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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
03 May 2018 (03.05.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/080490 A1

(51) International Patent Classification:
B22F 7/06 (2006.01) *E21B 10/42* (2006.01)
B22F 3/15 (2006.01) *E21B 10/54* (2006.01)
B22F 5/00 (2006.01)

(21) International Application Number:
PCT/US2016/058979

(22) International Filing Date:
27 October 2016 (27.10.2016)

(25) Filing Language: English

(26) Publication Language: English

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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, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, 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, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, 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, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *as to the identity of the inventor (Rule 4.17(i))*
— *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report (Art. 21(3))*

WO 2018/080490 A1

(54) Title: POLYCRYSTALLINE DIAMOND COMPACT WITH SINTERING AID COMPOUND, A COMPOUND FORMED FROM A SINTERING AID COMPOUND, OR A MIXTURE THEREOF

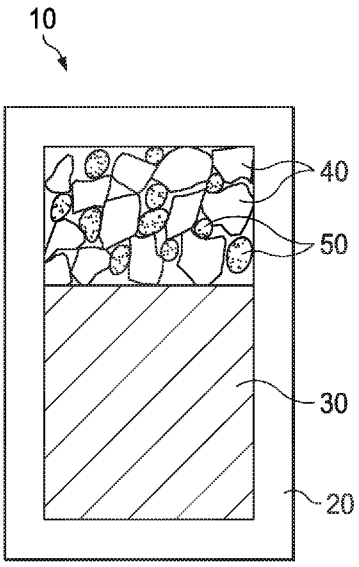


FIG. 1

(57) Abstract: The present disclosure provides a polycrystalline diamond compact (PDC) including a substrate and a polycrystalline diamond table including a sintering aid compound, a dissociated non-sintering aid component, a derivative compound, or a mixture thereof and further including dissociated sintering aid. The disclosure further provides an earth-boring drill bit containing a bit body and the PDC in the form of a cutter. The disclosure also provides a method of forming a PDC including placing a substrate and a mixture of diamond grains and a sintering aid compound in a can and performing an HTHP process to form a PDC including the substrate and a polycrystalline diamond table formed from the diamond grains and the sintering aid compound and including the sintering aid compound, a dissociated non-sintering aid component, a derivative compound, or a mixture thereof and dissociated sintering aid.

POLYCRYSTALLINE DIAMOND COMPACT WITH SINTERING AID COMPOUND, A COMPOUND FORMED FROM A SINTERING AID COMPOUND, OR A MIXTURE THEREOF

TECHNICAL FIELD

The current disclosure relates to a polycrystalline diamond compact (PDC), such as a cutter in an earth-boring drill bit.

BACKGROUND

Components of various industrial devices are often subjected to extreme conditions, such as high temperatures and high impact contact with hard and/or abrasive surfaces. For example, extreme temperatures and pressures are commonly encountered during drilling for oil extraction or mining purposes. Diamond, with its unsurpassed mechanical properties, can be the most effective material when properly used in a cutting element or abrasion-resistant contact element for use in drilling. Diamond is exceptionally hard, conducts heat away from the point of contact with the abrasive surface, and may provide other benefits in such conditions.

Diamond in a polycrystalline form has added toughness as compared to single-crystal diamond due to the random distribution of the diamond crystals, which avoids particular planes of cleavage from traversing the whole diamond thickness, such as, can be found in single-crystal diamond. Therefore, polycrystalline diamond is frequently the preferred form of diamond in many drilling applications. A drill bit cutting element that utilizes polycrystalline diamond is commonly referred to as a polycrystalline diamond compact (PDC) cutter. Accordingly, a drill bit incorporating PDC cutters may be referred to as a PDC bit.

PDCs can be manufactured in a cubic, belt, or other press by subjecting small grains of diamond and other starting materials to ultrahigh pressure and temperature conditions. One PDC manufacturing process involves forming a polycrystalline diamond table directly onto a substrate, such as a tungsten carbide substrate. The process involves placing a substrate containing a sintering aid, such as cobalt (Co), along with loose diamond grains mixed into a container of a press, and subjecting the contents of the press to a high-temperature high-pressure (HTHP) press cycle. The high temperature and pressure cause the small diamond grains to form into an integral

polycrystalline diamond table intimately bonded to the substrate, with Co acting as sintering aid to promote the formation of new diamond-diamond bonds.

Although useful in creating the polycrystalline diamond table, sintering aids, such as Co, typically have a coefficient of thermal expansion (CTE), both linear and volumetric, significantly higher than that of diamond, such that, when the PDC heats up during use, remaining sintering aid material within polycrystalline diamond (PCD_{LEFTH}) expands more rapidly or to a greater degree than the diamond, sometimes causing cracks/micro cracks or otherwise modifying residual stresses within the diamond grains. A polycrystalline diamond table may be leached to remove at least a portion of the sintering aid. The resulting leached PDC is more thermally stable than a similar, non-leached PDC. Leaching large portions of the sintering aid results in a thermally stable polycrystalline (TSP) diamond table. At a certain temperature, typically at least 750 °C at normal atmospheric pressure, the TSP cutters will not crack or graphitize, but non-leached PDC cutters will crack or graphitize under similar conditions. TSP diamond table needs to be reattached to a new substrate (the original one on which the polycrystalline diamond was formed often being removed prior to or destroyed in the leaching process) to form a TSP cutter.

Leaching thus remedies some of the problems causes by residual sintering aid in the diamond table of a PCD, but at the same time, it leaves pores or cavities where the leached sintering aid used to be, which can deteriorate mechanical properties of the PDC cutters, for example by making it brittle and decreasing its impact toughness.

BRIEF DESCRIPTION OF THE DRAWINGS

A more complete understanding of the present embodiments and advantages thereof may be acquired by referring to the following description taken in conjunction with the accompanying drawings, which show particular embodiments of the current disclosure, in which like numbers refer to similar components, and in which:

FIG. 1 is a not-to-scale, cross-sectional schematic diagram of a sintering assembly for a PDC cutter;

FIG. 2 is a not-to-scale, cross-sectional schematic diagram of a sintering assembly for a PDC cutter during sintering;

FIG. 3 is a not-to-scale, cross-sectional schematic diagram of a PDC in the form of a PDC cutter; and

FIG. 4 is a is an earth-boring drill bit including at least one PDC in the form of a PDC cutter.

DETAILED DESCRIPTION

The present disclosure relates to a PDC containing a sintering aid compound, a compound formed from the sintering aid compound, or a mixture thereof and methods of forming a PDC using a sintering aid compound. The sintering aid compound includes a sintering aid component and a non-sintering component. The sintering aid compound has a linear or volumetric CTE or both lower than that of the uncompounded sintering aid, making its linear or volumetric CTE or both closer to that of diamond and thereby reducing negative effects of different linear or volumetric CTEs or both of the diamond and sintering aid, such as cracking during actual use of PDC cutters in drilling and/or downhole applications.

In addition the sintering aid compound has a dissociation constant such that the sintering aid component dissociates from the sintering aid compound during HTHP press conditions in an amount sufficient to catalyze the formation of diamond-diamond bonds. However, the dissociation constant is also such that the sintering aid remains substantially in the sintering aid compound during PDC use and does not dissociate under use conditions in an amount sufficient to cause substantial graphitization of the polycrystalline diamond table or substantial damage due to its difference in linear or volumetric CTE or both as compared to diamond. This allows the PDC to benefit from the lower linear or volumetric CTE or both of the sintering aid compound and its ability to keep the sintering aid in a form that does not graphitize diamond, while still having sufficient dissociated sintering aid to form the polycrystalline diamond table in the first place.

In addition, residual sintering aid compound or a derivative compound formed from it may remain in the polycrystalline diamond table of the PDC and provide mechanical support. Derivative compounds typically also have a linear or volumetric CTE or both closer to that of diamond than the sintering aid does.

Referring to FIG. 1, sintering assembly 10 includes can 20 containing substrate 30, diamond grains 40, and sintering aid compound 50. As shown in FIG. 2, when can 20 is subjected to a HTHP process, some sintering aid compound 50 dissociates into dissociated sintering aid 60, which catalyzes diamond-diamond bonds between diamond grains 40. Dissociated sintering aid 60 may also catalyze diamond-substrate bonds between diamond grains 40 and substrate 30. Sintering aid compound 50 also forms dissociated non-sintering component 70, which may further react to form derivative compound 80.

After the HTHP process, polycrystalline diamond table 90 as shown in FIG. 3 has been formed on substrate 30 to produce PDC 100. PDC 100 contains sintering aid compound 50. It may also contain dissociated sintering aid 60, for instance in low amounts such as less than 0.5 wt%, less than 0.1 wt%, or less than 0.01 wt%, or it may not contain any substantial amounts of any dissociated sintering aid 60. Dissociated sintering aid 60 may be detected by X-ray diffraction or other phase analysis techniques.

PDC 100 may further contain dissociated non-sintering component 70 or derivative compound 80, formed from the dissociated non-sintering component of sintering aid compound 50. Although FIG. 3 illustrates PDC 100 with sintering aid compound 50, dissociated non-sintering component 70, and derivative compound 80, PDC 100 may have only one or only two such components. For instance, it is even possible that all of sintering aid compound 50 will dissociate during the HTHP process and only dissociated non-sintering component 70 or derivative compound 80 will remain. As noted above, small amounts of dissociated sintering aid 60 may also remain.

PDC 100 may be used as-is without being subjected to leaching or any other process to remove dissociated sintering aid 60 or sintering aid compound 50 or, if present dissociated non-sintering component 70 or derivative compound 80. PDC 100 may include TSP.

Substrate 30 may be any substrate suitable for use in PDC 100. In particular, it may be a conventional substrate, such as a cemented tungsten carbide substrate. Substrates in conventional PDC formation typically contain the sintering aid and supply it to the diamond grains during the HTPT process. PDC 100 is formed using

sintering aid compound 50, such that there is no need for a sintering aid in substrate 30. In some instances, it may actually be detrimental to have a sintering aid in substrate 30, as it will migrate into polycrystalline diamond table 90 during the HTHP process and cause the same detrimental effects as in a conventional PDC unless it is removed via leaching. Thus, substrate 30 may lack any sintering aid. As a result, substrate 30 may be formed from materials that do not require a sintering aid 60 in substrate 30 to form substrate 30, such as during the HTHP process, to remain intact, or at bond to polycrystalline diamond table 90.

Although FIGs. 1-3 illustrate a PDC with a substrate 30, it is also possible to form a PDC according to this disclosure without a substrate 30. A substrate may be later attached to a PDC thus formed, if needed.

Diamond grains 40 may be any suitable diamond grains, including diamond grains of substantially uniform grain sizes, diamond grains of mixed grain sizes, or mixtures thereof located in different areas of polycrystalline diamond table 90 after it is formed.

Sintering aid compound 50 may include any suitable sintering aid component able to form dissociated sintering aid 60 and another element or group of elements that form dissociated non-sintering component 70. Dissociated sintering aid 60 may include a group VIII metal. It may also include cobalt (Co), nickel (Ni), iron (Fe), copper (Cu), chromium (Cr), manganese (Mn), ruthenium (Ru), rhodium (Rh), platinum (Pt), tantalum (Ta), osmium (Os), or iridium (Ir). Dissociated sintering aid 60 may be a single metal, or it may be a combination of metals formed from different sintering aid compounds 50, one for each metal. The combination of metals may act separately, or they may alloy to form an alloyed dissociated sintering aid 60.

Sintering aid compound 50 may include one compound or combination of compounds. For instance, even when only one dissociated sintering aid 60 is used, it may be dissociated from a plurality of different compounds of that sintering aid. The plurality of different compounds may be added at the outset, or may form prior to, during or after sintering. Transition metals are able to exist in a variety of valence states and therefore are particularly likely to form a group of compounds even when compounded with the same elements or elements.

In addition, as noted above, dissociated sintering aid 60 may be formed from a combination of metals formed from different sintering aid compounds, in which case sintering aid compound 50 also includes a combination of compounds.

Although sintering aid compound 50 is discussed herein as an electroneutral compound, it may exist as paired ions in some circumstances.

Each individual compound in sintering aid compound 50 may have the general formula $M^1_xM^2_yQ_p$, wherein M^1 is a Group VIII metal, or Co, Ni, Fe, Cu, Cr, Mn, Ru, Rh, Pt, Ta, Os, or Is sintering aid, or a combination of at least two such metals and $x>0$, M^2 is a non-sintering metal or combination of at least two such non-sintering metals and $y\geq 0$, and Q is a non-metal, metalloid, or a combination of at least two non-metals or metalloids and $p>0$. x, y and p are also such that sintering aid compound 50 is electroneutral. $M^1_xM^2_yQ_p$ dissociates to form dissociated sintering aid 60 from M^1 and dissociated non-sintering component 70 from $M^2_yQ_p$. The general dissociation reaction (I) is as follows:

$$M^1_xM^2_yQ_p \leftrightarrow M^1 + M^2Q \qquad (I).$$

M^1 will typically be the metal in a neutral valence state. The relative amounts of elements in M^2Q will typically be such that the compound is electroneutral as well.

The further reaction of M^2Q may go on to further react to form derivative compound 80 as shown by reaction (II) as follows:

$$M^2Q + X \leftrightarrow M^2X + Q(II).$$

M^2X and Q will be such that the compounds are electroneutral or elements are in their neutral valence state. X may be carbon (C), such as carbon in diamond grains 40, or another component of the polycrystalline diamond table.

Alternatively the further reaction of M^2Q to form derivative compound 80 may be shown by reaction (III) as follows:

$$M^2Q \leftrightarrow M^2 + QX \qquad (III).$$

M^2 will typically be the metal in a neutral valence state. The relative amounts of elements in QX will typically be such that the material is electroneutral as well.

In one example, sintering aid compound 50 may be cobalt (II) titanate ($CoTiO_3$), which may dissociate into Co as dissociated sintering aid 60 and TiO_2 as dissociated non-sintering component 70. In addition, dissociated non-sintering component 70 may further react with C contained in diamond grains 40, to form titanium carbide (TiC) as derivative compound 80.

In general, derivative compound 80 may often be a metal carbide, as these materials tend to have a linear or volumetric CTE or both similar to that of substrate 30 and closer to the CTE of diamond than the sintering aid. In addition, metal carbides tend to have a desirable impact strength, imparting additional impact toughness to the PDC 100 overall.

Particularly useful M^2 metals include titanium (Ti), zirconium (Zr), tungsten (W), tantalum (Ta), molybdenum (Mo), vanadium (V), niobium (Nb) and hafnium (Hf) because these metals may form carbides.

Oxygen (O) is a particularly useful Q element because it can form oxygen gas (O_2) which may exit PDC 100 and which is relatively safe. Carbon-oxygen (C-O) compounds and ions, such as carbonates, or silicon-oxygen (Si-O) compounds and ions, such as silicates, may also be particularly useful Q components due to their ability to form O_2 or, in the case of carbon-oxygen compounds and ions, CO_2, which may also exit PDC 100, and to produce C or Si or their compounds in PDC 100.

Sintering aid compound 50 may have a linear CTE of 5 x 10^{-6} /K or less, 3 x 10^{-6} /K or less, or 2 x 10^{-6} /K or less at 20 °C. Non-sintering compound 70 may have a linear CTE of 5 x 10^{-6} /K or less, 3 x 10^{-6} /K or less, or 2 x 10^{-6} /K or less at 20 °C. Derivative compound 80 may have a linear CTE of 5 x 10^{-6} /K or less, 3 x 10^{-6} /K or less, or 2 x 10^{-6} /K or less at 20 °C.

Sintering aid compound 50 may have a linear CTE of 8 x 10^{-6} /K or less, 6 x 10^{-6} /K or less, or 4 x 10^{-6} /K or less at 20 °C. Non-sintering compound 70 may have a linear CTE of 8 x 10^{-6} /K or less, 6 x 10^{-6} /K or less, or 4 x 10^{-6} /K or less at 20 °C. . Derivative compound 80 may have a linear CTE of 8 x 10^{-6} /K or less, 6 x 10^{-6} /K or less, or 4 x 10^{-6} /K or less at 20 °C.

The disclosure further provides a method of forming a PDC, such as PDC 100. According to the method, diamond grains 40 and sintering aid compound 50 are placed in can 20 as shown in FIG. 1. Sintering aid compound 50 may be in the form

of microparticles, which have a largest dimension on average of between 1 μm and 1000 μm. Sintering aid compound 50 may also be in the form of nanoparticles, which have a largest dimension on average of between 1 nm and 1000 nm. In particular, sintering aid compound 50 may have a largest dimension of between 200 nm and 5 μm. In addition, sintering aid compound 50 may be mono-disperse, with an average size variation in the largest dimension of 10% or less.

Sintering aid compound 50 is mixed with diamond grains 40, as shown in FIG. 1. The mixing may be homogeneous or sintering aid compound 50 may be in higher proportions in some areas. The formation of a homogenous mixture may be facilitated by using sintering aid compound 50 particles that are similar in dimension to diamond grains 40. For instance sintering aid particles to may have an average largest dimension within 5% of the average largest dimension of diamond grains 40.

Sintering aid compound 50 may be formed into particles through mechanical processing, such as ball milling. Sintering aid compound may also be formed into discrete particles rather than clumps or agglomerates, with no more than 1% of particles physically attached to another particle. Discrete particles also facilitate the formation of a homogeneous mixture with diamond grains 40.

During a HTHP process, some of sintering aid compound 50 dissociates into dissociated sintering aid 60, as shown in FIG. 2. Dissociated sintering aid 60 is already located near diamond grains 40. As a result, less sintering aid may be used than in conventional processes or HTHP press cycle time is reduced to increase productivity, in which the sintering aid typically must migrate from a substrate into the diamond grains. This is particularly true when sintering aid compound 50 is in the form of particles homogeneously mixed with diamond grains 40. The amount of sintering aid compound 50 may be such that the total amount of the sintering aid component, such as Co, whether dissociated or in the compound, is less than 10 wt% of polycrystalline diamond table 90. It may also be less than 8 wt%, less than 4.5 wt%, less than 3 wt%, less than 2 wt%, or less than 1 wt%.

The temperature of the HTHP process is typically at least the eutectic temperature of the sintering aid component in sintering aid compound 50 so that dispersed sintering aid 60 is in a liquid state. If dispersed sintering aid 60 is formed from an alloy, the temperature of the HTHP process may be at least the applicable

alloying temperature, which is typically at least the eutectic temperature of the alloy component with the highest eutectic temperature.

Non-sintering aid component 70 may also be formed during the HTHP process. Derivative compound 80 may be formed during HTHP process or after the process has been completed and polycrystalline diamond table 90 is cooled.

The entire process results in PDC 100, as shown above in FIG. 3.

A PDC as described herein may be incorporated into an industrial device, such as an earth-boring drill bit, as illustrated in FIG. 4. FIG. 4 illustrates a fixed cutter drill bit 200 containing a plurality of cutters 210 coupled to drill bit body 220. At least one of cutters 210 may be a PDC 100 as described in FIG. 3.

Bit body 220 may include a plurality of blades 230 extending therefrom. Bit body 220 may be formed from steel, a steel alloy, a matrix material, or other suitable bit body material with desired strength, toughness and machinability. Bit body 220 may be formed to have desired wear and erosion properties. PDC cutters 210 may be mounted on the bit using methods of this disclosure or using other methods. PDC cutters may be located in gage region 240, or in a non-gage region, or both.

Drilling action associated with drill bit 200 may occur as bit body 220 is rotated relative to the bottom of a wellbore in response to rotation of an associated drill string. At least some PDC cutters 210 disposed on associated blades 230 may contact adjacent portions of a downhole formation during drilling. These PDC cutters 210 may be oriented such that their polycrystalline diamond tables contact the formation.

The present disclosure provides an embodiment A relating to a PDC including a substrate and a polycrystalline diamond table including a sintering aid compound, a dissociated non-sintering aid component, a derivative compound, or a mixture thereof and dissociated sintering aid.

The present disclosure also provides an embodiment B relating to an earth-boring drill bit containing a bit body and the PDC of embodiment A in the form of a cutter.

The present disclosure also provides an embodiment C relating to a method of forming a PDC including placing a substrate and a mixture of diamond grains and a sintering aid compound in a can to form a sintering assembly and performing an

HTHP process on the sintering assembly to form a PDC including the substrate and a polycrystalline diamond table formed from the diamond grains and the sintering aid compound and including the sintering aid compound, a dissociated non-sintering aid component, a derivative compound, or a mixture thereof and further including dissociated sintering aid.

In addition, embodiments A, B and C may be used in conjunction with the following additional elements, which may also be combined with one another unless clearly mutually exclusive, and which method elements may be used to obtain devices and which device elements may result from methods: i) the substrate may not include a sintering aid; ii) the sintering aid compound may include a sintering aid component M^1 and a non-sintering aid component M^2Q and have the general formula $M^1_xM^2_yQ_p$, wherein M^1 is a Group VIII metal,
M^2 is a metal other than M^1, Q is a non-metal, metalloid, or a combination of at least two non-metals or metalloids, $x>0$, $y\geq0$, $p>0$, and x, y and p are such that the sintering aid compound is electroneutral; iii) the derivative compound may be formed from the dissociated non-sintering aid component; iv) the derivative compound may be a metal carbide; v) each of the sintering aid compound, dissociated non-sintering aid component, and derivative compound may have a linear coefficient of thermal expansion (CTE) of 5×10^{-6} /K or less; vi) the sintering aid compound may be in the form of particles; vii) the mixture of diamond grains and sintering aid compound maybe homogeneous; viii) the sintering aid compound particles may have an average largest dimension within 5% of an average largest dimension of the diamond grains; ix) the sintering aid compound may dissociate into a sintering aid component and a non-sintering component during an HTHP process, such that the sintering aid component catalyzes the formation of diamond-diamond bonds between the diamond grains; x) the sintering aid compound may include at least two compounds; xi) each of the at least two compounds may include the same sintering aid; xii) each of the at least two compounds may include a different sintering aid and the sintering aids may form an alloy during the HTHP process; xiii) the dissociated non-sintering component may react with carbon to form a metal carbide derivative compound; xiv) the carbon may be from the diamond in the diamond grains.

Although only exemplary embodiments of the invention are specifically described above, it will be appreciated that modifications and variations of these examples are possible without departing from the spirit and intended scope of the invention. For instance, the use of PDCs on other industrial devices may be determined by reference to the drill bit example.

CLAIMS

1. A polycrystalline diamond compact (PDC) comprising:

a substrate; and

a polycrystalline diamond table including a sintering aid compound, a dissociated non-sintering aid component, a derivative compound, or a mixture thereof and further including dissociated sintering aid.

2. The PDC of claim 1, wherein the substrate does not comprise a sintering aid.

3. The PDC of claim 1, wherein the sintering aid compound comprises a sintering aid component M^1 and a non-sintering aid component M^2Q and has the general formula $M^1_xM^2_yQ_p$, wherein

M^1 is a Group VIII metal,

M^2 is a metal,

Q is a non-metal, metalloid, or a combination of at least two non-metals or metalloids,

$x>0$,

$y\geq0$, $p>0$., and

x, y and p are such that the sintering aid compound is electroneutral.

4. The PDC of claim 1, wherein the derivative compound is formed from the dissociated non-sintering aid component.

5. The PDC of claim 1, wherein the derivative compound is a metal carbide.

6. The PDC of Claim 1, wherein each of the sintering aid compound, dissociated non-sintering aid component, and derivative compound has a linear coefficient of thermal expansion (CTE) of 5×10^{-6} /K or less.

7. An earth-boring drill bit comprising:

a bit body; and

a polycrystalline diamond compact (PDC) in the form of a cutter, the PDC comprising:

a substrate; and

a polycrystalline diamond table including a sintering aid compound, a dissociated non-sintering aid component, a derivative compound, or a mixture thereof and further including dissociated sintering aid.

8. The earth-boring drill bit of claim 1, wherein the substrate does not comprise a sintering aid.

9. The earth-boring drill bit of claim 1, wherein the sintering aid compound comprises a sintering aid component M^1 and a non-sintering aid component M^2Q and has the general formula $M^1_xM^2_yQ_p$, wherein

M^1 is a Group VIII metal,

M^2 is a metal other than M^1,

Q is a non-metal, metalloid, or a combination of at least two non-metals or metalloids,

$x>0$,

$y\geq0$, $p>0$, and

x, y and p are such that the sintering aid compound is electroneutral.

10. The earth-boring drill bit of claim 1, wherein the derivative compound is formed from the dissociated non-sintering aid component.

11. The earth-boring drill bit of claim 1, wherein the derivative compound is a metal carbide.

12. The earth-boring drill bit of Claim 1, wherein each of the sintering aid compound, dissociated non-sintering aid component, and derivative compound has a linear coefficient of thermal expansion (CTE) of 5×10^{-6} /K or less.

13. A method of forming a polycrystalline diamond compact (PDC) comprising:

placing a substrate and a mixture of diamond grains and a sintering aid compound in a can to form a sintering assembly; and

performing a high temperature high pressure (HTHP) process on the sintering assembly to form a PDC including the substrate and a polycrystalline diamond table formed from the diamond grains and the sintering aid compound and including the sintering aid compound, a dissociated non-sintering aid component, a derivative compound, or a mixture thereof and further including dissociated sintering aid.

14. The method of claim 13, wherein the sintering aid compound is in the form of particles and the mixture of diamond grains and sintering aid compound is homogeneous.

15. The method of claim 13, wherein the sintering aid compound is in the form of particles having an average largest dimension within 5% of an average largest dimension of the diamond grains.

16. The method of claim 13, wherein the sintering aid compound dissociates into a sintering aid component and a non-sintering component during the HTHP process, such that the sintering aid component catalyzes the formation of diamond-diamond bonds between the diamond grains.

17. The method of claim 13, wherein the sintering aid compound comprises at least two compounds.

18. The method of claim 17, wherein each of the at least two compounds comprises the same sintering aid.

19. The method of claim 17, wherein each of the at least two compounds comprises a different sintering aid and wherein the sintering aids form an alloy during the HTHP process.

20. The method of claim 13, wherein the dissociated non-sintering component reacts with carbon to form a metal carbide derivative compound.

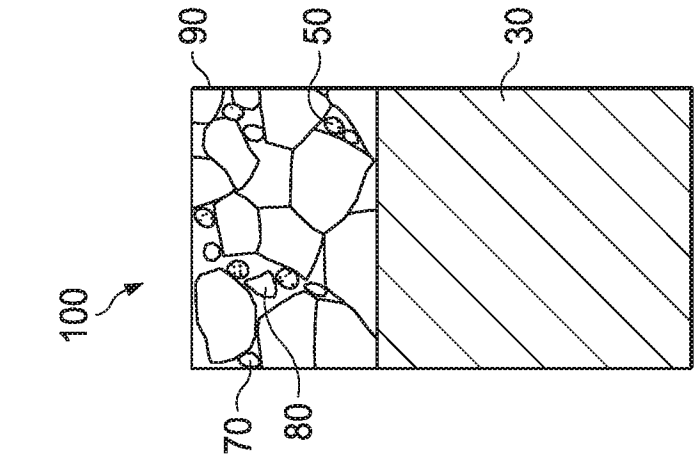


FIG. 3

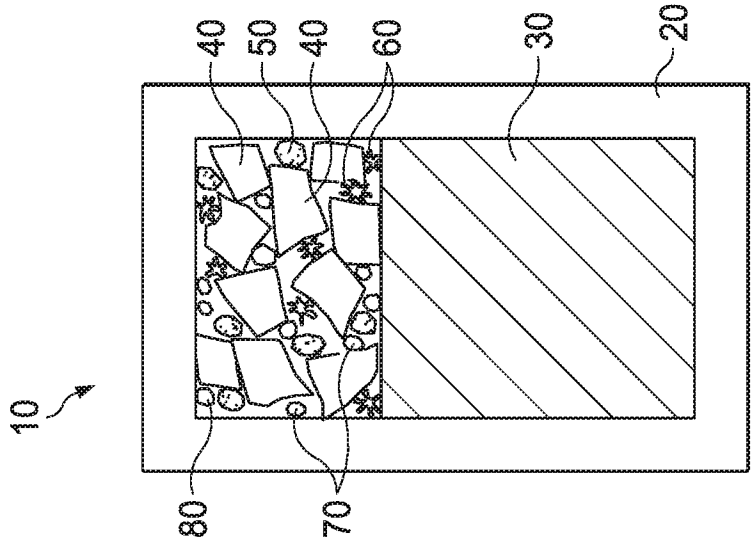


FIG. 2

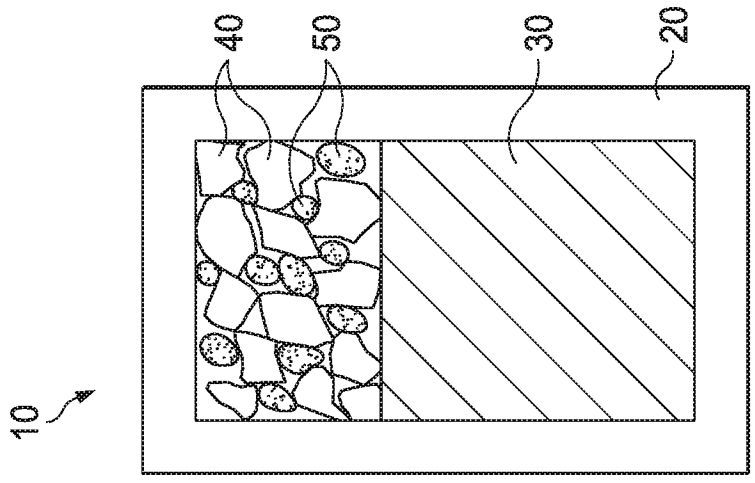


FIG. 1

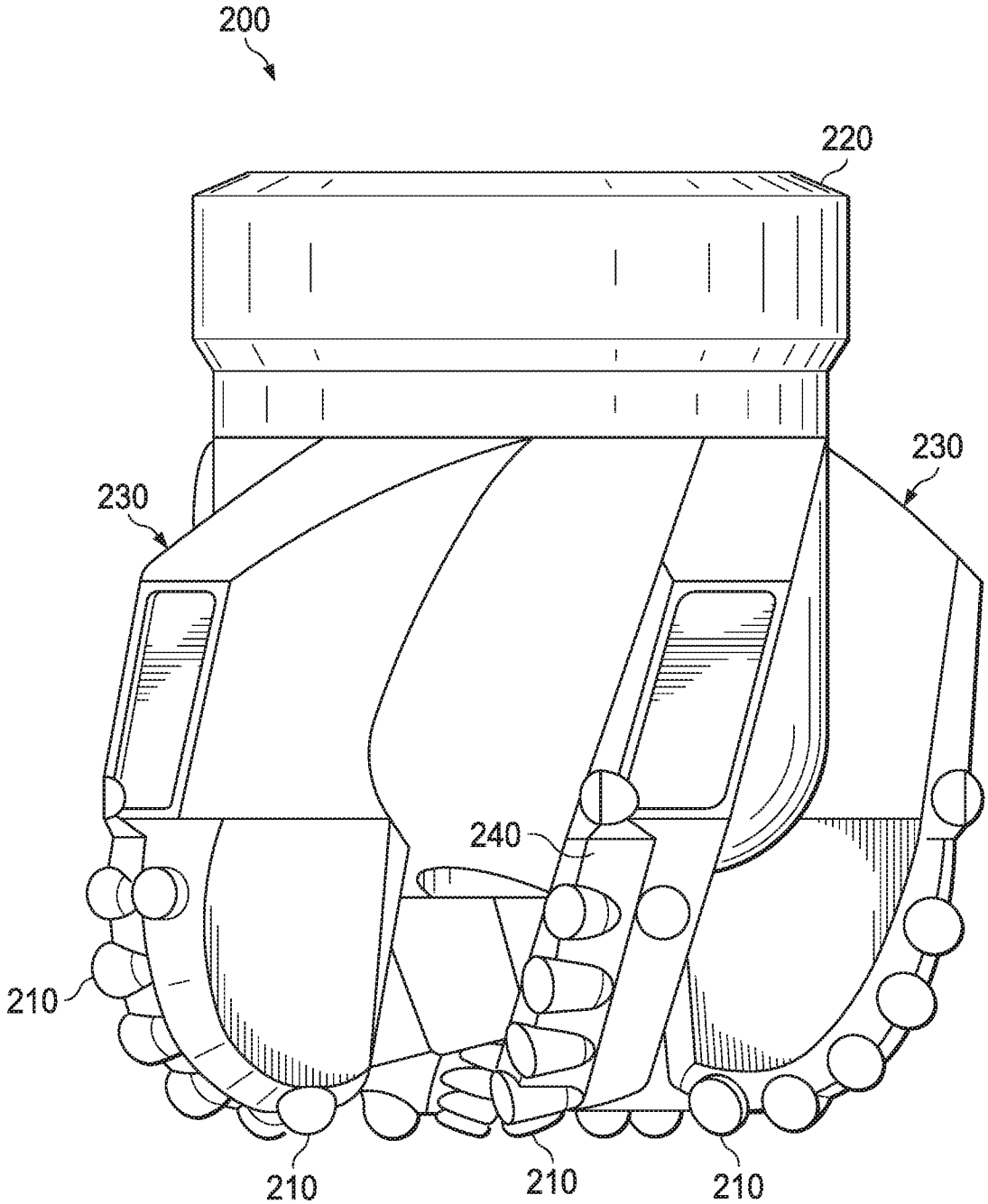


FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/058979

A. CLASSIFICATION OF SUBJECT MATTER

B22F 7/06(2006.01)i, B22F 3/15(2006.01)i, B22F 5/00(2006.01)i, E21B 10/42(2006.01)i, E21B 10/54(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 7/06; B24D 3/10; E21B 10/36; E21B 10/46; B24D 18/00; B24D 3/04; B22F 3/15; B22F 5/00; E21B 10/42; E21B 10/54

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: PDC, polycrystalline diamond, sintering aid, compound, cutter, bit, and cobalt

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2012-0211284 A1 (DIGIOVANNI, ANTHONY A.) 23 August 2012 See paragraphs [0049]-[0053], [0059]-[0060] and claims 1-2, 17, 21.	1-2,6-8,12-19
Y		3-5,9-11,20
Y	US 8789627 B1 (SANI et al.) 29 July 2014 See column 8, lines 35-54 and claim 1.	3-5,9-11,20
A	US 8573332 B2 (SCOTT, DANNY E.) 05 November 2013 See abstract and claims 1, 14.	1-20
A	US 2014-0223835 A1 (THIGPEN et al.) 14 August 2014 See paragraphs [0034]-[0044] and claims 1, 8.	1-20
A	US 8753413 B1 (MICHAEL A. VAIL) 17 June 2014 See abstract and claims 1, 9, 16.	1-20

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

* Special categories of cited documents:
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
07 July 2017 (07.07.2017)	**10 July 2017 (10.07.2017)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2016/058979

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