface ranges from 1 wt % to 80 wt % and the Carbide particles are formed of a metal carbide selected from the group consisting of tungsten carbide, titanium carbide, tantalum carbide, and mixtures thereof from the group of IVB, VB, or VIB metals, and comprising a multi modal particle size distribution for optimal packing with a size range of 1 nm to 100 μm., at least 5 wt % of the particles may be >50 μm to ensure adequate erosion resistance of the HTHP in-situ formed substrate.

The diamond particles, interface and WC particle bed may be preforms manufactured using a fugitive binder like PEG, mineral oil and methyl cellulose to limit segregation during transfer to the can 100, where a moldable diamond mix is pressed in the can 100 to conform to the sacrificial substrate 110 texture, an interface is formed by using a probing tool to transfer a given amount of WC mix into the diamond mix, a WC mix is pressed into the can 100 above the interface, and, the fugitive binder is removed in the presence of hydrogen.

The superhard composite may also have a sink for a catalyst abridging the WC bed to reduce catalyst content in the densified PCD/substrate where the sink comprises loose Zirconia ceramic particles and the like, that have greater resistance to HTHP sintering than WC particles in the presence of the catalyst, and wherein the sink is removed after HTHP processing via an EDM, laser or abrasive cutting and furthermore, substrate removal may be by a mechanical dry/wet abrasives grinding or chemical leaching or a combination of both methods.

The PCD face may be coated with a nano coating diamond or diamond like coating, and the cutter shape may have an irregular cross section, or an asymmetric cross section such as an oval, triangular, or a trapezoidal shape.

Furthermore, described herein is a superhard composite material having a polycrystalline diamond material comprising a generally flat cutting surface of a polycrystalline diamond material and having a thickness of about 3 mm further comprising a high-temperature, high-pressure (HTHP) in-situ cemented carbide substrate integrally bonded to the PCD.

The material may also comprise a can 100 and a lid 112 for the HTHP component assembly with a shrink factor of about 1.10 for minimal OD grinding, and have a cobalt catalyst for Diamond-Diamond particle sintering and WC-WC cementation that is supplied by a sacrificial cemented carbide substrate with an average grain size of 20 μm and cobalt of 35 wt. %.

The finished cutter described above may be about 1613 mm in diameter, and have a the sacrificial substrate 110 in contact with the diamond particle forms a conic bevel at an outside diameter to form an in-situ chamfer on the PCD after HTHP processing.

In addition, the diamond feed stock is a mono modal size of about 50 μm and the WC particle size in contact with the diamond particle may be a mono modal size of about 50 μm.

The superhard composite material may have a transition Diamond--WC layer is formed by using a probing tool that is used to selectively transfer WC particle into the diamond particle bed to a depth of about 1 mm, and be processed in a can 100 and lid 112 which are mechanically sealed.

During processing, the can 100 may be exposed to an HTHP process to enable composite densification aided via a catalyst infiltration from the cemented carbide substrate into the diamond and WC particle bed, so that the cemented carbide substrate acts as a sacrificial substrate 110, and the HTHP processing requires at least 40 kbar pressures and a temperature of at least 1000°C.

The sweep or movement of the catalyst during HTHP processing may flow from the top of the PCD surface to the bottom of the in situ formed substrate.

The sacrificial substrate 110 may be formed of a metal carbide selected from the group consisting of a tungsten carbide, titanium carbide, tantalum carbide, and mixtures thereof or it may be formed of a carbide from the group of IVB, VB, or VIB metals which is pressed and sintered in the presence of a binder of cobalt, nickel, iron, and alloys thereof, and may further have:

an average carbide particle size greater than >3 μm,

a weight of binder >3%,

the binder containing Co, Ni, or Fe with at least 5 wt % Co in the sacrificial binder phase. The WC may be replaced with MC comprising M=V, Mo, Ti, Ta (and mixes thereof) with a WC content of at least 5 wt %.

The sacrificial binder substrate may also form a M, C, Co (Fe, Ni), a eutectic composition forming 100% melt at the eutectic temperature; the W, C, Co--Ni eutectic temperate is about 1270 degrees C.

The surface texture of the sacrificial substrate 110 in contact with the diamond particle may form a surface texture on the substrate that is the negative of the desired roughness on the cutting element face, and the texture may be formed by pressing the grade mix or post sintered operations including laser, EDM or other methods for providing the texture.

The texture may have incorporated within it chip breaker geometries used for milling and turning inserts to aid with chipping of formation, and the diamond particles may have a multi-modal size distribution for optimal packing with a size range of 1 nm to 100 μm, and the diamond particles have a carbon phase additive >5 wt % that is amorphous or nano structure fullerenes.

The diamond particles may be replaced with CBN particles or may be a mixture of Diamond and CBN particles comprising at least 0.5 wt % diamond particles. The interface probing depth may be 100% of the PCD layer with a low WC concentration near the sacrificial substrate 110 and with a high concentration near the WC-diamond interface.

The WC content in diamond particle bed ranges at the preformed interface ranges from 1 wt % to 80 wt %, and the Carbide particles may be formed of a metal carbide selected from the group consisting of tungsten carbide, titanium carbide, tantalum carbide, and mixtures thereof from the group of IVB, VB, or VIB metals, and further have a multi modal particle size distribution for optimal packing with a size range of 1 nm to 100 μm. At least 5 wt % of the particles are >50 μm to ensure adequate erosion resistance of the HTHP in-situ formed substrate.

The superhard composite may have the diamond particles, interface and WC particle bed as made as performs, manufactured using a fugitive binder like PEG, mineral oil and methyl cellulose to limit segregation during transfer to the can, so that a moldable diamond mix may be pressed in the can to conform to the sacrificial substrate 110 texture, and an interface is formed by using a probing tool to transfer a given amount of WC mix into the diamond mix and a WC mix is pressed into the can above the interface, and then the fugitive binder is removed in the presence of hydrogen.

The superhard composite may also have a sink for a catalyst abridging the WC bed to reduce catalyst content in the densified PCD/substrate such that the sink has loose Zirconia ceramic particles and/or the like, that have greater resistance to HTHP sintering than WC particles in the presence of the catalyst, and the sink is removed after HTHP processing via a EDM, laser or abrasive cutting.

The substrate may be removed from the superhard composite by a mechanical dry/wet abrasives grinding or chemical leaching or a combination of both methods, and furthermore, the PCD face of the composite may be coated with a nano coating diamond or diamond like coating. The cutter shapes may include those with an irregular cross section or symmetric cross section, such as an oval, triangular, or a trapezoidal shape.

Finally, the superhard composite may also form a composite tool with a typical geometry for cutting and milling inserts, or, it may have a typical geometry of inserts used for rolling cutter earth boring drill bits.

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

What is claimed:

1. A cutting element for a drill bit of a downhole tool, comprising:

a base substrate;

a diamond layer bonded to the base substrate, the diamond layer formed from a sacrificial substrate comprising a catalyst, the sacrificial substrate removably bonded to the diamond layer such that the catalyst sweeps from the sacrificial substrate to the base substrate and impurities in the diamond layer are drawn away from a working surface of the diamond layer.

2. The cutting element of Claim 1, wherein the sacrificial substrate has a surface texture defining a pattern on the working surface of the diamond layer when bonded thereto.

3. The cutting element of Claim 1, wherein the sacrificial substrate comprises a carbide selected from the from the group of IVB, VB, VIB, and combinations thereof.

4. The cutting element of Claim 1, wherein the catalyst comprises one of cobalt, nickel, iron and combinations thereof.

5. The cutting element of Claim 1, wherein the diamond layer comprises one of a diamond feedstock, a carbon phase additive, cubic boron nitride, tungsten carbide, and combinations thereof.

6. The cutting element of Claim 1, wherein the diamond layer has a thickness between 1mm and 5mm.

7. The cutting element of Claim 1, further comprising a coating on the working surface of the diamond layer, the coating comprising one of a diamond nano coating and a diamond like coating.

8. The cutting element of Claim 1, further comprising an in situ formed substrate between the diamond layer and the base substrate.

9. The cutting element of Claim 8, wherein particles of the carbide are transferred from the in situ substrate into the diamond layer to a depth of about 1mm.

10. The cutting element of Claim 8, further comprising a transition layer between the diamond layer and the in situ substrate.

11. The cutting element of Claim 8, further comprising an interface between the diamond layer and the in situ substrate.

12. The cutting element of Claim 11, wherein the diamond layer has a probing depth along the interface that is 100% of the diamond layer with a low tungsten carbide concentration near the sacrificial substrate and a high concentration near the interface.

13. The cutting element of Claim 8, further comprising a removable sink between the in situ substrate and the base substrate, the removable sink comprising zirconia ceramic particles.

14. The cutting element of Claim 8, further comprising a particle bed between the in situ substrate and the diamond layer, the particle bed comprising a moldable mix of diamond particles, carbide particles, and a removable fugitive binder.

15. The cutting element of Claim 14, wherein the removable fugitive binder for the moldable mix comprises one of polyethylene glycol, mineral oil and methyl cellulose.

16. A cutting element for a drill bit of a downhole tool, comprising:

a base substrate;

a diamond layer bonded to the base substrate, the diamond layer having a working surface and a peripheral working surface, the diamond layer formed from a sacrificial substrate removably bonded to the diamond layer, the sacrificial substrate having a surface texture for defining a pattern on the working surface of the diamond layer when bonded thereto.

17. The cutting element of Claim 16, wherein the sacrificial substrate comprises a catalyst, the sacrificial substrate removably bonded to the diamond layer such that the catalyst sweeps from the sacrificial substrate to the base substrate and impurities in the diamond layer are drawn away from the working surface of the diamond layer.

18. The cutting element of Claim 16, wherein the surface texture is a negative of a desired roughness on the working surface of the diamond layer.

19. The cutting element of Claim 16, wherein the pattern comprises at least one of a radial groove, a concentric groove, a depression, a protrusion, and combinations thereof.

20. The cutting element of Claim 16, wherein the pattern comprises a plurality of pie shaped sections with spaces therebetween.

21. The cutting element of Claim 16, wherein the sacrificial catalyst has a conic bevel on an outside diameter thereof for forming an in-situ chamfer in the diamond layer

22. The cutting element of Claim 16, wherein the surface texture defines chip breaker geometries in the diamond layer to aid with chipping of a formation.

23. The cutting element of Claim 16, wherein the cutting element has one of an irregular cross section and a symmetric cross section.

24. The cutting element of Claim 16, wherein the cutting element has one of an oval, triangular, and a trapezoidal cross-section.

25. A method of forming a cutting element for a drill bit of a downhole tool, comprising:

bonding a diamond layer bonded to a base substrate; and

bonding a sacrificial substrate to the diamond layer such that a catalyst of the sacrificial substrate sweeps from the sacrificial substrate to the base substrate and impurities in the diamond layer are drawn away from a working surface of the diamond layer; and

removing the sacrificial substrate from the diamond layer.

26. The method of Claim 25, wherein the bonding further comprises bonding the sacrificial substrate to the diamond layer such that a surface texture of the sacrificial substrate defines a pattern on the working surface of the diamond layer.

27. The method of Claim 25, further comprising finishing the diamond layer.

28. The method of Claim 25, further comprising positioning the base substrate, the diamond layer and the sacrificial substrate in a can with a lid and applying a high pressure, high temperature process thereto.

29. The method of Claim 28, wherein the high pressure is at least 40 kbar and the high temperature is at least 1000 °C.

30. The method of Claim 28, further comprising removing the can, the lid and the sacrificial substrate by one of a mechanical dry/wet abrasives grinding, outer diameter grinding, chemical leaching or a combination thereof.

31. The method of Claim 25, further comprising bonding an in situ substrate between the sacrificial substrate and the diamond layer.

32. The method of Claim 31, further comprising forming a transition layer between the in situ substrate and the diamond layer.

33. The method of claim 31, further comprising transferring carbide from the in situ substrate into the diamond layer to a depth of about 1 mm.

34. The method of Claim 31, further comprising providing an interface between the in situ substrate and the diamond layer.

35. The method of Claim 31, further comprising forming a removable sink between the diamond layer and the in situ substrate, the removable sink comprising loose zirconia ceramic particles.

36. The method of Claim 35, further comprising removing the removable sink via one of a electrical discharge machining, laser, and abrasive cutting.

37. The method of Claim 31, further comprising forming a particle bed between the in situ substrate and the diamond layer, the particle bed comprising a moldable mix of diamond particles, carbide particles and a fugitive binder.

38. The method of Claim 37, further comprising limiting segration during bonding by using the fugitive binder to preform the particle bed.

39. The method of Claim 37, further comprising removing the fugitive binder.

40. A method of forming a cutting element for a drill bit of a downhole tool, comprising:

bonding a diamond layer to a base substrate, the diamond layer having a working surface and a peripheral working surface; and

bonding a sacrificial substrate to the diamond layer such that a surface texture of the sacrificial substrate defines a pattern on the working surface of the diamond layer; and

removing the sacrificial substrate from the diamond layer.

41. The method of Claim 40, wherein the bonding the sacrificial substrate further comprises bonding the sacrificial substrate to the diamond layer such that a catalyst of the sacrificial substrate sweeps from the sacrificial substrate to the base substrate and impurities in the diamond layer are drawn away from the working surface of the diamond layer.

42. The method of Claim 40, further comprising forming the pattern on the diamond layer by one of pressing a grade mix, post sintering by laser, post sintering by electrical discharge machining, and combinations thereof.

43. The method of Claim 40, further comprising chamfering a periphery of the working surface of the diamond layer.

44. The method of Claim 40, further comprising pressing the moldable mix in the can to conform to the geometric configuration of the sacrificial substrate texture.

45. The method of Claim 40, further comprising finishing the diamond layer.

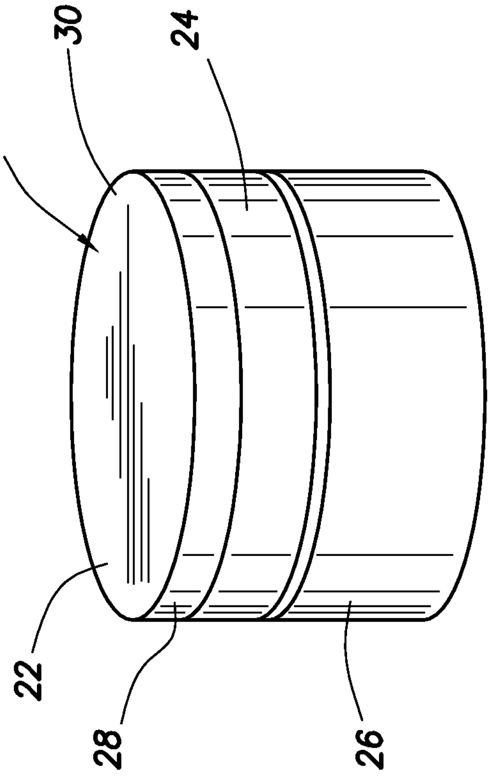

FIG.2

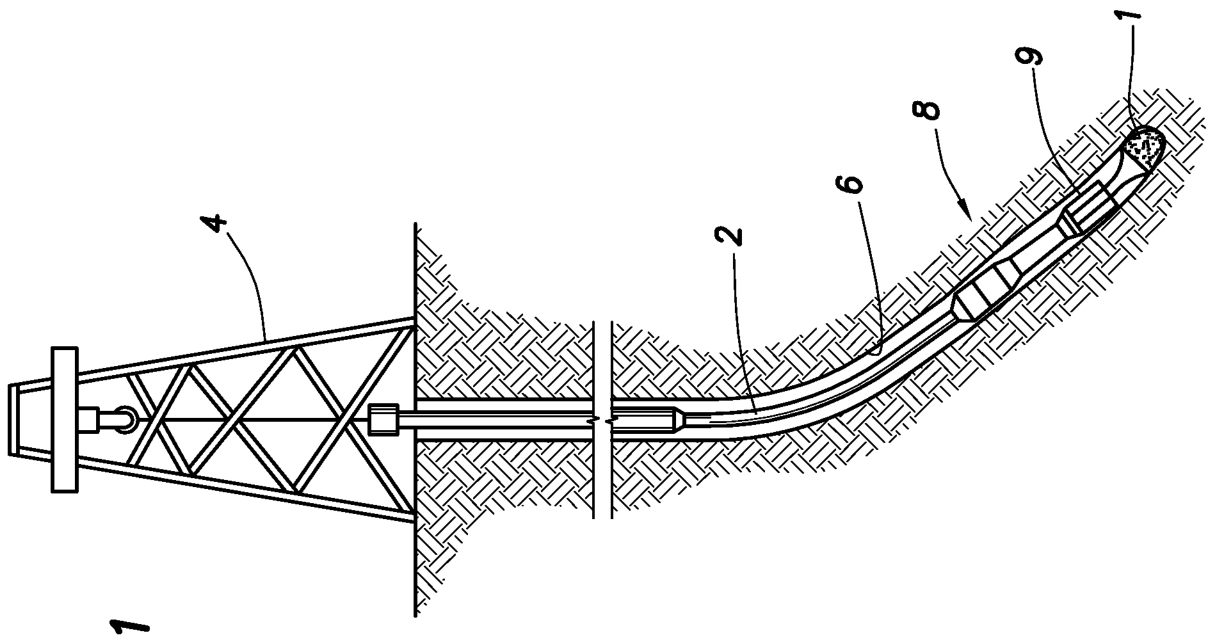

FIG.1

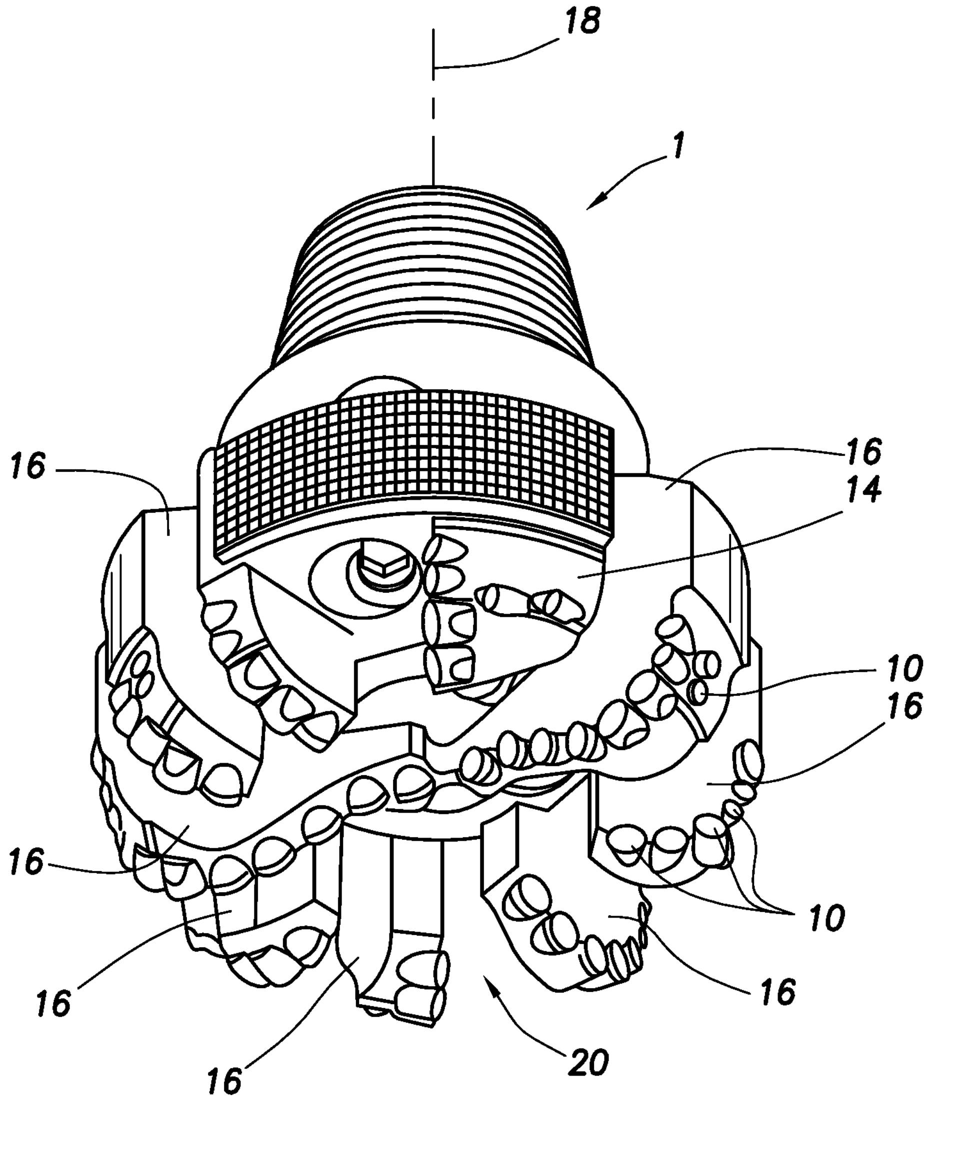

FIG.3

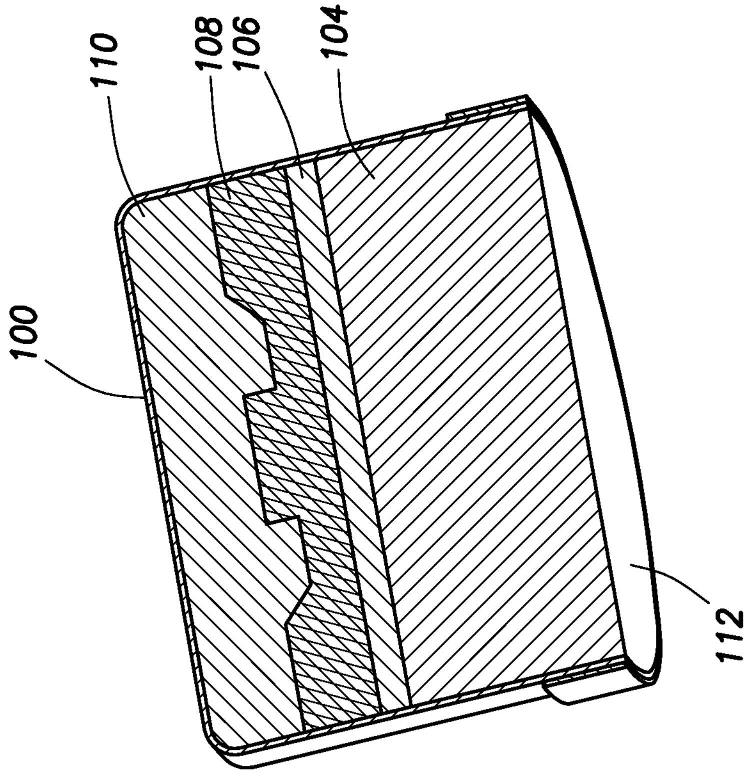

FIG.5

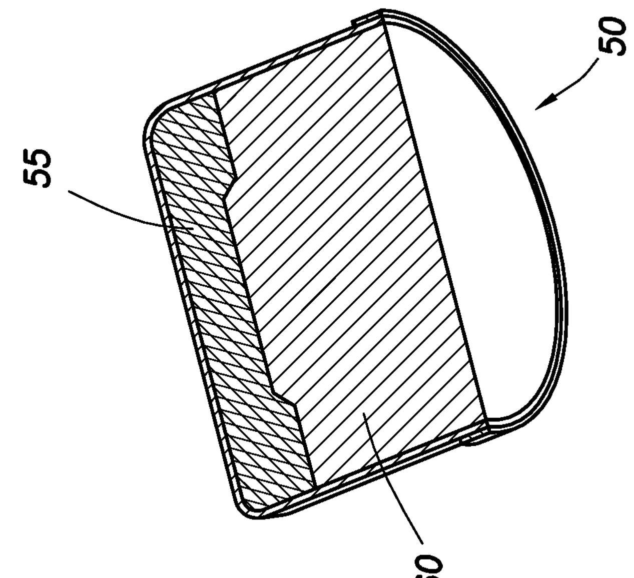

FIG.4
(PRIOR ART)

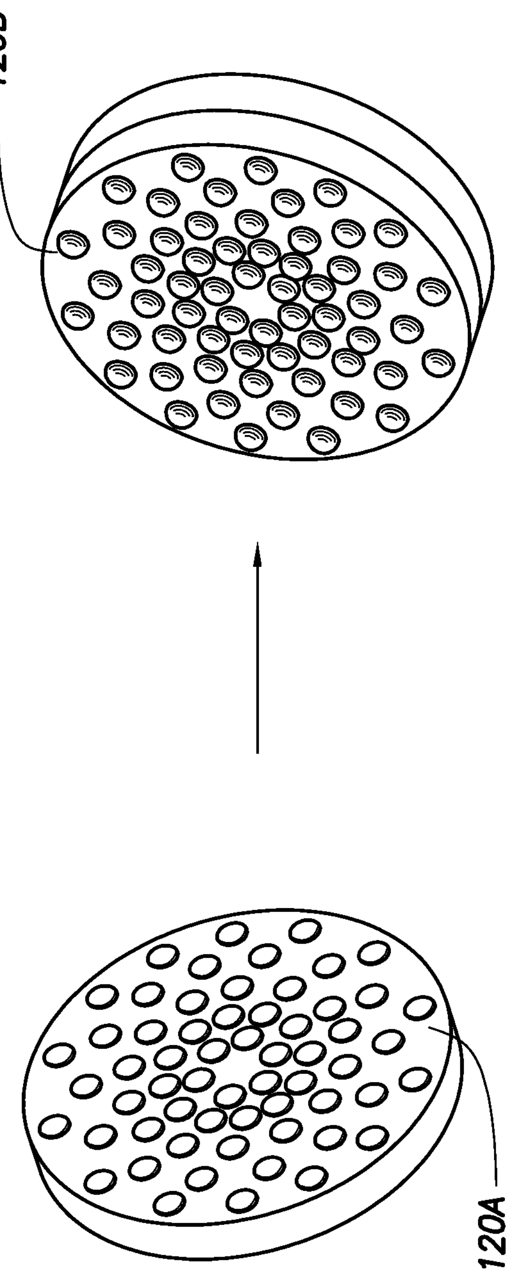

FIG.6B

FIG.6A

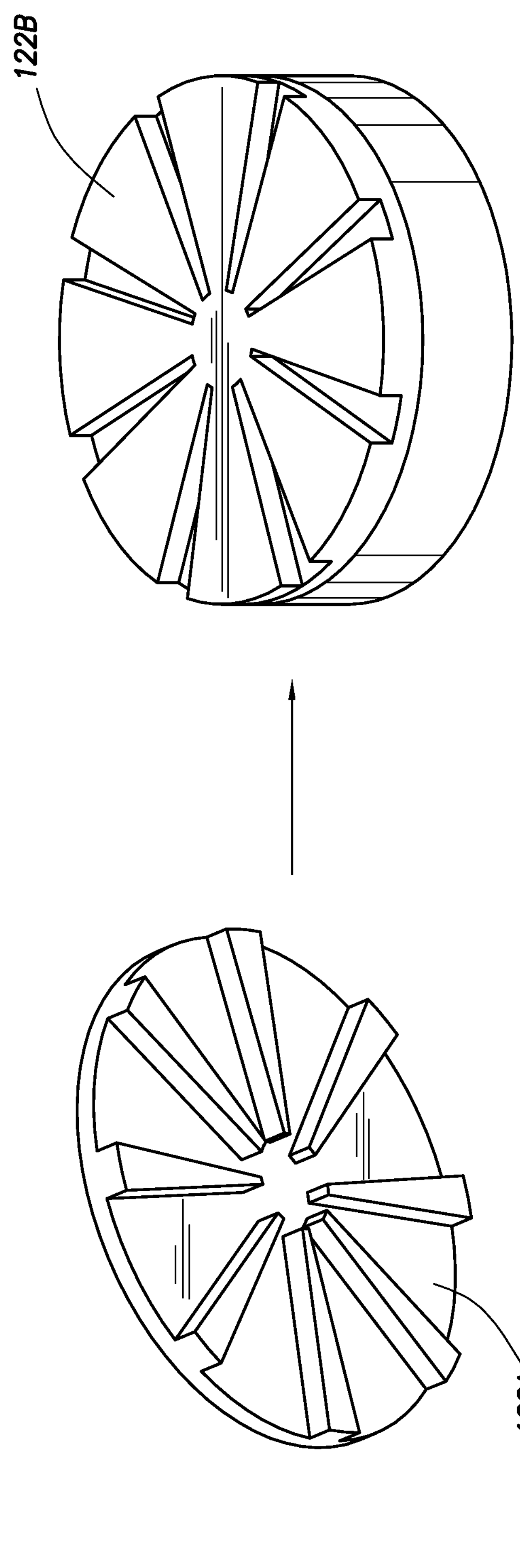

FIG.7B

FIG.7A

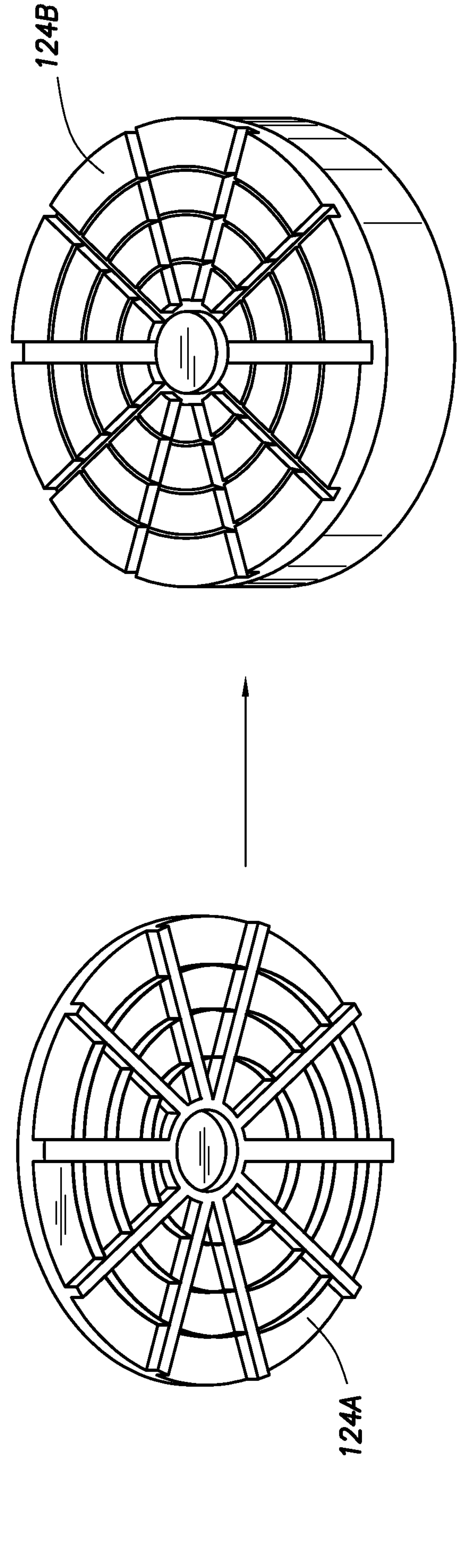

FIG.8A

FIG.8B

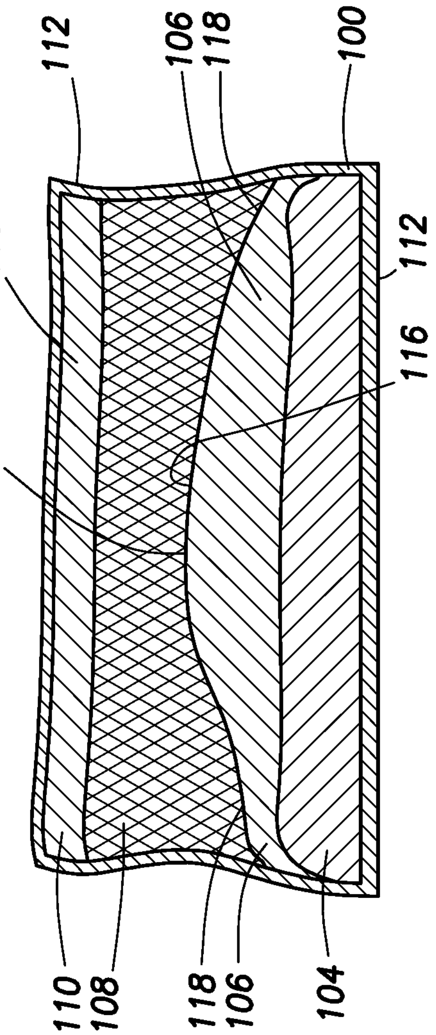

FIG.9