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(54) Title: ERUPTION CONTROL IN THERMALLY STABLE PCD PRODUCTS BY THE ADDITION OF TRANSITION METAL CARBIDE

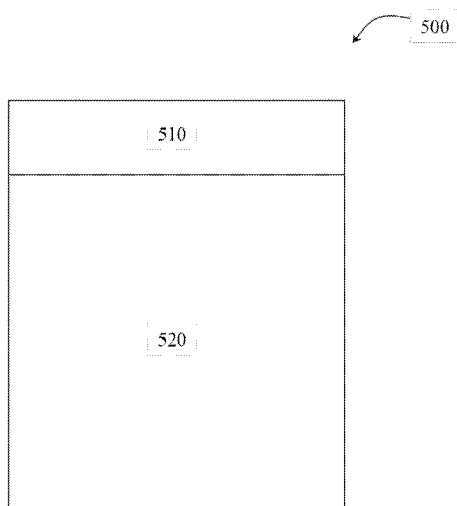


FIG. 5

(57) **Abstract:** A method of forming a diamond compact includes adding an additive material to a tungsten carbide substrate, the additive material including a transition metal carbide other than tungsten carbide, placing a diamond body adjacent to an interface surface of the tungsten carbide substrate, and subjecting the diamond body and the tungsten carbide substrate to a high pressure high temperature bonding process to bond the diamond body to the tungsten carbide substrate.



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ERUPTION CONTROL IN THERMALLY STABLE PCD PRODUCTS BY THE ADDITION OF TRANSITION METAL CARBIDE

BACKGROUND

[0001] Polycrystalline diamond (“PCD”) materials and PCD elements formed therefrom are well known in the art. Conventional PCD may be formed by subjecting diamond particles in the presence of a suitable solvent metal catalyst material to processing conditions of high pressure/high temperature (HPHT), where the solvent metal catalyst promotes desired intercrystalline diamond-to-diamond bonding between the particles, thereby forming a PCD structure. The resulting PCD structure produces enhanced properties of wear resistance and hardness, making such PCD materials useful in aggressive wear and cutting applications where high levels of wear resistance and hardness are desired. FIG. 1 illustrates a microstructure of conventionally formed PCD material 10 including a plurality of diamond grains 12 that are bonded to one another to form an intercrystalline diamond matrix first phase. The catalyst/binder material 14, e.g., cobalt, used to facilitate the diamond-to-diamond bonding that develops during the sintering process is dispersed within the interstitial regions formed between the diamond matrix first phase. The term “particle” refers to the powder employed prior to sintering a superabrasive material, while the term “grain” refers to discernable superabrasive regions subsequent to sintering, as known and as determined in the art.

[0002] 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. In some cases, 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 grains. 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.

[0003] Solvent catalyst materials may facilitate diamond intercrystalline bonding and bonding of PCD layers to each other and to an underlying substrate. Solvent catalyst materials used for forming conventional PCD may include metals from Group VIII of the Periodic table, such as cobalt, iron, or nickel and/or mixtures or alloys thereof, with cobalt being the most common. Conventional PCD may include from 85 to 95% by volume diamond and a remaining amount of the solvent catalyst material. However, while higher metal content may increase 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 layers having desired levels of both hardness and toughness.

[0004] Conventional PCD is stable at temperatures of up to 700-750°C, after which observed increases in temperature may result in permanent damage to and structural failure of PCD. For example, upon heating of PCD, the difference in the coefficient of thermal expansion of the binder material, which may be cobalt, as compared to diamond results in the cobalt and the diamond lattice expanding at different rates, which may cause cracks to form in the diamond lattice structure and result in deterioration of the PCD. High operating temperatures may also lead to back conversion of the diamond to graphite causing loss of microstructural integrity, strength loss, and rapid abrasive wear.

[0005] In order to overcome this problem, strong acids may be used to “leach” the cobalt from the diamond lattice structure (either a thin volume or the entire body) to at least reduce the damage experienced from different expansion rates within a diamond-cobalt composite during heating and cooling. Briefly, a strong acid, such as nitric acid or combinations of several strong acids (such as nitric and hydrofluoric acid)

may be used to treat a PCD body, e.g., by submersing the body in the acid, thereby removing at least a portion of the catalyst from the PDC composite. In certain embodiments, a select portion of a diamond composite is treated, in order to gain thermal stability with less effect on impact resistance.

SUMMARY

[0006] 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.

[0007] In one aspect, embodiments disclosed herein relate to a method of forming a diamond compact, where the method includes adding an additive material to a tungsten carbide substrate, where the additive material includes a transition metal carbide other than tungsten carbide, placing a diamond body adjacent to an interface surface of the tungsten carbide substrate, and subjecting the diamond body and the tungsten carbide substrate to a high pressure high temperature bonding process to bond the diamond body to the tungsten carbide substrate.

[0008] In another aspect, embodiments disclosed herein relate to a cutting element having a substrate, where the substrate includes tungsten carbide grains bonded together with a cobalt binder, and a polycrystalline diamond table bonded to the substrate at an interface, where the polycrystalline diamond table has a cutting face and a microstructure including a plurality of bonded together diamond grains and a plurality of interstitial regions disposed among the bonded together diamond grains, where at least a portion of the interstitial regions include the cobalt binder and a transition metal carbide, and where the polycrystalline diamond table is substantially free of eruptions.

[0009] Other aspects and advantages of the claimed subject matter will be apparent from the following description and the appended claims.

BRIEF DESCRIPTION OF DRAWINGS

- [0010] Embodiments of the present disclosure are described with reference to the following figures. The same numbers are used throughout the figures to reference like features and components.
- [0011] FIG. 1 shows the microstructure of conventionally formed polycrystalline diamond.
- [0012] FIG. 2 is a picture of a conventionally formed reinfiltrated diamond table.
- [0013] FIG. 3 is a picture of a reinfiltrated diamond table formed according to embodiments of the present disclosure.
- [0014] FIG. 4 is a cross-sectional view of a conventionally formed diamond compact.
- [0015] FIG. 5 is a cross-sectional view of a reattached compact formed using methods of the present disclosure.
- [0016] FIG. 6 is a cross-sectional view of a cutting element formed according to methods of the present disclosure.

DETAILED DESCRIPTION

- [0017] Polycrystalline ultra-hard materials, and compacts formed therefrom, are specifically engineered having a polycrystalline ultra-hard material body having a material microstructure that is substantially free of substrate material eruptions, e.g., catalyst or infiltrant material eruptions, and thereby free of localized concentrations, regions or volumes of the catalyst or infiltrant material therein, and substantially free of any other substrate constituent material. As used herein, “eruptions” refer to precipitated regions of carbide grains and binder pools (catalyst or infiltrant material) formed from the substrate material that create voids or inclusions that are substantially larger than the interstitial regions formed in a polycrystalline diamond body. As used herein, the eruptions may be at least an order of magnitude larger than conventional interstitial regions. Eruptions may occur during HPHT bonding methods of attaching a diamond body to a substrate without pressure control, where the eruptions precipitate from the substrate into the diamond body.

[0018] Preformed diamond bodies may be formed of polycrystalline diamond (“PCD”), for example, or other diamond-bonded material with or without a second phase (such as a catalyst or binder second phase). As used herein, the term “PCD” refers to polycrystalline diamond that has been formed, at high pressure/high temperature (HPHT) conditions, through the use of a catalyst, such as solvent metal catalysts from Group VIII of the Periodic table, non-metallic catalysts including carbonates, as well as non-catalyst formed polycrystalline diamond formed with even higher temperatures and pressure than those used to form polycrystalline diamond with cobalt.

[0019] According to embodiments of the present disclosure, PCD may be formed by HPHT sintering of diamond grains in the presence of a suitable catalyst or binder material, such as cobalt and/or other transition metal from Group VIII of the Periodic Table, to achieve intercrystalline bonding between the diamond grains. Upon sintering the PCD body, the catalyst binder may remain within the interstitial regions formed between the bonded together diamond grains. The network of interstitial regions formed between the bonded together diamond grains may include interstitial regions that are directly or indirectly accessible to other interstitial regions formed within the PCD body, as well as interstitial regions that are inaccessible, which may be dispersed throughout PCD microstructure.

[0020] As used herein, the term “sintering” refers to the process of forming PCD using a HPHT process, examples of which may be found in U.S. Patent Nos. 4,694,918, 5,370,195, and 4,525,178. Briefly, to form a sintered PCD body, an unsintered mass or volume of diamond grains may be placed within an enclosure of a reaction cell of a HPHT apparatus. Examples of suitable HPHT apparatuses are described in U.S. Patent Nos. 2,947,611, 2,941,241, 3,609,818, 4,289,503, 4,673,414, and 4,954,139. A metal solvent catalyst material, such as described above, may be included with the unsintered mass of crystalline particles to promote intercrystalline diamond-to-diamond bonding. The catalyst material may be provided in the form of powder and mixed with the diamond grains, or may be infiltrated into the diamond grains during HPHT sintering, such as from an adjacent carbide substrate. The reaction cell is then placed under HPHT processing conditions sufficient to cause the intercrystalline bonding between the diamond particles.

[0021] HPHT processing may be carried out at elevated pressures of about 4 to 7 GPa or greater, and at elevated temperatures of about 1,300 °C (2,372 °F) to 1,600 °C (2,912 °F) or greater. However, a variety of temperatures and pressures may be used, depending on, for example, the type of catalyst material being used, the amount of diamond being bonded together, and the diamond grain size.

[0022] It should be noted that if too much additional non-diamond material is present in the powdered mass of crystalline particles, appreciable intercrystalline bonding is prevented during the sintering process. Such a sintered material where appreciable intercrystalline bonding has not occurred is not within the definition of PCD. Following such formation of intercrystalline bonding, a PCD body may be formed that has at least about 80 percent by volume diamond, with the remaining balance of the interstitial regions between the diamond grains occupied by the catalyst material. In other embodiments, the PCD body may have at least 85 percent by volume diamond, and in another embodiment at least 90 percent by volume diamond.

[0023] Diamond grains used for forming PCD or other diamond bonded material may include any type of diamond particle, including natural or synthetic diamond powders having a wide range of particle sizes. For example, such diamond powders may have an average particle size in the range from submicrometer to about 100 micrometers, and from 1 to 80 micrometers in other embodiments. Further, the diamond powder used may include particles having a mono-modal or multi-modal distribution. According to some embodiments, diamond bodies may have an average grain size ranging from less than 1 micrometer. According to other embodiments, diamond bodies may have an average grain size ranging from 1 to 80 micrometers. In yet other embodiments, diamond bodies may have an average grain size ranging from greater than 80 micrometers.

[0024] In various embodiments, a formed PCD body having a catalyst material in the interstitial spaces between bonded diamond grains may be subjected to a leaching process (before or after attachment to a substrate), whereby the catalyst material is removed from the PCD body. As used herein, the term “removed” refers to the reduced presence of catalyst material in the PCD body, and is understood to mean that a substantial portion of the catalyst material no longer resides in the PCD body.

However, one skilled in the art would appreciate that the leaching process is limited in that trace amounts of catalyst material may still remain in the microstructure of the PCD body within the interstitial regions and/or adhered to the surface of the diamond grains. Such trace amounts may result from limited access of leaching agents during the leaching process, and because of this limited access, other methods may be used to reduce the thermal coefficient differential between the remaining catalyst material and diamond.

[0025] Rather than actually removing the catalyst material remaining in the interstitial spaces and/or adhered to the surface of the diamond grains from the PCD body or compact, the selected region of the PCD body or compact may be rendered thermally stable by treating the catalyst material in a manner that reduces the potential for the catalyst material to adversely impact the intercrystalline bonded diamond at elevated temperatures due to the thermal mismatch between the diamond and the remaining catalyst material as well as potential back conversion or graphitization. For example, the catalyst material may be combined chemically with another material or transformed into another material, thus causing it to no longer act as a catalyst material. Accordingly, as used herein, the terms “removing substantially all” or “substantially free” as used in reference to the catalyst material is intended to cover the different methods in which the catalyst material can be treated to no longer adversely impact the intercrystalline diamond in the PCD body or compact with increasing temperature.

[0026] The quantity of the catalyst material remaining in the material PCD microstructure after the PCD body has been subjected to a leaching treatment may vary, for example, on factors such as the treatment conditions, including treatment time, as well as whether the PCD body is attached to the substrate body before or after leaching. Further, one skilled in the art would appreciate that it may be desired in certain applications to allow a small amount of catalyst material to remain in the PCD body. In a particular embodiment, the PCD body may include up to 1-2 percent by weight of the catalyst material. However, one skilled in the art would appreciate that the amount of residual catalyst present in a leached PCD body may depend on the diamond density of the material and body thickness.

[0027] A conventional leaching process involves the exposure of an object to be leached with a leaching agent, such as described in U.S. Patent No. 4,224,380. In select embodiments, the leaching agent may be a weak, strong, or mixtures of acids. In other embodiments, the leaching agent may be a caustic material such as NaOH or KOH. Suitable acids may include, for example, nitric acid, hydrofluoric acid, hydrochloric acid, sulfuric acid, phosphoric acid, or perchloric acid, or combinations of these acids. In addition, caustics, such as sodium hydroxide and potassium hydroxide, have been used by the carbide industry to digest metallic elements from carbide composites. In addition, other acidic and basic leaching agents may be used as desired. Those having ordinary skill in the art will appreciate that the molarity of the leaching agent may be adjusted depending on the time desired to leach, concerns about hazards, etc.

[0028] Once the leaching step is completed and the PCD body is removed from the leaching agent, the resulting material microstructure of the leached portion of the diamond body may include a first matrix phase of the bonded-together diamond grains and a second phase of a plurality of empty interstitial regions dispersed within the matrix phase. In other words, at the end of the leaching process, the treated interstitial regions may be substantially empty so that the second phase may be described as a plurality of voids or empty regions dispersed throughout the diamond-bonded matrix phase. Thus, the leached portion of the diamond body may be substantially free of the catalyst material used to initially form or sinter the diamond body, and may be referred to as thermally stable polycrystalline diamond.

[0029] Leached diamond bodies may be attached (or reattached) to a substrate after completing the leaching process by methods disclosed herein, to facilitate attachment to a bit, cutting tool, or other end use application or device. For example, according to embodiments of the present disclosure, a method of forming a diamond compact (i.e., a diamond body attached to a substrate) may include adding a transition metal carbide other than tungsten carbide to a tungsten carbide substrate and placing a leached diamond body adjacent to an interface surface of the tungsten carbide substrate. The tungsten carbide substrate may be provided as a pre-sintered body or as a powdered layer. The leached diamond body and the adjacent tungsten carbide substrate may then be subjected to a HPHT bonding process to bond the diamond

body to the tungsten carbide substrate. A HPHT bonding process may include, for example, placing a diamond body and a substrate with a transition metal carbide added thereto within a sealed can and subjecting the can and its contents to elevated pressures, such as greater than 5,000 MPa, and elevated temperatures, such as greater than 1,300 °C. The HPHT bonding process may have different durations, temperatures, and pressures than the HPHT sintering step.

[0030] Substrates of the present disclosure may include wear resistant material having hard particles dispersed in a binder metal matrix. An example substrate material may include tungsten carbide particles dispersed in a cobalt binder, such as cemented tungsten carbide and cobalt (WC/Co). Such substrate materials include a hard particle phase made of tungsten carbide particles and a metal binder phase made of cobalt. Tungsten carbide substrates may have, for example, a grain size ranging from about 6 microns or less (fine grain) in some embodiments, or greater than 6 microns (coarse grain) in other embodiments, and a binder content ranging from a lower limit selected from 6%, 8% and 10% by weight to an upper limit selected from 10%, 12%, 14% and 16% by weight.

[0031] In addition to the hard particle (tungsten carbide) phase and metal binder phase (cobalt) described above, substrates of the present disclosure may also include an additive material, where the additive material is made of one or more transition metal carbide materials other than tungsten carbide. The transition metal carbide may be selected from at least one of vanadium carbide (VC), molybdenum carbide (Mo_2C), chromium carbide (Cr_3C_2), niobium carbide (NbC), tantalum carbide (TaC) and titanium carbide (TiC). According to embodiments of the present disclosure, the additive material may form greater than 0.2 percent by weight and up to 1 percent by weight of the tungsten carbide substrate. According other embodiments, the amount of additive material added to a tungsten carbide substrate may range from a lower limit selected from 0.1, 0.2 and 0.3 percent by weight of the tungsten carbide substrate to an upper limit selected from 0.4, 0.5, 0.8 and 1.0 percent by weight of the tungsten carbide substrate, where any lower limit may be used in combination with any upper limit.

[0032] One or more additive transition metal carbides may be added to a tungsten carbide substrate by forming the tungsten carbide substrate with the transition metal carbide premixed therein. For example, a mixture of tungsten carbide particles, cobalt (or other binder) powder and an additive material may be pressed into a green compact and then sintered to form a substrate having tungsten carbide grains bonded together with a cobalt binder and the additive material dispersed throughout. As used herein, an additive material refers to a transition metal carbide other than tungsten carbide, and may be selected from one or more of VC, Mo₂C, Cr₃C₂, NbC, TaC and TiC. The substrate may be sintered, for example, at temperatures ranging from about 1,400 °C (2,552 °F) to about 1,600 °C (2,912 °F). Other sintering methods known in the art for sintering tungsten carbide substrates may be used, such as, for example, HPHT sintering or hot isostatic pressing.

[0033] According to other embodiments of the present disclosure, an additive material may be added to a tungsten carbide substrate by coating an interface surface of the tungsten carbide substrate with the additive material. For example, an additive material, such as chromium carbide, may be coated onto a surface of a tungsten carbide substrate that will eventually interface a preformed diamond body. The additive material may be coated onto the interface surface, for example, by applying a foil, applying a layer of powder, applying a layer of paste, casting, brushing, spraying, chemical vapor deposition (“CVD”), or physical vapor deposition (“PVD”) methods.

[0034] According to yet other embodiments, an additive material may be added to a tungsten carbide substrate by coating an interface surface of a preformed diamond body with the additive material. For example, an additive material, such as chromium carbide, may be coated onto a surface of the diamond body that will eventually interface the substrate. The additive material may be coated onto the interface surface, for example, by applying a foil, applying a layer of powder, applying a layer of paste, casting, brushing, spraying, chemical vapor deposition (“CVD”), or physical vapor deposition (“PVD”) methods.

[0035] By incorporating the additive material into a diamond compact (i.e., a diamond body bonded to a substrate) during the method of bonding or reattaching the diamond body to the tungsten carbide substrate, eruptions composed of tungsten

carbide grains and cobalt pools that would have otherwise occurred may be prevented. As used herein, “eruptions” refer to precipitated regions of carbide grains and binder pools (e.g., catalyst or infiltrant material) formed from the substrate material that create voids or inclusions that are substantially larger than the interstitial regions formed in a polycrystalline diamond body. Eruptions may have a distinct form and composition from the remaining TSP microstructure and also produce a non-uniform substrate microstructure. For example, FIG. 2 shows an example of a conventional diamond table 200 that had been attached to a tungsten carbide substrate (not shown) by HPHT bonding without using additive material (e.g., VC, Mo₂C, Cr₃C₂, NbC, TaC or TiC). The diamond table 200 has a plurality of pores 210 formed therein. As described above, the pores 210 were formed from eruptions that precipitated from the substrate into the diamond body. In contrast, FIG. 3 shows a diamond table 300 formed according to methods of the present disclosure, where the diamond table 300 had been attached to a substrate (not shown) by HPHT bonding using an additive material. As shown, the diamond table 300 has a substantially continuous microstructure, where no pores have been formed.

[0036] Further, eruptions may create a non-uniform microstructure in the diamond body. Particularly, eruptions formed using conventional methods of attaching a tungsten carbide substrate to a diamond body may include precipitated tungsten carbide grains and cobalt pools extending into the diamond body in a tree-shaped or branched pattern. Thus, the attached polycrystalline diamond body may have a microstructure including a plurality of bonded together diamond grains, a plurality of interstitial regions disposed among the bonded together diamond grains, and extensions of precipitated tungsten carbide grains and cobalt pools extending from the interface between the tungsten carbide substrate and diamond body a distance into the diamond body and through the bonded together diamond grains and interstitial regions. However, diamond compacts formed according to methods of the present disclosure may have an attached diamond body that is substantially free of eruptions. For example, an attached polycrystalline diamond body may have a substantially uniform microstructure including a plurality of bonded together diamond grains and a plurality of interstitial regions disposed among the bonded together diamond grains.

[0037] FIG. 4 shows an example of a diamond compact 400 formed by HPHT bonding of a diamond body 410 to a tungsten carbide substrate 420 without using an additive material (as described above). During the attaching step, eruptions 430 of tungsten carbide and cobalt precipitated from the substrate 420 into the diamond body 410 in a branched pattern. Eruptions 430 occurring from the HPHT bonding process of attaching a diamond body 410 to a tungsten carbide substrate 420 are distinct from substrate material that may infiltrate into the diamond body 410 during the HPHT bonding process. For example, as described above, eruptions 430 may be made of precipitated tungsten carbide and cobalt, which has a tree-like or dendrite form extending into the diamond body. During the HPHT bonding process, substrate material may also infiltrate into the diamond body. Infiltration occurs when the temperature of the HPHT bonding process reaches the melting temperature of the substrate material. For example, when the HPHT bonding process temperature reaches the melting point of cobalt, the cobalt from the tungsten carbide substrate may melt and infiltrate into the diamond body, thereby filling at least a portion of the interstitial regions. Further, prior to attachment to the substrate, the diamond body 410 may include bonded together diamond grains and substantially empty interstitial regions between the bonded together diamond grains. After the HPHT bonding process, the diamond body 410 may have an amount of infiltrated cobalt disposed within the interstitial regions, thereby reducing thermal stability.

[0038] However, referring now to FIG. 5, eruptions may not occur when additive materials of the present disclosure are used to reattach a diamond body to a substrate to form a diamond compact. Particularly, FIG. 5 shows a diamond compact 500 formed by HPHT bonding of a diamond body 510 to a tungsten carbide substrate 520, wherein an additive material of the present disclosure, such as chromium carbide, was used in the diamond compact during the HPHT bonding process, such as by premixing the additive material within the substrate or coating the additive material onto the interface surface of the tungsten carbide substrate or the diamond body. The final diamond compact 500 (i.e., diamond body bonded to a substrate) formed with an additive material may have a diamond body microstructure made of a plurality of bonded together diamond grains and a plurality of interstitial regions between the bonded together diamond grains and is substantially free of eruptions. As described

above, in some embodiments, cobalt from the substrate 520 may infiltrate into the diamond body 510 during the HPHT bonding process. In such embodiments, the diamond body may have infiltrated cobalt disposed within a plurality of the previously emptied interstitial regions. Further, in some embodiments, an amount of the additive material may infiltrate into the interstitial regions of the diamond body from the substrate during the HPHT bonding process. For example, according to some embodiments, an additive material made of a transition carbide material other than tungsten carbide, such as chromium carbide, may be added to a tungsten carbide substrate, such as by premixing the additive material within the substrate or providing the additive material at the interface between the substrate and the diamond body. During the HPHT bonding process, an amount of the additive material along with an amount of cobalt from the substrate may infiltrate into the diamond body and may be disposed within at least a portion of the interstitial regions.

[0039] Thus, diamond compacts formed according to embodiments of the present disclosure may include a substrate attached to a polycrystalline diamond table, where the diamond table has a microstructure substantially free of precipitated tungsten carbide grains and cobalt pools. The substrate may include tungsten carbide grains bonded together with a cobalt binder. Further, according to some embodiments, an amount of the additive material used during HPHT attachment may remain within the substrate. The attached diamond body may be substantially free of eruptions and may include a plurality of bonded together diamond grains and a plurality of interstitial regions disposed among the bonded together diamond grains. According to some embodiments, the diamond body may also include an amount of the additive material used during HPHT attachment. Further, according to some embodiments, the additive material may be disposed at the interface between the substrate and the diamond body. Additive material used to form diamond compacts of the present disclosure may include a transition metal carbide selected from at least one of VC, Mo₂C, Cr₃C₂, NbC, TaC and TiC. Further, diamond compacts of the present disclosure may include up to 1.0 percent by weight of additive material, up to 0.08 percent by weight of additive material, and up to 0.05 percent by weight of additive material according to some embodiments.

[0040] Diamond compacts formed according to methods of the present disclosure may form cutting elements for use on a down hole tool. Down hole tools may include, for example, bits having a body, a plurality of blades extending from the body, and at least one cutting element disposed on the plurality of blades. The cutting element(s) may be disposed on the blades such that a cutting face, *i.e.*, a surface that contacts and cuts the formation being drilled, is positioned at a leading face of the blade and faces in the direction of the drill's rotation. The cutting element may be formed according to methods disclosed herein, where a diamond body is attached to a substrate having an additive material therein by HPHT sintering.

[0041] Referring now to FIG. 6, a cross-sectional view of a cutting element formed using an additive material according to methods disclosed herein is shown. Particularly, the cutting element 600 may include a polycrystalline diamond table 610 attached to a tungsten carbide substrate 620 at an interface 615, where the polycrystalline diamond table 610 has a cutting face 605 opposite from the interface 615. The polycrystalline diamond table 610 may have a height 612 measured between the interface 615 and the cutting face 605. According to embodiments of the present disclosure, the height 612 may range from about 0.05 mm to about 12 mm. The polycrystalline diamond table 610 may have a plurality of bonded together diamond grains and a plurality of interstitial regions disposed between the bonded together diamond grains, where cobalt binder from the attached tungsten carbide substrate 620 may occupy at least a portion of the interstitial regions. Further, according to embodiments of the present disclosure, the additive material may occupy at least a portion of the interstitial regions. According to some embodiments of the present disclosure, cobalt binder from the attached substrate and an amount of the additive material may occupy the interstitial regions of the polycrystalline diamond table throughout the entire height of the polycrystalline diamond table. According to other embodiments, cobalt binder from the attached substrate and an amount of the additive material may occupy the interstitial regions of the polycrystalline diamond table throughout a partial height of the polycrystalline diamond table.

[0042] Although only a few example embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the example embodiments without materially departing from this

invention. Accordingly, all such modifications are intended to be included within the scope of this disclosure as defined in the following claims.

CLAIMS

What is claimed is:

1. A method of forming a diamond compact, comprising:
adding an additive material to a tungsten carbide substrate, the additive material comprising a transition metal carbide other than tungsten carbide;
placing a diamond body adjacent to an interface surface of the tungsten carbide substrate; and
subjecting the diamond body and the tungsten carbide substrate to a high pressure high temperature bonding process to bond the diamond body to the tungsten carbide substrate.
2. The method of claim 1, wherein the transition metal carbide is selected from the group consisting of VC, Mo₂C, Cr₃C₂, NbC, TaC, TiC, and combinations thereof.
3. The method of claim 1, wherein the additive material is added to the tungsten carbide substrate by coating the interface surface of the tungsten carbide substrate.
4. The method of claim 3, wherein the additive material is added by a coating method selected from the group consisting of applying a foil, applying a layer of powder, applying a layer of paste, casting, brushing, spraying, chemical vapor deposition, and physical vapor deposition.
5. The method of claim 1, wherein the step of adding comprises coating a surface of the diamond body with the additive material and placing the coated surface adjacent to the tungsten carbide substrate.
6. The method of claim 5, wherein the additive material is added by a coating method selected from the group consisting of applying a foil, applying a layer of powder, applying a layer of paste, casting, brushing, spraying, chemical vapor deposition, and physical vapor deposition.

7. The method of claim 1, wherein the additive material is added to the tungsten carbide substrate by forming the tungsten carbide substrate with the additive material premixed therein.
8. The method of claim 1, wherein the additive material comprises up to 0.5 percent by weight of the tungsten carbide substrate.
9. The method of claim 1, wherein the tungsten carbide substrate is provided as a powdered layer.
10. The method of claim 1, wherein the tungsten carbide substrate is provided as a pre-sintered body.
11. The method of claim 1, wherein the high pressure high temperature bonding process comprises a pressure of greater than 5,000 MPa and a temperature of greater than 1,300 °C.
12. The method of claim 1, further comprising:
sintering diamond crystals and a catalyst material at a first high pressure high temperature condition to form a polycrystalline diamond material; and
leaching the polycrystalline diamond material to form the diamond body.
13. The method of claim 1, wherein the diamond body has a height ranging from about 0.05 mm to about 12 mm.
14. A cutting element, comprising:
a substrate, the substrate comprising tungsten carbide grains bonded together with a cobalt binder; and
a polycrystalline diamond table bonded to the substrate at an interface, the polycrystalline diamond table comprising:
a cutting face; and
a microstructure comprising a plurality of bonded together diamond grains and a plurality of interstitial regions disposed among the bonded together diamond grains, at least a portion of the interstitial regions comprising the cobalt binder and a transition metal carbide,

the polycrystalline diamond table being substantially free of eruptions.

15. The cutting element of claim 14, wherein the transition metal carbide is also disposed at the interface between the polycrystalline diamond table and the substrate.
16. The cutting element of claim 14, wherein the substrate further comprises the transition metal carbide.
17. The cutting element of claim 14, wherein the transition metal carbide is selected from the group consisting of VC, Mo₂C, Cr₃C₂, NbC, TaC, TiC, and combinations thereof.
18. The cutting element of claim 14, wherein the transition metal carbide comprises up to 0.5 percent by weight of the substrate.
19. The cutting element of claim 14, wherein the polycrystalline diamond table further comprises a height measured between the interface and the cutting face ranging from about 0.05 mm to about 12 mm.
20. The cutting element of claim 19, wherein the cobalt binder and the transition metal carbide occupy the interstitial regions throughout the entire height of the polycrystalline diamond table.

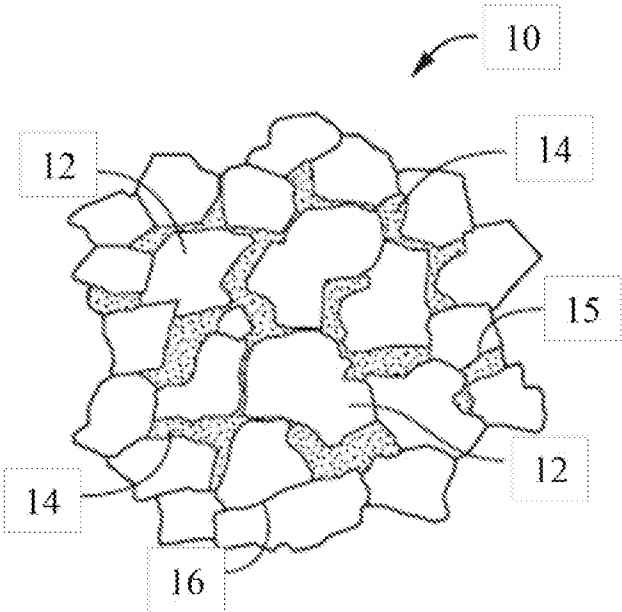


FIG. 1
(Prior Art)

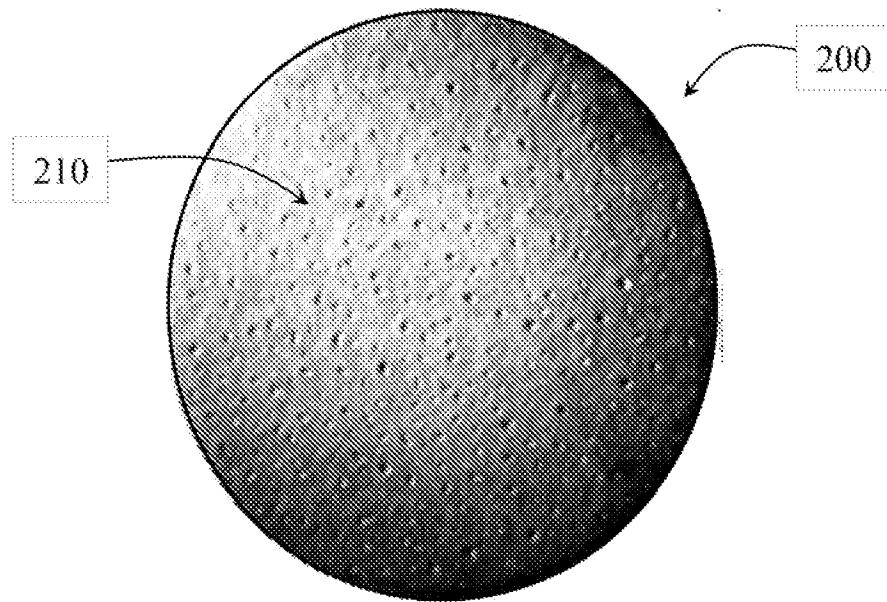


FIG. 2
(Prior Art)

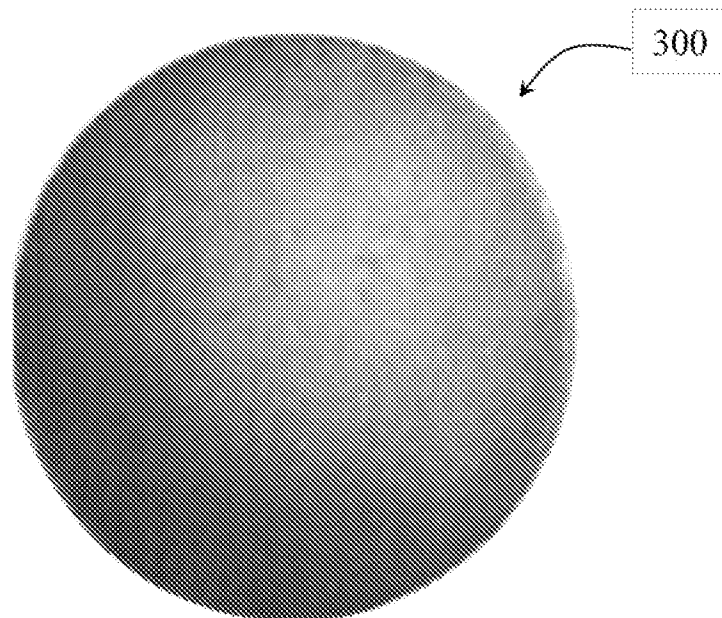


FIG. 3

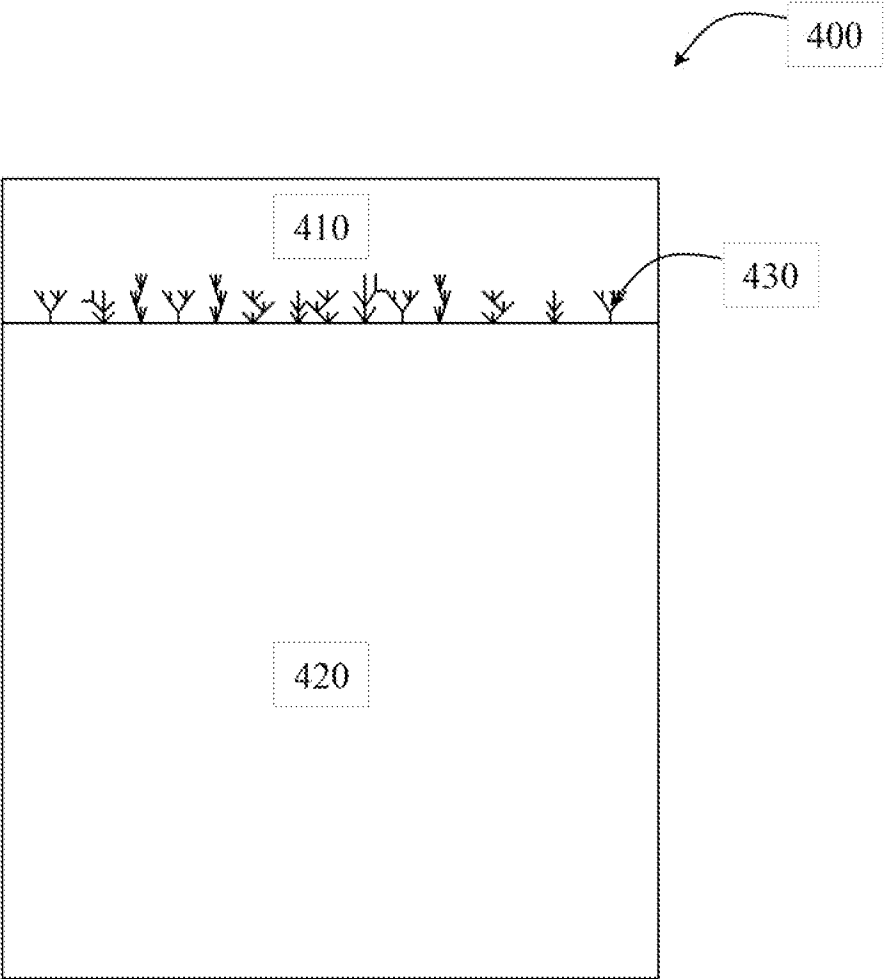


FIG. 4
(Prior Art)

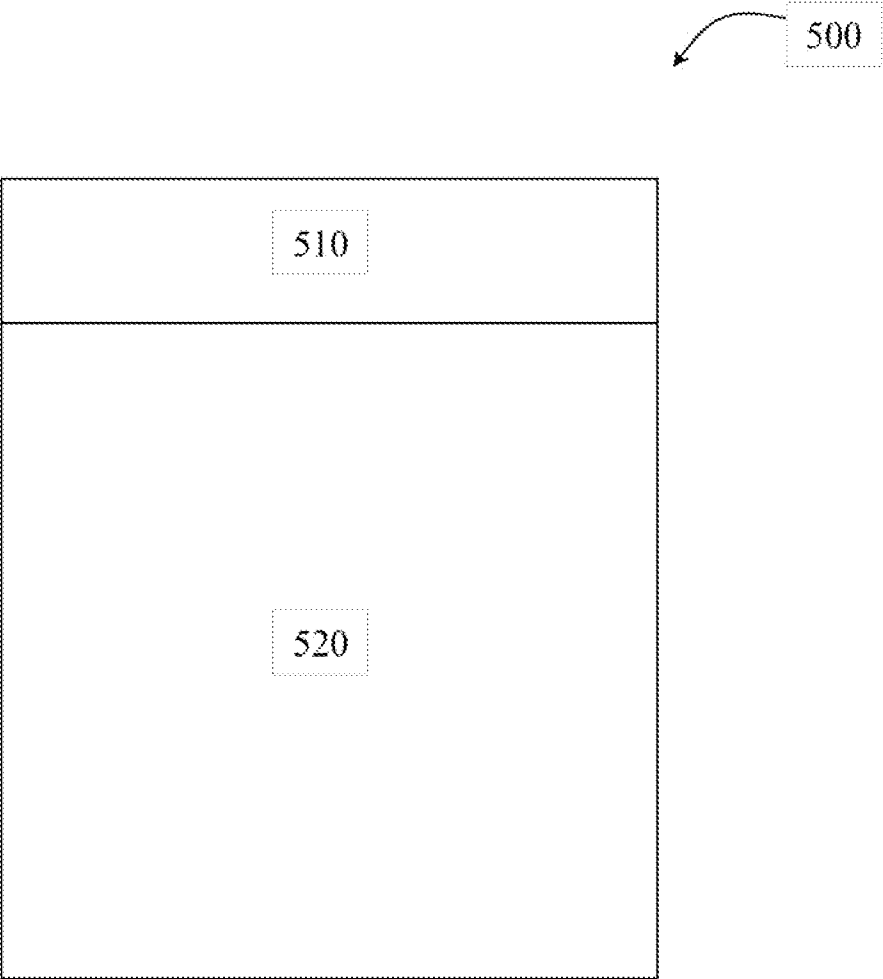


FIG. 5

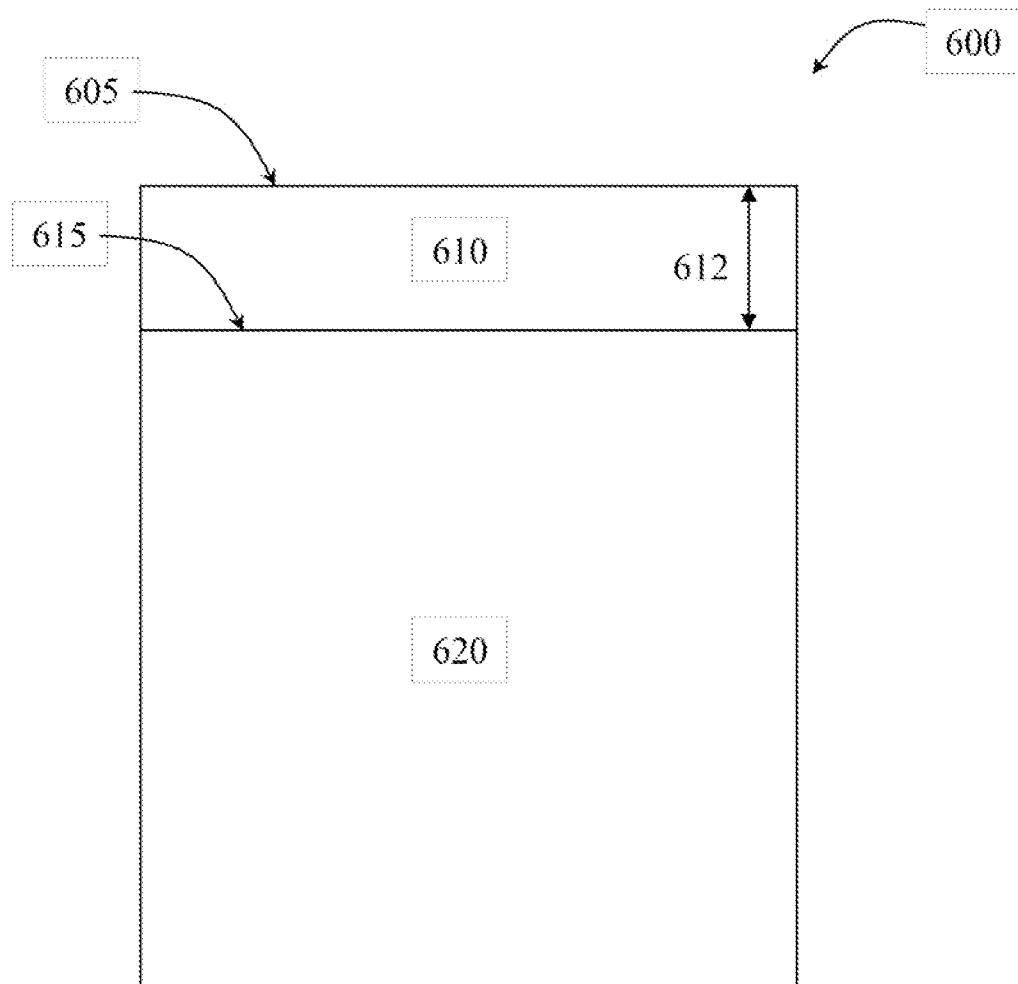


FIG. 6

A. CLASSIFICATION OF SUBJECT MATTER**B22F 7/00(2006.01)i, B22F 3/15(2006.01)i, B23B 27/20(2006.01)i, C04B 35/64(2006.01)i, C01B 31/06(2006.01)i**

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B22F 7/00; B32B 9/00; E21B 10/36; B26D 1/00; E21B 10/46; B22F 3/12; B21K 21/00; B24D 18/00; B22F 3/15; B23B 27/20; C04B 35/64; C01B 31/06

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: diamond, tungsten carbide, eruption, polycrystalline, cobalt, sintering, powder, binder, and grain

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2007-0144790 A1 (FANG et al.) 28 June 2007 See abstract; paragraphs [0013]-[0014], [0035], [0072]-[0075]; and claims 1, 18, 22, 31.	1-20
Y	US 3909895 A (ABRAHAMSON et al.) 07 October 1975 See abstract and column 2, lines 39-54, column 4, lines 1-43.	1-13, 16
Y	US 2010-0270088 A1 (ZHANG et al.) 28 October 2010 See paragraphs [0034]-[0037], [0059]-[0060] and claim 1.	12
Y	US 7211218 B2 (FANG et al.) 01 May 2007 See abstract; column 6, lines 50-63; and claims 1, 2, 9.	14-20
A	US 2004-0141867 A1 (DREYER et al.) 22 July 2004 See abstract; paragraph [0019]; and claim 2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search

07 March 2014 (07.03.2014)

Date of mailing of the international search report

10 March 2014 (10.03.2014)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/071905

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