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(54) **Title:** DIAMOND ENHANCED INSERT WITH FINE AND ULTRAFINE MICROSTRUCTURE OF PCD WORKING SURFACE RESISTING CRACK FORMATION

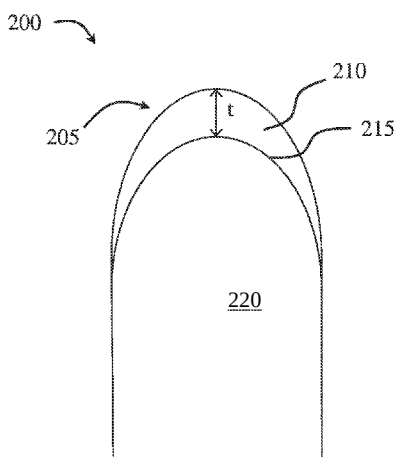


FIG. 2

(57) **Abstract:** An insert for a drill bit may include a metallic carbide body; an outer layer of polycrystalline diamond material on the uppermost end of the insert, wherein the polycrystalline diamond material comprises: a plurality of interconnected diamond grains; a plurality of additive grains; a binder material; wherein the average additive grain size is smaller than the average diamond grain size.



DIAMOND ENHANCED INSERT WITH FINE AND ULTRAFINE MICROSTRUCTURE OF PCD WORKING SURFACE RESISTING CRACK FORMATION

BACKGROUND

Field of the invention

[0001] Embodiments disclosed herein relate generally to diamond enhanced inserts.

Background Art

[0002] An earth-boring drill bit is typically mounted on the lower end of a drill string and is rotated by rotating the drill string at the surface or by actuation of downhole motors or turbines, or by both methods. When weight is applied to the drill string, the rotating drill bit engages the earth formation and proceeds to form a borehole along a predetermined path toward a target zone.

[0003] There are several types of drill bits, including roller cone bits, hammer bits, and drag bits. The term "drag bits" (also referred to as "fixed cutter drill bits") refers to those rotary drill bits with no moving elements. Fixed cutter bits include those having cutting elements attached to the bit body, which predominantly cut the formation by a shearing action. Cutting elements used on fixed cutter bits may include polycrystalline diamond compacts (FDCs), diamond grit impregnated inserts ("grit hot-pressed inserts" (GHIs), or natural diamond. Roller cone rock bits include a bit body adapted to be coupled to a rotatable drill string and include at least one "cone" that is rotatably mounted to a cantilevered shaft or journal as frequently referred to in the art. Each roller cone in turn supports a plurality of cutting elements that cut and/or crush the wall or floor of the borehole and thus advance the bit. The cutting elements, either inserts or milled teeth, contact with the formation during drilling to crush, gouge, and scrape rock at the bottom of a hole being drilled. Hammer bits are typically include a one piece body with having crown. The crown includes inserts pressed therein for being cyclically "hammered" and rotated against the earth formation being drilled.

[0004] Depending on the type and location of the cutting elements on a drill bit, the cutting elements perform different cutting functions, and as a result, also experience different loading conditions during use. Two kinds of wear-resistant inserts have been

developed for use as cutting elements on drill bits: tungsten carbide inserts (TCIs) and polycrystalline diamond enhanced inserts (DEIs). Tungsten carbide inserts are typically formed of cemented tungsten carbide (also known as sintered tungsten carbide): tungsten carbide particles dispersed in a cobalt binder matrix. A polycrystalline diamond enhanced insert typically includes a cemented tungsten carbide body as a substrate and a layer of polycrystalline diamond ("PCD") directly bonded to the tungsten carbide substrate on the top portion of the insert. An outer layer formed of a PCD material can provide improved wear resistance, as compared to the softer, tougher tungsten carbide inserts.

[0005] FIG. 1 illustrates a microstructure of conventionally formed PCD material 10 comprising a plurality of diamond grains 12 that are bonded to one another to form an intercrystalline diamond matrix first phase. A catalyst/binder material 14, e.g., cobalt, is used to facilitate the diamond-to-diamond bonding that develops during the sintering process into the diamond crystal bonded network. The catalyst/binder material used to facilitate diamond-to-diamond bonding can be provided generally in two ways. The catalyst/binder can be provided in the form of a raw material powder that is pre-mixed with the diamond grains or grit prior to sintering. Alternatively, the catalyst/binder can be provided by infiltration into the diamond material (during high temperature/high pressure processing) from an underlying substrate material that the final PCD material is to be bonded to. After the catalyst/binder material has facilitated the diamond-to-diamond bonding, the catalyst/binder material is generally distributed throughout the diamond matrix within interstitial regions formed between the bonded diamond grains. Particularly, as shown in FIG. 1, the binder material 14 is not continuous throughout the microstructure in the conventional PCD material 10. Rather, the microstructure of the conventional PCD material 10 may have a uniform distribution of binder among the PCD granules. Thus, crack propagation through conventional PCD material will often travel through the less ductile and brittle diamond grains, either transgranularly through diamond grain/binder interfaces 15, or intergranularly through the diamond grain/diamond grain interfaces 16.

[0006] The layer(s) of PCD conventionally include diamond and a metal in an amount of up to about 20 percent by weight of the layer to facilitate diamond intercrystalline bonding and bonding of the layers to each other and to the underlying substrate. Metals

employed in PCD are often selected from cobalt, iron, or nickel and/or mixtures or alloys thereof and can include metals such as manganese, tantalum, chromium and/or mixtures or alloys thereof. However, while higher metal content typically increases the toughness of the resulting PCD material, higher metal content also decreases the PCD material hardness, thus limiting the flexibility of being able to provide PCD coatings having desired levels of both hardness and toughness. Additionally, when variables are selected to increase the hardness of the PCD material, typically brittleness also increases, thereby reducing the toughness of the PCD material.

[0007] Although the polycrystalline diamond layer is extremely hard and wear resistant, a polycrystalline diamond enhanced insert may still fail during normal operation. Failure typically takes one of three common forms, namely wear, fatigue, and impact cracking. The wear mechanism occurs due to the relative sliding of the PCD relative to the earth formation, and its prominence as a failure mode is related to the abrasiveness of the formation, as well as other factors such as formation hardness or strength, and the amount of relative sliding involved during contact with the formation. Excessively high contact stresses and high temperatures, along with a very hostile downhole environment, also tend to cause severe wear to the diamond layer. The fatigue mechanism involves the progressive propagation of a surface crack, initiated on the PCD layer, into the material below the PCD layer until the crack length is sufficient for spalling or chipping. Lastly, the impact mechanism involves the sudden propagation of a surface crack or internal flaw initiated on the PCD layer, into the material below the PCD layer until the crack length is sufficient for spalling, chipping, or catastrophic failure of the enhanced insert.

[§008] It is, therefore, desirable that an insert structure be constructed that provides desired PCD properties of hardness and wear resistance with improved properties of fracture toughness and chipping resistance, as compared to conventional PCD materials and insert structures, for use in aggressive cutting and/or drilling applications.

SUMMARY OF INVENTION

[0009] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key

or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

[0010] In one aspect, embodiments disclosed herein relate to an insert for a drill bit that includes a metallic carbide body; an outer layer of polycrystalline diamond material on the uppermost end of the insert, wherein the polycrystalline diamond material comprises: a plurality of interconnected diamond grains; a plurality of additive grains; a binder material; wherein the average additive grain size is smaller than the average diamond grain size.

[0011] In another aspect, embodiments disclosed herein relate to a drill bit that includes a bit body; at least one insert disposed on the drill bit, wherein the insert includes: a metallic carbide body; an outer layer of polycrystalline diamond material on the uppermost end of the insert, wherein the polycrystalline diamond material includes: a plurality of interconnected diamond grains; a plurality of additive grains; a binder material; wherein the average additive grain size is smaller than the average diamond grain size.

[0012] Other aspects and advantages of the invention will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

[0013] Embodiments of the present disclosure are described with reference to the following figures.

[0014] FIG. 1 shows a schematic of a portion of conventional polycrystalline diamond material.

[0015] FIG. 2 shows a cross-sectional view of a diamond enhanced insert according to embodiments of the present disclosure.

[0016] FIGS. 3A-D show top and cross-sectional views of a conventional PCD outer layer of a diamond enhanced insert.

[0017] FIG. 4 shows a cross-sectional view of a diamond enhanced insert according to embodiments of the present disclosure.

[0018] FIG. 5 is a perspective side view of a roller cone drill bit having inserts made according to embodiments of the present disclosure.

[0019] FIG. 6 is a perspective side view of a percussion or hammer bit having inserts made according to embodiments of the present disclosure.

DETAILED DESCRIPTION

[0020] Embodiments disclosed herein relate generally to diamond enhanced inserts having a crack resistant working surface. In particular, inserts of the present disclosure may have a body and an outer layer of polycrystalline diamond ("PCD") material forming the working surface of the insert. For example, FIG. 2 shows an insert 200 according to embodiments of the present disclosure, wherein the insert 200 has an outer layer 210 of PCD material, a substrate body 220, and an interface 215 therebetween. The outer layer 210 of PCD material is disposed at the uppermost end 205 of the insert 200 and forms the working or cutting surface. The PCD material forming the outer layer of inserts according to the present disclosure has a distinct composition (described below) from conventional PCD, which may provide the working surface of an insert with improved crack resistance. The substrate body of inserts according to the present disclosure may be made of a metallic carbide material, such as a cemented or sintered carbide of one of the Group IVB, VB, and VLB metals, *e.g.*, tungsten carbide, tantalum carbide, or titanium carbide, which are generally pressed or sintered in the presence of a binder, such as cobalt, nickel, or iron or the alloys thereof. In the substrate body, the metal carbide grains are supported within the metallic binder. It is well known that various metal carbide compositions and binders may be used, in addition to tungsten carbide and cobalt. Thus, references to the use of tungsten carbide and cobalt are for illustrative **purposes** only, and no limitation on the type of substrate or binder used is intended.

[0021] The inventors of the present disclosure have found a distinct composition for PCD material used for the outer layer of an insert that may provide improved crack resistance when compared with conventional PCD material for use as the outer layer of an insert. Referring now to FIGS. 3A-D, various views of a conventional PCD outer layer of an insert are shown. The insert shown in FIGS. 3A-D may use, for example, a mixture of 80wt% diamond (6 microns in average particle size) with 20wt% cobalt or a mixture of 85wt% diamond (10 microns in average particle size) with 15wt% cobalt. In particular,

FIG. 3A shows a top view of a conventional PCD outer layer having a reptile skin wear pattern 305 on the surface, formed from drilling, and FIG. 3B shows a closer view of the wear pattern 305. As shown, a reptile skin wear pattern is a type of wear pattern design that may form in the outer layer of a conventional PCD insert that includes multiple "valleys" formed at the surface of the FCD outer layer. The valleys formed in the reptile skin wear pattern often provide sites for crack initiation. For example, FIG. 3C shows a cross-sectional view of the conventional PCD outer layer having a reptile skin wear pattern and crack formation 315 within the valleys of the reptile skin wear pattern. FIG. 3D shows a magnified cross-sectional view of a crack 315 formed at the bottom of a valley in a reptile skin wear pattern of a conventional PCD outer layer. The reptile skin wear pattern often forms in conventional PCD outer layers having a PCD material composition of relatively coarse diamond grains, *e.g.*, having an average grain size equal to or larger than 6 microns. Further, as shown in FIG. 3C, cracks 315 may initiate in the valleys of the reptile skin wear pattern, which may eventually cause premature failure of the insert. In particular, once cracks initiate in the valleys of the reptile skin wear pattern, the cracks may propagate through the outer layer and into the insert body, thus resulting in premature failure of the insert. However, the PCD material used to form outer layers of the present disclosure have a distinct composition that may inhibit such reptile skin wear patterns and crack formation.

[0022] According to embodiments disclosed herein, a PCD material used to form an insert outer layer may have an average diamond grain size of less than or equal to 4 microns, which may be referred to as a "fine diamond microstructure," or PCD material having a "fine diamond grain size." According to some preferred embodiments, PCD material used to form an insert outer layer may have an average diamond grain size of less than 2 microns and larger than 100 ~~nm~~. Other embodiments may use a lower limit of any of 0.1, 0.25, 0.5, 0.75, 1.0, or 1.25 microns, and an upper limit of any of 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, or 2.0 microns, where any lower limit may be used with any upper limit. Advantageously, the inventors of the present disclosure have found that by using a PCD material having a fine diamond grain size, the outer layer may have improved wear resistance and reduced formation of reptile wear patterns and crack formation. Particularly, unlike the coarse diamond grains of conventional insert PCD material, which fractures and eventually leads to reptile skin wear formation of the surface and premature

failure of the insert, the fine diamond microstructure of the presently disclosed outer layer PCD material has a higher strength that may lead to a more favorable wear pattern, thus delaying or preventing crack formation and penetration into the insert body.

[0023] In addition to the PCD material of the present disclosure having a fine diamond grain size, the PCD material may also include a non-diamond additive material. The microstructure of such PCD material thus includes bonded together grains of diamond, additive material, and binder/catalyst material. Additive material may include carbides, carbonitrides, nitrides, and combinations thereof of metals such as those of Groups IVB, VB, or VIB. For example, additive material may include WC, TiC, and/or TiCN. According to embodiments of the present disclosure, additive material may comprise over 2% by weight of the PCD material of an insert outer layer. In some preferred embodiments, the additive material may comprise over 5% by weight of the PCD material of an insert outer layer. Further, the additive material may have an average additive grain size smaller than the average diamond grain size. For example, an average additive grain size of an outer layer PCD microstructure may be less than that of the diamond grains, less than 2 microns in another embodiment, and less than 1 micron in yet another embodiment. Other embodiments may use a lower limit of any of 0.1, 0.25, 0.5, 0.75, 1.0, or 1.25 microns, and an upper limit of any of 0.5, 0.75, 1.0, 1.25, 1.5, 1.75, or 2.0 microns, where any lower limit may be used with any upper limit. The inventors of the present disclosure have found that by forming a PCD outer layer using the additive material described herein with an average grain size less than the average diamond grain size, the additive material may act as a diamond abnormal grain growth inhibitor. Thus, the additive material of the present disclosure may facilitate forming a PCD outer layer having a fine and uniform diamond microstructure. Further, additive material of the present disclosure may also increase the toughness of the PCD outer layer.

[0024] According to embodiments of the present disclosure, PCD material forming an outer layer of an insert may have a diamond content of less than 90% by weight. In some embodiments, the PCD material forming an outer layer of an insert may have a diamond content of less than 85 or 80% by weight. The remainder of the PCD microstructure may include additive material and a binder/catalyst material. For example, a PCD outer layer according to embodiments of the present disclosure may have a diamond content of less than 85% by weight, an additive content of greater than 2% by weight, and the remainder

of the diamond sintering catalyst material. In other embodiments, the diamond content may range from 40 weight percent to 85 weight percent, where the lower limit may be any of 40 weight percent, 50 weight percent, 60 weight percent, 70 weight percent, or 75 weight percent and the upper limit may be any of 50 weight percent, 60 weight percent, 70 weight percent, 80 weight percent, 85 weight percent, or 90 weight percent, where any lower limit may be used with any upper limit. The additive may be present in an amount that is at least 0.5 weight percent, 2 weight percent or at least 5 weight percent, where the balance of the layer may be the diamond sintering catalyst material.

[0025] Diamond binder or catalyst material may include, for example, Co, Ni, Fe, or combinations thereof. PCD material of the present disclosure may include a binder or catalyst material content ranging from about 15 weight percent to about 30 weight percent of the diamond material, or from 18 weight percent to 25 weight percent of the diamond material. For example, according to some embodiments, the PCD material forming the outer layer of an insert may include a cobalt binder content ranging from about 15 weight percent to about 30 weight percent, or ranging from 18 weight percent to 25 weight percent.

[0026] The binder material may act as a catalyst for the formation of bonds between the diamond crystals resulting in the formation of a layer of randomly oriented diamond crystals (and additive grains) organized in a lattice structure with the metallic binder located in the interstitial spaces between the diamond and additive material grains. Thus, when the binder material acts to catalyze diamond-to-diamond bonding, the binder material may often be referred to as a catalyst material.

[0027] A catalyst material may be provided by mixing a desired amount of catalyst material powder with the diamond and additive material. For example, diamond crystals and cobalt may be ball milled together and then ball milled with an additive material, such as a carbide. The mixture may then be subjected to high pressure high temperature (HPHT) processing known in the art, for example, pressures of greater than 5,000 MPa and temperatures ranging from 1,300°C to 1,500°C. Examples of HPHT processes can be found, for example, in U.S. Patent Nos. 4,694,918; 5,370,195; and 4,525,178. Briefly to form the outer layer, an unsintered mass of diamond crystalline particles, a metal catalyst, and additive particles is placed within a metal enclosure of the reaction cell of a HPHT

apparatus. The reaction cell is then placed under processing conditions sufficient to cause intercrystalline bonding between the diamond particles. Further, application of HPHT processing may cause the diamond crystals and the additive particles to sinter such that they are no longer in the form of discrete particles than can be separated from each other.

[0028] Alternatively, a catalyst may be provided by infiltration during HPHT processing from the adjacent insert body (or adjacent transition layer in embodiments having at least one transition layer between the outer layer and the insert body, as described below). In such embodiments, the insert body may be formed from metallic and cermet materials having a metal solvent catalyst, such as one selected from Group VI elements of the Periodic table, that is capable of infiltrating into an adjacent diamond and additive powder mixture during HPHT processing to facilitate and provide a bonded attachment therewith. For example, an insert body may be formed of cemented tungsten carbide and cobalt, wherein cobalt may infiltrate into an adjacent mixture of diamond and additive powder to act as a catalyst material to form the outer layer PCD material of the present disclosure.

[0029] While the geometry of the inserts described herein have been shown as having a curved interfaces between the outer layer and the insert body (or transition layers), it is to be understood that the inserts of the present disclosure may be configured to have interface geometries that are flat or that have another shaped non-planar configuration, depending on the particular end-use application. Various interface geometries may be used to help reduce residual stresses formed between the outer layer and the body. Further, at least one transition layer may be used between the outer layer and the body of an insert, for example, to help alleviate residual stresses created by trying to bond the different materials of the outer layer and the body together.

[0030] For example, referring to FIG. 4, a cross-sectional view of an insert having at least one transition layer according to embodiments of the present disclosure is shown. As shown, the insert 400 has a substrate body 420, an outer layer 410 of PCD material on the uppermost end 405 of the insert 400, and at least one transition layer 430 between the body 420 and the outer layer 410. Although the insert shown in FIG. 4 has one transition layer 430 between the outer layer 410 and the substrate body 420, other embodiments may have more than one transition layer. For example, an insert of the present disclosure

may have two, three, or more transition layers between the outer layer and body of the insert. Further, the outer layer/transition layer interface 415 and the transition layer/body interface 435 are shown as having a curved shape, concentric with the outer surface 411 of the outer layer 410. However, as described above, interface geometry may vary to help reduce stresses formed between the layers.

[0031] The PCD material forming the outer layer 410 may have a fine diamond microstructure made of a plurality of interconnected diamond grains, a plurality of additive grains, and a binder material, wherein the average additive grain size is equal to or smaller than the average diamond grain size. The composition of the at least one transition layer may vary, such as described in U.S. Patent Publication 2006/0180354, which is incorporated herein. In one embodiment, the composition of a transition layer adjacent to the outer layer may have similar composition of the outer layer, but vary in terms of grain size. In other embodiments, the adjacent transition layer and/or other transition layers may also have different composition (as compared to the outer layer), having equal or larger size diamond grains; binder phase and WC or other refractory carbides.

[0032] According to embodiments of the present disclosure, the at least one transition layer may include composites of diamond crystals, additive grains, and binder material that are similar to the composition of the outer layer, but vary in terms of grain size or in the relative proportions of the composite materials, such as the amount of diamond, additive and binder material. For example, a transition layer may include a plurality of bonded together diamond grains, a plurality of additive grains, and binder material, wherein the average additive grain size is less than the average diamond grain size, and wherein the average diamond grain size of the transition layer is equal to or larger than the average diamond grain size of the outer layer. In some embodiments having more than one transition layer, the transition layers may create an average diamond grain size gradient, wherein the average diamond grain size is finest in the outer layer and coarsest in the transition layer closest to the insert body.

[0033] In other embodiments having more than one transition layer, the transition layers may create a diamond content gradient, wherein the proportion of diamond content decreases between the transition layers, moving inwardly toward the insert body.

Alternatively, an insert may have a single transition layer, wherein the single transition layer includes a gradient of diamond content with the region of the single transition layer near the outer layer having a diamond content greater than the region of the single transition layer near the insert body. The gradient within the single transition layer may be generated by methods known in the art, such as, for example, described in U.S. Patent No. 4,694,918.

[0034] Furthermore, embodiments of the present disclosure may have an outer layer of PCD material having a thickness greater than that of conventional diamond enhanced inserts. For example, referring again to FIG. 4, an insert 400 has an outer layer 410, a body 420, and at least one transition layer 430 between the outer layer and the body. The outer layer 410 is made of a PCD material according to the present disclosure, including plurality of bonded together diamond grains, a plurality of additive grains, and binder material and may have a thickness t ranging between 250 and 1500 microns. In some preferred embodiments, a diamond enhanced insert may have an outer layer with a thickness t ranging between 400 and 800 microns. In other embodiments, the outer layer thickness may have a lower limit of any of 250, 300, 400, 500, 600, or 800 microns, and an upper limit of any of 600 microns, 800 microns, 1000 microns, 1200 microns, or 1500 microns, where any lower limit may be used with any upper limit. Further, in various embodiments, the transition layer thickness may be equal to or less than the outer layer thickness.

[0035] Inserts of the present disclosure may be used with downhole drill bits, such as roller cone drill bits or percussion or hammer drill bits. For example, referring to FIG. 5, inserts 500 of the present disclosure may be mounted to a roller cone drill bit 550. The roller cone drill bit 550 has a body 560 with three legs 561, and a roller cone 562 mounted on a lower end of each leg 561. Inserts 500 according to the present disclosure may be provided in the surfaces of at least one roller cone 562. Referring now to FIG. 6, inserts 600 of the present disclosure may be mounted to a percussion or hammer bit 650. The hammer bit 650 has a hollow steel body 660 with a pin 662 on an end of the body for assembling the bit onto a drill string (not shown) and a head end 664 of the body. A plurality of inserts 600 may be provided in the surface of the head end for bearing on and cutting the formation to be drilled.

[0036] Advantageously, embodiments of the present disclosure provide a diamond enhanced insert that has improved resistance to crack formation at the working surface. For example, the fine microstructure of the diamond material used to form the outer layer of an insert according to the present disclosure may provide the outer layer with a higher strength and a more favorable wear pattern, which may delay or prevent the formation of cracks in the outer surface. Further, while diamond material used to form other types of cutting elements, such as the cutting layer of shear cutters or conventional diamond enhanced inserts, may have a high diamond content, the PCD material of the present disclosure used to form an outer layer of a diamond enhanced insert may include a comparatively lower diamond content. In particular, comparatively higher diamond content has conventionally been used in prior art cutting elements, such as the cutting layer of a shear cutter, to meet the high temperature material property requirements encountered in the drilling conditions. However, the inventors of the present disclosure have found that the outer layer of a diamond enhanced insert may be formed of a PCD material having a comparatively lower diamond content, such as less than 85% by weight, that includes a plurality of bonded together diamond grains, an additive material having an average grain size less than the average grain size of the diamond grains, and a binder material. The composition of the PCD material of the present disclosure provides improved material properties for a diamond enhanced insert outer layer that may prevent or delay crack initiation unique to conventional diamond enhanced insert outer layers.

[0037] While the invention has been described with respect to a limited number of embodiments, those skilled in the art, having benefit of this disclosure, will appreciate that other embodiments can be devised which do not depart from the scope of the invention as disclosed herein. Accordingly, the scope of the invention should be limited only by the attached claims,

CLAIMS

What is claimed is:

1. An insert for a drill bit comprising;
a metallic carbide body;
an outer layer of polycrystalline diamond material on the uppermost end of the insert,
wherein the polycrystalline diamond material comprises:
a plurality of interconnected diamond grains;
a plurality of additive grains;
a binder material;
wherein the average additive grain size is smaller than the average diamond grain size.
2. The insert of claim 1, wherein the average diamond grain size is less than or equal to 4 microns,
3. The insert of claim 1, wherein the average diamond grain size is less than or equal to 2 microns,
4. The insert of any of the preceding claims, wherein the average diamond grain size is at least 0.1 microns,
5. The insert of any of the preceding claims, wherein the average additive grains size is less than 1 micron.
6. The insert of any of the preceding claims, wherein the additive grains are selected from at least one of carbides, carbonitrides, and nitrides,
7. The insert of any of the preceding claims, wherein the additive grains comprise greater than 0.5 percent by weight of the polycrystalline diamond material,
8. The insert of any of the preceding claims, wherein the additive grains comprise greater than 2 percent by weight of the polycrystalline diamond material.

9. The insert of any of the preceding claims, wherein the diamond grains comprise less than 85% by weight of the polycrystalline diamond material.
10. The insert of any of the preceding claims, wherein the outer layer has a thickness greater than 250 microns.
11. The insert of any of the preceding claims, further comprising at least one transition layer between the metallic carbide body and the outer layer.
12. The insert of claim 11, wherein the at least one transition layer comprises diamond grains having an average grain size larger than the average diamond grain size of the outer layer.
13. The insert of any of the preceding claims, wherein the binder material comprises from 15 percent by weight to 30 percent by weight of the outer layer.
14. The insert of any of the preceding claims, wherein the binder material comprises cobalt.
15. A drill bit comprising;
a bit body;
at least one insert disposed on the **drill** bit, wherein the insert comprises:
 - a metallic carbide body;
 - an outer layer of polycrystalline diamond material on the uppermost end of the insert, wherein the polycrystalline diamond material comprises:
 - a plurality of interconnected diamond grains;
 - a plurality of additive grains;
 - a binder material;
 - wherein the average additive grain size is smaller than the average diamond grain size.
16. The drill bit of claim 15, wherein the average diamond grain size is less than or equal to 4 microns.
17. The drill bit of claim 15, wherein the average diamond grain size is less than or equal to 2 microns.

18. The drill bit of claim 15, wherein the average additive grains size is less than 1 micron.
19. The drill bit of any of claims 15 to 18, wherein the additive grains are selected from at least one of carbides, carbonitrides, and nitrides.
20. The drill bit of any of claims 15 to 19, wherein the additive grains comprise greater than 0.5 percent by weight of the polycrystalline diamond material.
21. The drill bit of any of claims 15 to 20, wherein the diamond grains comprise less than 85% by weight of the polycrystalline diamond material.
22. The drill bit of any of claims 15 to 21, wherein the outer layer has a thickness greater than 250 microns.
23. The drill bit of any of claims 15 to 22, further comprising at least one transition layer between the metallic carbide body and the outer layer.
24. The drill bit of claim 23, wherein the at least one transition layer comprises diamond grains having an average grain size larger than the average diamond grain size of the outer layer.
25. The drill bit of any of claims 15 to 24, wherein the bit body has a plurality of cones mounted thereon, and wherein the at least one insert is inserted into a hole in the one of the plurality of cones.
26. The insert of any of claims 15 to 25, wherein the binder material comprises from 15 percent by weight to 30 percent by weight of the outer layer.
27. The insert of any of claims 15 to 26, wherein the binder material comprises cobalt.

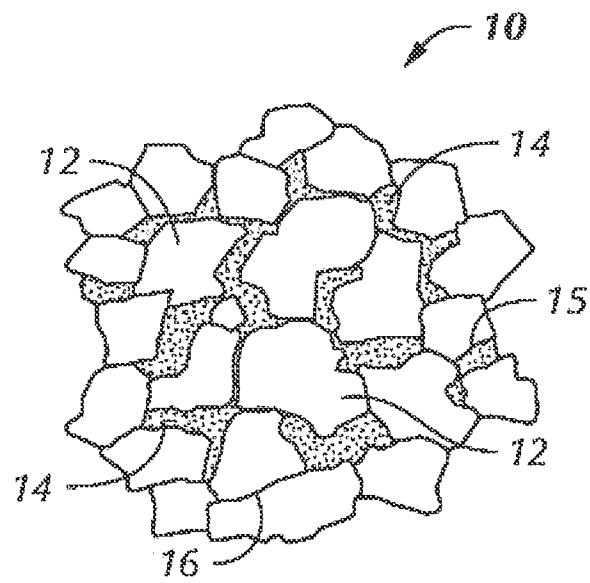


FIG. 1
(Prior Art)

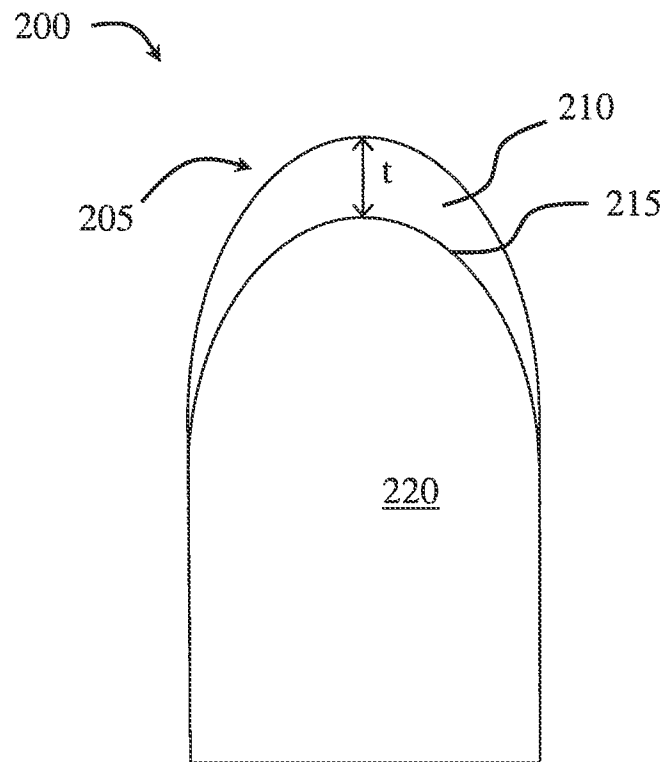


FIG. 2

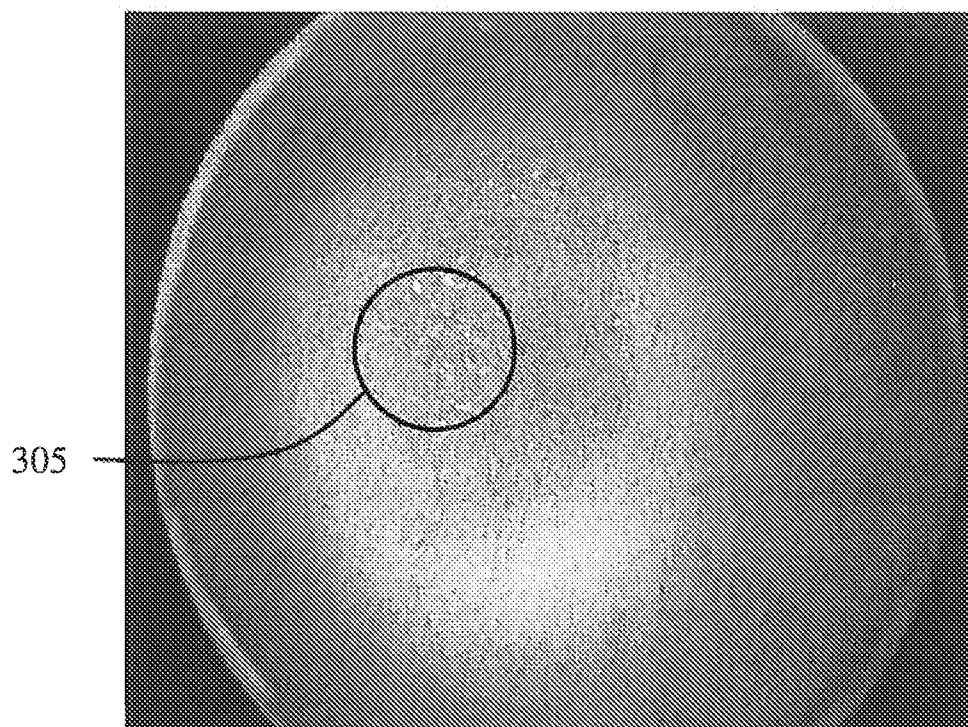


FIG. 3A

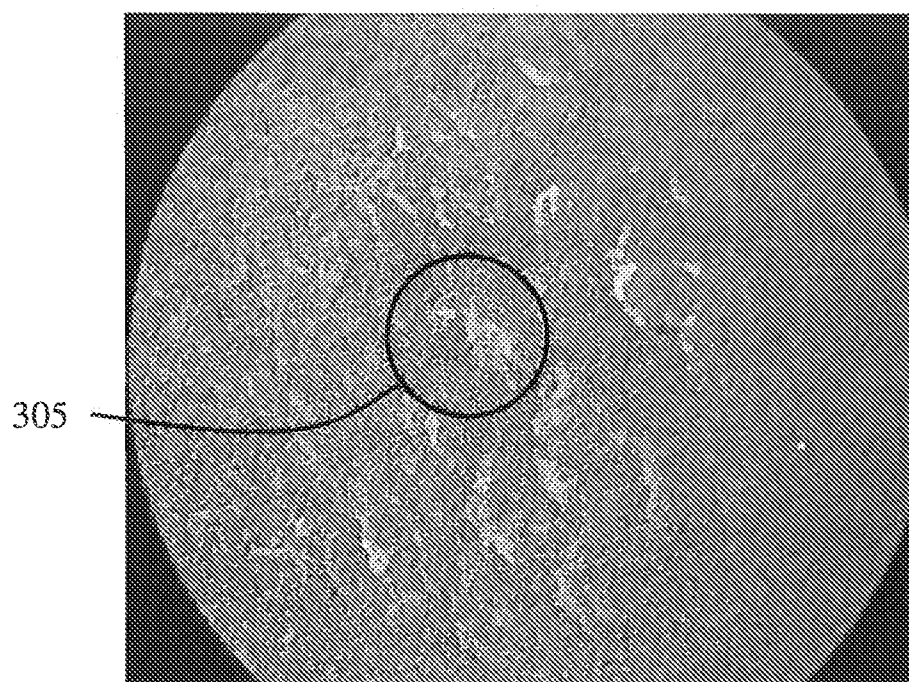


FIG. 3B

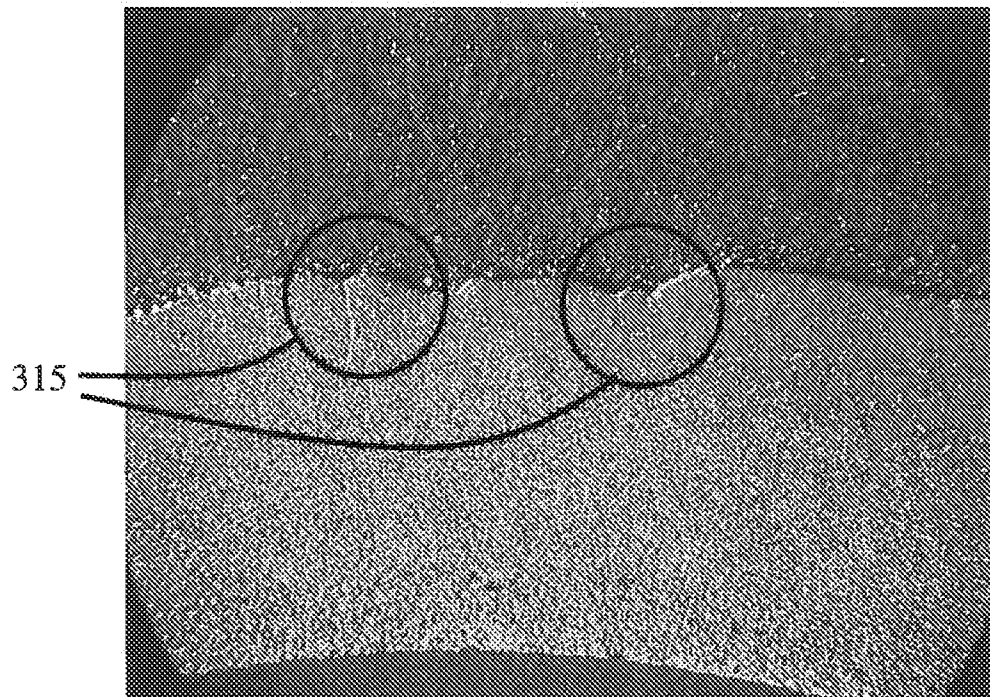


FIG. 3C

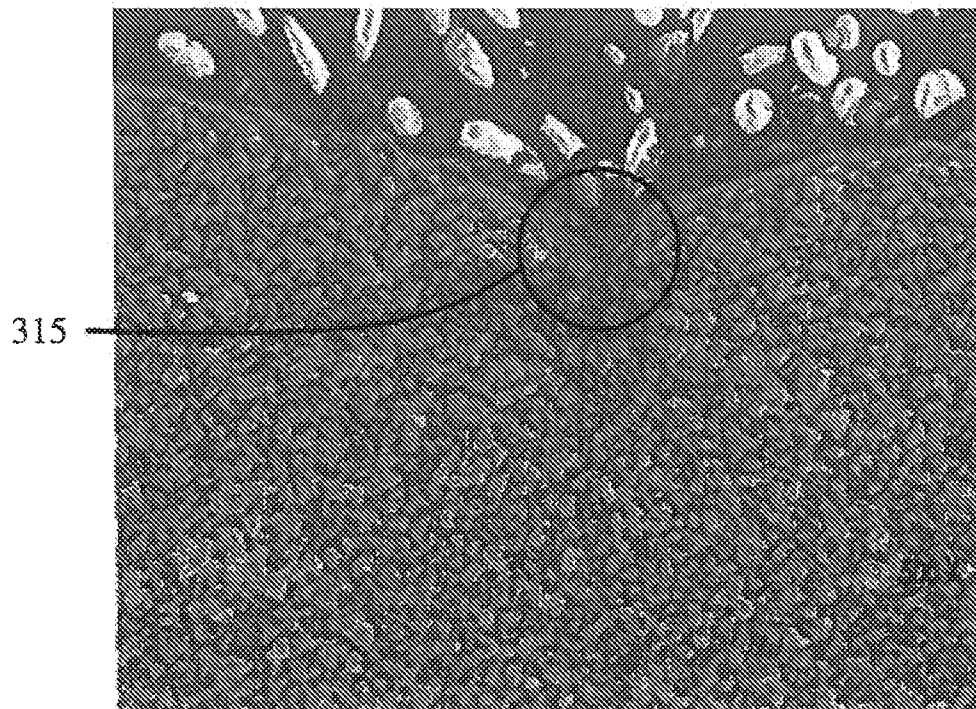


FIG. 3D

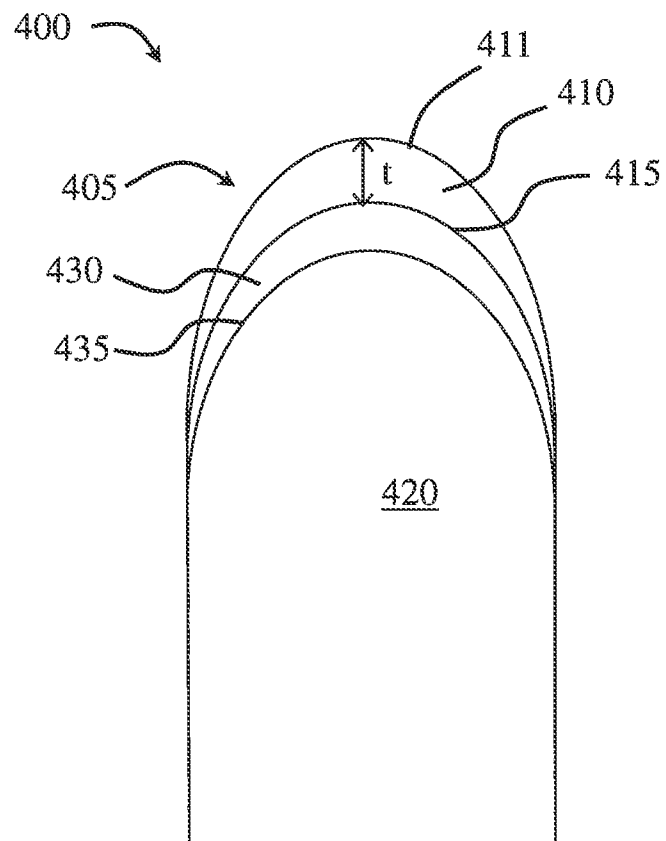
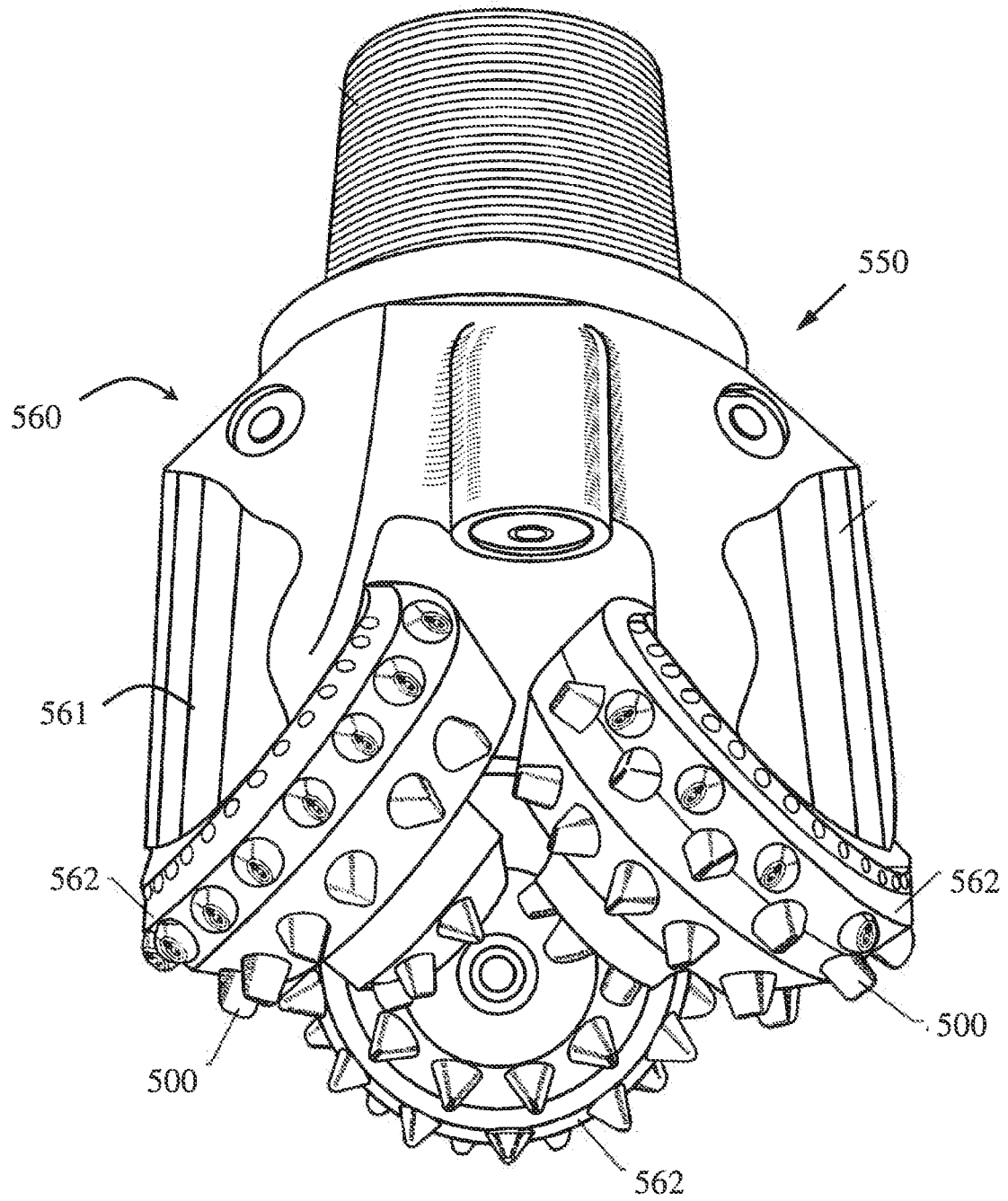


FIG. 4

**FIG. 5**

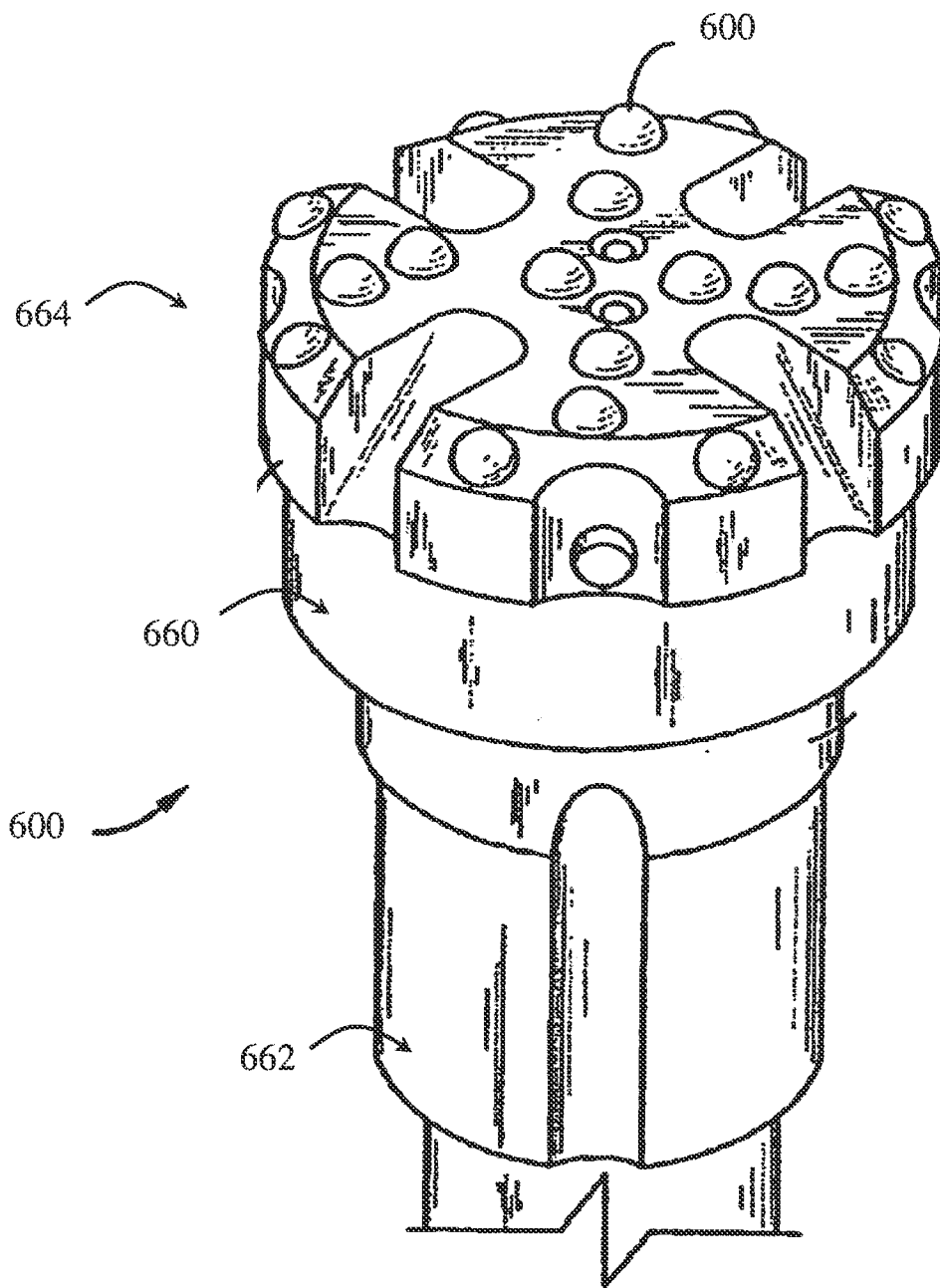


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/071107**A. CLASSIFICATION OF SUBJECT MATTER****E21B 10/46(2006.01)i, B24D 3/10(2006.01)1**

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 10/46; B22F 7/06; B32B 31/26; E21B 10/16; E21B 10/56; E21B 10/55; B22F 1/00

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: metal carbide, body, substrate, diamond, grain, particle, material, and size

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011-0031033 A1 (MOURIK et al.) 10 February 2011 See abstract; paragraphs [0026], [0073]; claims 1,2,13-22; and figures 2,3.	1-4,15-19
A	QS 5766394 A (ANDERSON et al.) 16 June 1998 See abstract; column 3, lines 44-53; and figure 3.	1-4,15-19
A	QS 2001-0008190 A1 (SCOTT et al.) 19 July 2001 See abstract; paragraphs [0019], [0020]; and figure 2.	1-4,15-19
A	QS 2006-0162969 A1 (BELNAP et al.) 27 July 2006 See abstract; paragraphs [0023], [0025]; and figure 3.	1-4,15-19
A	EP 0235455 A2 (SMITH INTERNATIONAL, INC.) 09 September 1987 See abstract; column 4, line 42 - column 5, line 13; and figure 3.	1-4,15-19



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

15 April 2013 (15.04.2013)

Date of mailing of the international search report

16 April 2013 (16.04.2013)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
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City, 302-701, Republic of Korea

Facsimile No. 82-42-472-7140

Authorized officer

LEE, Jong Kyung

Telephone No. 82-42-481-3360



INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2012/071107

Box No. II **Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☒ Claims Nos.: 12 **and** 24
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

Claims 12 and 24 are unclear under PCT Article 6 since they refer to multiple dependent claims which are not searchable due to not being drafted in accordance with the third sentence of Rule 6.4(a)
3. ☒ Claims Nos.: **5-11, 13-14, 20-23, and 25-27**
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☒ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☒ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☒ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/071 107

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2012/071107

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