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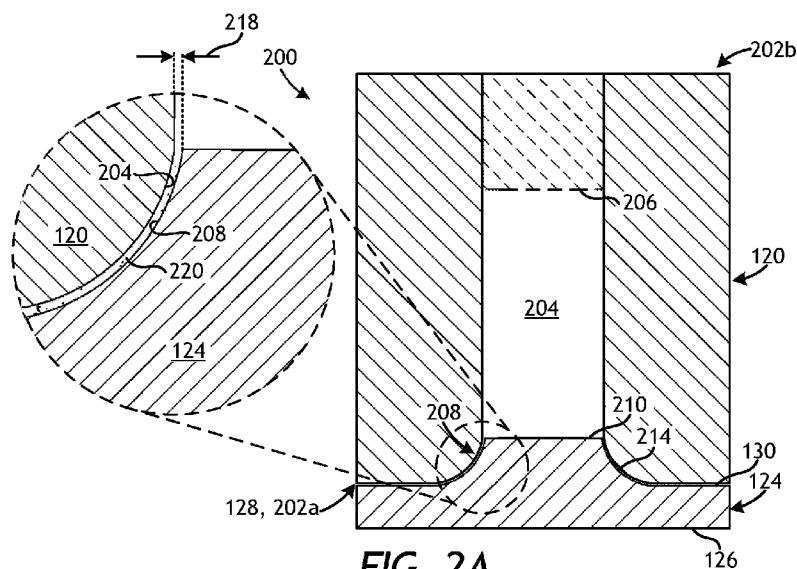
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(54) Title: DRILL BIT CUTTERS AND CUTTER ASSEMBLIES

**FIG. 2A**

(57) Abstract: A cutter for a drill bit includes a substrate defining a hole at least partially through the substrate. A diamond table including a protrusion is received within the hole such that a gap is defined between the protrusion and the substrate ranging between 0.001 and 0.010 inches when the substrate and diamond table are at standard temperature and pressure (STP). A braze alloy couples the diamond table to the substrate at an interface between the diamond table and the substrate. At least a portion of the braze alloy is disposed in the gap in compression between the protrusion on the diamond and the hole in the substrate.

DRILL BIT CUTTERS AND CUTTER ASSEMBLIES

BACKGROUND

[0001] Wellbores for the oil and gas industry are commonly drilled by a process of rotary drilling. In conventional rotary drilling, a drill bit is mounted on the end of a drill string, which may be lengthened to reach a desired depth by progressively adding tubing segments on site while drilling. At the surface of the wellbore, a rotary table or top drive turns the drill string, including the drill bit arranged at the bottom of the hole to increasingly penetrate the earth, while drilling fluid is pumped through the drill string. In other drilling configurations, the drill bit may be rotated using a mud motor arranged in the drill string adjacent the drill bit and powered using the circulating drilling fluid.

[0002] One common type of drill bit used to drill wellbores is known as a "fixed cutter" or "drag" drill bit. A fixed cutter drill bit generally includes a bit body formed from a high strength and/or high toughness material and a plurality of cutters attached at fixed locations about the bit body. Cutters on fixed cutter drill bits often include a substrate or support stud made of cemented-carbide (e.g., tungsten carbide), and a cutting surface layer or "diamond table," which can be made of a variety of ultra-hard materials. One ultra-hard material commonly employed is polycrystalline diamond, and cutters that used polycrystalline diamond are commonly referred to as polycrystalline diamond compact ("PDC") cutters.

[0003] Conventionally, the diamond table is simultaneously formed and bonded to the substrate in a single high-temperature, high-pressure (HTHP) press cycle. Various other methods for securing the diamond table to the substrate are also under investigation, whereby the diamond table may be formed in a first HTHP cycle, and optional post-processing steps may be performed, such as leaching the diamond table, before attaching or re-attaching the leached diamond table to a substrate. Such other methods of attachment may include, for example, bonding the diamond-table to the substrate in a subsequent press cycle, or by brazing the diamond table to a substrate with an active metal braze alloy.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] The following figures are included to illustrate certain aspects of the present disclosure, and should not be viewed as exclusive embodiments. The subject matter disclosed is capable of considerable modifications, alterations, combinations, and equivalents in form and function, without departing from the scope of this disclosure.

[0005] FIG. 1A is an isometric schematic drawing of an exemplary fixed-cutter drill bit that may employ the principles of the present disclosure.

[0006] FIG. 1B is a schematic drawing of an exemplary cutter that may be used with the drill bit of FIG. 1A.

[0007] FIGS. 2A and 2B are assembled and exploded cross-sectional side views, respectively, of an exemplary cutter.

[0008] FIG. 2C is an isometric view of another embodiment of the diamond table of FIGS. 2A and 2B.

[0009] FIGS. 3A and 3B are cross-sectional side views of the cutter of FIGS. 2A-2B.

[0010] FIG. 4 is an exploded cross-sectional side view of a cutter assembly.

[0011] FIG. 5 is an exploded cross-sectional side view of another cutter assembly.

DETAILED DESCRIPTION

[0012] The present disclosure is related to downhole tools used in the oil and gas industry and, more particularly, to drill bit cutters and methods of manufacturing and mounting drill bit cutters and cutter assemblies. Embodiments of the present disclosure include methods of attaching a diamond table to a substrate of a drill bit cutter.

[0013] In some example embodiments discussed, the diamond table defines a protrusion that extends from a bottom surface of the diamond table to be received within a hole defined in the substrate, where the hole and the protrusion are formed with an intentionally-formed gap. Such a gap may be between, for example, 0.001 and 0.010 inches when the diamond and substrate are both at around room temperature. The protrusion may be brazed into the hole, with the intentional gap occupied by the braze alloy. The dimension of the hole and protrusion may be selected in view of the coefficient of thermal

expansion of the substrate and/or the diamond table to allow the hole to expand during the heating induced by brazing, such that, upon cooling the substrate back to room temperature, the braze alloy is in compression. This may prove advantageous in improving the thermo-mechanical integrity of the drill bit cutter, improve abrasion resistance, and minimize failure at the joint between the substrate and the diamond table.

[0014] In other embodiments, in contrast to leaving an intentional gap, the protrusion may be secured within the hole via an interference fit. In such embodiments, the interference fit may withstand expected drilling operating temperatures. In yet other embodiments, the diamond table and the substrate may be coupled by a combination of an interference fit between the protrusion and hole, and brazing some portion of an interface between the diamond table and substrate.

[0015] FIG. 1A is an isometric view of an example of a fixed-cutter drill bit 100 that may employ the principles of the present disclosure. The drill bit 100 has a bit body 102 that includes radially and longitudinally extending blades 104 having leading faces 106. A threaded pin connection 108 is coupled to the bit body 102 for connecting the drill bit 100 to a drill string (not shown). The bit body 102 may be made of steel or a metal matrix of a harder material, such as tungsten carbide. The bit body 102 is configured for rotation about a longitudinal axis 110 to drill into a subterranean formation via application of weight on the bit body 102 (*i.e.*, weight-on-bit). Corresponding junk slots 112 are defined between circumferentially adjacent blades 104, and a plurality of nozzles or ports 114 can be defined within the junk slots 112 for ejecting drilling fluid that cools the drill bit 100 and flushes away cuttings and debris generated during the drilling operation.

[0016] The bit body 102 further includes a plurality of cutters 116 each disposed within a corresponding cutter pocket 118 sized and shaped to receive the cutters 116. The cutters 116 are held in the blades 104 and corresponding cutter pockets 118 at predetermined angular orientations and radial locations to position the cutters 116 with a desired backrake angle against the formation being penetrated. As the bit body 102 is rotated, the cutters 116 are driven through the underlying rock by the combined forces of weight-on-bit and torque assumed at the drill bit 100.

[0017] FIG. 1B is a plan view of one of the cutters 116 of FIG. 1A, which includes a generally cylindrical substrate 120 and a diamond table 124 (alternatively referred to as a disc) coupled to the substrate 120 at an interface 122 between the substrate 120 and the diamond table 124. The substrate 120 may be formed of a variety of hard or ultra-hard materials including, but not limited to, steel, steel alloys, tungsten carbide, cemented carbide, and any derivatives and combinations thereof. Suitable cemented carbides may contain varying proportions of titanium carbide (TiC), tantalum carbide (TaC), and niobium carbide (NbC). In at least one embodiment, the substrate 120 may comprise a cylindrical tungsten carbide "blank" that is sufficiently long to act as a mounting stud for the diamond table 124.

[0018] The diamond table 124 may include one or more layers of an ultra-hard material, such as polycrystalline diamond (PCD), polycrystalline cubic boron nitride, impregnated diamond, or another super-abrasive material. The diamond table 124 generally defines or provides a working surface 126, at least a portion of which engages the formation during drilling for cutting/failing the formation. In the orientation shown in FIG. 1B, the interface 122 between the diamond table 124 and the substrate 120 extends between a top surface 128 of the substrate 120 and a bottom surface 130 of the diamond table 124, where the bottom surface 130 is opposite the working surface 126.

[0019] In some embodiments, the diamond table 124 may be formed by subjecting particulate material to a high-temperature, high-pressure (HTHP) press cycle. In at least one embodiment, a catalyzing material (alternately referred to in the art as a catalyst), such as cobalt, iron, nickel or Group VIII elements (and alloys thereof), may be provided to promote bonding between diamond particles during formation of the diamond table 124. Optionally, following the HTHP press cycle used to form the diamond table, the diamond table 124 may be prepared for higher temperature resistance and/or higher wear/abrasion resistance by removing the residual cobalt catalyst from the diamond table 124, such as through a leaching process, prior to bonding the diamond table 124 to the substrate 120. Leaching the diamond table 124 prior to attaching it to the substrate may allow for a more thorough leaching than could be obtained if the diamond table 124 were already mounted to the substrate, in which case leaching can only be done to a controlled depth away from the interface between the diamond table 124 and substrate 120. The

leaching may result in what may be referred to as thermally stable polycrystalline (TSP) diamond. Accordingly, such a diamond table 124 may alternatively be referred to as a "TSP."

[0020] In other embodiments, the TSP may be produced without leaching, by forming the diamond with a non-cobalt catalyst during a single HTHP press cycle. In such embodiments, a particulate mixture comprising grains of a hard material and a non-cobalt or carbonate catalyst material (*e.g.*, a carbonate of one or more of magnesium, calcium, strontium, and barium) may be subjected to elevated temperatures (*e.g.*, temperatures greater than about 2000°C) and elevated pressures (*e.g.*, pressures greater than about 7GPa). This HTHP press cycle may result in the formation of inter-granular bonds between the particles of hard material, and thereby forming the inter-bonded grains of the TSP diamond material without the need for leaching. Accordingly, in at least one embodiment, the diamond table 124 may comprise TSP diamond, but may generally include any PCD that has been become thermally stable, whether leached or not. The as-formed diamond table 124 may subsequently be bonded to the substrate 120, as discussed below.

[0021] Referring now to FIGS. 2A and 2B, illustrated are assembled and exploded cross-sectional side views, respectively, of an exemplary cutter 200, according to one or more embodiments of the disclosure. The cutter 200 may be the same as or similar to the cutter 116 of FIG. 1B and therefore may be best understood with reference thereto, where like numerals represent like elements or components not described again. Similar to the cutter 116 of FIG. 1B, for example, the cutter 200 may include the substrate 120 and the diamond table 124.

[0022] As illustrated, the substrate 120 may provide a first end 202a and a second end 202b opposite the first end 202a. The first end 202a is the same as or similar to the top surface 128 of the substrate 120 depicted in FIG. 1B. At least one hole 204 may be defined within the substrate 120 at the first end 202a. In some embodiments, as illustrated, the hole 204 may extend between the first and second ends 202a,b and otherwise through the entire length of the substrate 120. In other embodiments, however, the hole 204 may not extend the entire length of the substrate 120. Rather, the substrate 120 may alternatively provide a bottom 206 (shown in dashed lines) at a location between the first and second ends 202a,b.

[0023] The diamond table 124 may provide and otherwise define one or more protrusions 208 (one shown) that protrude or extend from the bottom surface 130 of the diamond table 124. The protrusion 208 may be sized and otherwise configured to be received within the hole 204 of the substrate 120. While only one protrusion 208 is depicted in FIGS. 2A and 2B, more than one protrusion 208 may protrude from the bottom surface 130 of the diamond table 124, as shown in FIG. 2C, without departing from the scope of the present disclosure. In such embodiments, each protrusion 208 may be received within a corresponding individual hole 204 defined in the first end 202a of the substrate 120.

[0024] In some embodiments, the protrusion 208 may be formed by laser cutting the diamond table 124 to the desired dimensions and geometry that result in the formation of the protrusion 208. In other embodiments, the protrusion 208 may be formed by electrical discharge machining (EDM) the diamond table 124 to the desired dimensions and geometry. In yet other embodiments, the protrusion 208 may be formed through other known machining, processing, or forming (e.g., molding) methods. In at least one embodiment, the protrusion 208 may be formed during polycrystalline diamond sintering by introducing elements and/or materials inside the forming receptacle, which can provide the required contour or profile without being affected by the HTHP process.

[0025] In some embodiments, as illustrated, the protrusion 208 may exhibit a generally circular cross-section and the hole 204 may correspondingly exhibit a circular cross-section. In other embodiments, however, the protrusion 208 and the hole 208 may each exhibit other cross-sectional shapes including, but not limited to, oval, ovoid, polygonal (e.g., triangular, square, rectangular, pentagonal, etc.), or any combination thereof, without departing from the scope of the disclosure.

[0026] The protrusion 208 may extend from the bottom surface 130 of the diamond table 124, terminating at an end 210. The length or height 212 (FIG. 2B) of the protrusion 208 extending between the bottom surface 130 and the end 210 may vary depending on the application and/or the depth of the hole 204. In at least one embodiment, the height 212 may be about 0.080 inches (2.0 mm), but could alternatively be more or less than 0.080 inches, without departing from the scope of the disclosure. As will be appreciated, having a

larger or greater height 212 may prove advantageous in providing an increased amount of surface area between an outside surface of the protrusion 208 and an inside surface of the hole 204 that may be used to help attach the diamond table 124 to the substrate 120.

[0027] In some embodiments, the protrusion 208 may also provide and otherwise define a transition surface 214 extending between the bottom surface 130 of the diamond table 124 and the side(s) of the protrusion 208. In some embodiments, as illustrated, the transition surface 214 may comprise a radius and may otherwise provide a curved surface. In other embodiments, however, the transition surface 214 may comprise an angled surface, such as a beveled or chamfered surface. In yet other embodiments, the transition surface 214 may comprise a right angle between the bottom surface 130 and the side(s) of the protrusion 208, without departing from the scope of the disclosure. The opening to the hole 204 at the first end 202a of the substrate 120 may be configured to receive and otherwise accommodate the various configurations of the transition surface 214 such that a tight or close fit (but still, optionally, with either an intentional gap or an intentional interference fit, as further discussed herein) between the two components is facilitated.

[0028] As best seen in FIG. 2B, the hole 204 may exhibit a hole width 216a and the protrusion 208 may exhibit a protrusion width 216b. In embodiments where the hole 204 and the protrusion 208 are circular, as discussed above, the hole and protrusion widths 216a,b may comprise corresponding diameters for the hole 204 and the protrusion 208, respectively. According to one or more embodiments, the diamond table 124 may be coupled to the substrate 120 by brazing with an active braze alloy. In such embodiments, the hole 204 may be at least slightly larger than the protrusion 208 at standard temperature and pressure, providing a gap 218 therebetween, such that the protrusion 208 is able to be received within the hole 204. As used herein, the term "standard temperature and pressure" (STP) refers to a pressure of 101325 Pa (1.01325 bar, 14.5 psi, 0.9869 atm) and a temperature of 273 K (0°C, 32°F), although for most practical purposes, typical ambient temperature (i.e. room temperature) and ambient pressure conditions in a drill bit manufacturing environment will be a sufficient approximation of STP for purposes of the present disclosure.

[0029] In the case of a circular hole 204 and protrusion 208, for example, the diameter of the hole 204 may be slightly larger than the diameter of the protrusion 208 to provide the gap 218. In such embodiments, as seen in the enlarged view of FIG. 2A, the gap 218 may be formed between the protrusion 208 and the hole 204 when the protrusion 208 is received within the hole 204. In embodiments where the protrusion 208 and the hole 204 are each circular, the gap 218 may comprise a radial gap between the hole 204 and the protrusion 208. In some embodiments, the gap 218 may occupy a constant radial volume between the about outer peripheries of the hole 204 and the protrusion 208. In other embodiments, however, the size of the gap 218 may vary either radially or along the height 212 (FIG. 2B) of the protrusion 208.

[0030] The gap 218 may allow a selected braze alloy 220 to be deposited at the interface between the protrusion 208 and the hole 204 to form a chemical bond between the diamond table 124 and the braze alloy 220 as well as between the braze alloy 220 and the substrate 120. The size of the gap 218 may allow the braze alloy 220 to migrate into and within the gap 218 during the brazing process by capillary action or otherwise, and thereby secure the diamond table 124 to the substrate 120. The presence of the gap 218 may further prevent the braze alloy 220 from being entirely squeezed out of the hole 204, so that the braze alloy 220 remains in the gap 218 to facilitate bonding between the diamond table 124 and the substrate 120. In at least one embodiment, for instance, the gap 218 may exhibit a dimension that allows for a thickness of the braze alloy 220 at standard temperature to be between about 0.001 inches and about 0.010 inches, since braze alloys achieve maximum joining strength when its thickness is between 0.001 inches to 0.010 inches.

[0031] The braze alloy 220 may comprise an inert, oxidation-resistant metal or metal alloy that can be brazed within the gap 218 with little or no generation of oxides. The material used for the braze alloy 220 may be selected based on one or more critical properties of the material, such as melting temperature (solidus and liquidus temperatures), coefficient of thermal expansion (CTE), ductility, corrosion resistance, and the presence of an active carbide former. An 'active' carbide former is a substance that forms a carbide layer with diamond. Active carbide formers that may be present in a selected braze alloy can include tungsten, molybdenum, titanium, chromium, manganese,

yttrium, zirconium, niobium, hafnium, tantalum, vanadium, or any combination, mixture, or alloy thereof.

[0032] Suitable materials for the braze alloy 220 include, but are not limited to, silver (Ag), copper (Cu), gold (Au), nickel (Ni), indium (In), tin (Sn), palladium (Pd), boron (B), chromium (Cr), silicon (Si), molybdenum (Mo), vanadium (V), iron (Fe), aluminum (Al), manganese (Mn), cobalt (Co), any alloy thereof, and any eutectic/non-eutectic combination thereof. Example "active" braze materials that may be used include those having the following composition and liquidus temperature (LT) and solidus temperatures (ST), where the composition amounts are provided in the form of weight percentages: 81.25 Au, 18 Ni, 0.75 Ti, LT=960°C., ST=945°C.; 82 Au, 16 Ni, 0.75 Mo, 1.25 V, LT=960°C, ST=940°C.; 20.5 Au, 66.5 Ni, 2.1 B, 5.5 Cr, 3.2 Si, 2.2 Fe, LT=971°C., ST=941°C.; 56.55 Ni, 30.5 Pd, 2.45 B, 10.5 Cr, LT=977°C., ST=941°C.; 92.75Cu, 3 Si, 2 Al, 2.25 Ti, LT=1,024°C., ST=969°C.; 82.3 Ni, 3.2 B, 7 Cr, 4.5 Si, 3 Fe, LT=1,024°C.; ST=969°C.; 96.4 Au, 3 Ni, 0.6 Ti, LT=1,030°C., ST=1,003°C; 67.0 Ti, 33.0 Ni, LT=980°C, ST=942°C; 70.0 Ti, 15 Ni, 15 Cu, LT=960°C, ST=910°C, 60.0 Ti, 25 Ni, 15 Cu, LT=940°C, ST=890°C; 92.75 Ag, 5.0 Cu, 1.0 Al, 1.25 Ti, LT=912°C, ST=860°C; 68.8 Ag, 26.7 Cu, 4.5 Ti, LT=900°C, ST=780°C; 63.0 Ag, 35.25 Cu, 1.75 Ti, LT=815°C, ST=780°C; 63.0 Ag, 34.25 Cu, 1.0 Sn, 1.75 Ti, LT=805°C, ST=775°C; and 59.0 Ag, 27.25 Cu, 12.5 In, 1.25 Ti, LT=715°C, ST=605°C.

[0033] Example "nonactive" braze materials that may be used include those having the following composition and LT and ST, where the composition amounts are provided in the form of weight percentages: 52.5 Cu, 9.5 Ni, 38 Mn, LT=925°C., ST=880°C.; 31 Au, 43.5 Cu, 9.75 Ni, 9.75 Pd, 16 Mo, LT=949°C., ST=927°C.; 54 Ag, 21 Cu, 25 Pd, LT=950°C., ST=900°C.; 67.5 Cu, 9 Ni, 23.5 Mn, LT=955°C., ST=925°C.; 58.5 Cu, 10 Co, 31.5 Mn, LT=999°C., ST=896°C.; 35 Au, 31.5 Cu, 14 Ni, 10 Pd, 9.5 Mn, LT=1,004°C., ST=971°C.; 25 Sn, 37 Cu, 10 Ni, 15 Pd, 13 Mn, LT=1,013°C., ST=970°C.; and 35 Au, 62 Cu, 3 Ni, LT=1,030°C., ST=1,000°C.

[0034] Braze materials suitable for use in accordance with the present disclosure can be active and react with the diamond table 124. In an example embodiment, where such an active braze material is used, the braze material can react with the material of the diamond table 124 to form a reaction product therein and/or between it and the adjacent substrate 120. The presence of such

a reaction product can operate to enhance the thermal and/or mechanical properties of the diamond table 124. For example, where the braze material includes silicon or titanium and the diamond table 124 comprises a polycrystalline diamond ultra-hard phase, the silicon or titanium in the braze material can react with the carbon in the diamond to form silicon carbide (SiC) or titanium carbide (TiC).

[0035] In some embodiments, the braze alloy 220 may be doped and/or infiltrated with various materials to enhance the bond between the substrate 120 and the diamond table 124 and/or optimize the CTE of the braze alloy 220. Suitable doping or infiltration materials include a ceramic, a metal with high ductility or yield stress, a polymeric material, or a mixture or combination thereof. Suitable ceramics that may be used to dope the braze alloy 220 include, but are not limited to, tungsten carbide, silicon carbide, diamond, nanodiamond, nanocarbon, graphene, carbon nanotubes, and the like. Suitable metals that may be used to dope the braze alloy 220 include, but are not limited to, copper, silver, gold, nickel, and any combination thereof.

[0036] In preparation for the brazing process, the braze alloy 220 may be deposited at various locations on the cutter 200 to ensure a strong bond between the substrate 120 and the diamond table 124. Portions of the braze alloy 220, for example, may be deposited on outer surfaces of the diamond table 124, such as on the bottom surface 130, the end 210, the transition surface 214, and any locations therebetween. The braze alloy 220 may also be applied to the inner surfaces of the hole 204 and on the first end 202a (*i.e.*, the top surface 128) of the substrate 120. In some embodiments, an amount of the braze alloy 220 may be deposited within the hole 204 via the opening at the second end 202b (*i.e.*, when the bottom 206 is omitted) or placed at the bottom 206 of the hole 204. In such embodiments, upon melting the braze alloy 220 during the brazing process, the liquefied braze alloy 220 may migrate due to capillary effect and fill in the gap 218 between the substrate 120 and the diamond table 124.

[0037] In some embodiments, the substrate 120 may be made of a material that exhibits a CTE that is greater than the CTE of the material of the diamond table 124. For example, the substrate 120 may comprise cemented-tungsten carbide (WC), which exhibits a CTE ($10^{-6}/^{\circ}\text{K}$) of about 4.5 to about 6.5, and the diamond table 124 may comprise TSP, which exhibits a CTE ($10^{-6}/^{\circ}\text{K}$) of

about 1.0 to about 1.5. Accordingly, during the brazing process, which increases the temperature of the cutter 200 to a point at or above the melting temperature of the braze alloy 220, the hole 204 will thermally expand to a greater extent than the protrusion 208, and the dimensions of the gap 218 will correspondingly increase. As the braze alloy 220 melts, as mentioned above, it may be able to migrate into and fill the expanded gap 218 between the substrate 120 and the diamond table 124 via capillary action. Upon cooling the cutter 200, the gap 218 returns to standard temperature dimensions (i.e., dimensions when the cutter is at or around room temperature) and thereby places the solidified braze alloy 220 between the protrusion 208 and the hole 204 in compression.

[0038] A small portion of the braze alloy 220 may be forced out of the gap 218 under compression while the temperature of the braze alloy 220 is higher than its solidus temperature and the size of the hole 204 decreases with decreasing temperature. Once the temperature of the braze alloy 220 reaches and surpasses the solidus temperature during the cooling cycle of the brazing process, however, the substrate 120 (i.e., the hole 204) still contracts at a faster rate than the diamond table 124 (i.e., the protrusion 208), and thereby places the braze alloy 220 in compression.

[0039] In one example case, the size of the gap 218 may be about 0.002 inches at standard temperature, but at brazing temperature the size of the gap 218 may increase to about 0.004 inches. As a result, during cooling back to standard temperature almost half of the volume of the braze alloy 220 will be squeezed out of the braze joint between the protrusion 208 and the hole 204, and the braze alloy 220 that remains in the braze joint will be placed in compression and tightly secured between the protrusion 208 and adjacent portions of the substrate 120. Moreover, the resulting compressive forces on the braze alloy 220 at the gap 218 may remain up to at least the solidus temperature of the braze alloy 220.

[0040] As will be appreciated, placing the braze alloy 220 in compression may increase the shear strength of the cutter 200 and reduce the risk of detaching the diamond table 124 from the substrate 120 during downhole drilling operations. This is in contrast to standard brazing of a TSP diamond disc with a flat interface to a substrate, where there is no resulting compression on the braze alloy 220. In such cases, residual stresses may be present at the

interface between the TSP diamond and the substrate due to a mismatch in CTE between the TSP diamond, the braze alloy 220, and the substrate.

[0041] According to one or more additional embodiments, the diamond table 124 may alternatively be coupled to the substrate 120 by generating an interference fit between the protrusion 208 and the hole 204. As will be appreciated, an interference fit between the protrusion 208 and the hole 204 may optionally avoid the need for conventional joining techniques, such as brazing or an HTHP press cycle configured to join the diamond table 124 to the substrate 120. Rather, the respective geometries of the protrusion 208 and the hole 204 and the respective CTE of the substrate 120 and the diamond table 124 may be selected such that the interference fit, alone, may be sufficient to maintain the diamond table 124 coupled to the substrate 120 during drilling operations.

[0042] In such embodiments, for instance, the hole width 216a may be smaller than the protrusion width 216b at standard temperature and may also be smaller over an expected range of drilling operating temperatures. Commonly expected drilling operating temperatures at least at a point of contact between the diamond table 214 and the formation being cut can range between about 800°C and about 900°C at the tip or outer surface of the diamond table(s) 214. To achieve a robust interference fit for drilling, the hole width 216a will be smaller than the protrusion width 216b and will remain smaller even at temperatures exceeding the expected range of drilling operating temperatures.

[0043] Moreover, in such embodiments, the substrate 120 may again be made of a material (*e.g.*, cemented-WC) that exhibits a CTE that is greater than the CTE of the material (*e.g.*, TSP) of the diamond table 124. The interference fit between the protrusion 208 and the hole 204 may be generated by various methods. In one embodiment, for instance, the interference fit may be generated by heating the substrate 120 to a temperature above that of the expected range of drilling operating temperatures. This will allow the hole 204 to thermally expand and otherwise increase the size of the hole width 216a to a dimension greater than that of the protrusion width 216b. At that point, the hole 204 may be large enough to receive the protrusion 208. Once the protrusion 208 is inserted into the hole 204, the substrate 120 may then be cooled back to standard temperature, thereby allowing the hole 204 to thermally contract as the size of the hole width 216a decreases to standard temperature

dimensions. At standard temperature, the protrusion 208 may be secured within the hole 204 via an interference fit that may withstand the expected range of drilling operating temperatures.

[0044] In other cases, the interference fit may be generated by cooling the diamond table 124 such that the protrusion 208 thermally contracts and the dimensions of the protrusion width 216b otherwise become smaller than that of the hole width 216a. At that point, the protrusion 208 may be small enough to be received within the hole 204. Once the protrusion 208 is inserted into the hole 204, the diamond table 124 may then be allowed to warm back up to standard temperature, whereby the protrusion 208 thermally expands to the protrusion width 216b standard temperature dimensions and an interference fit is thereby generated at the interface between the protrusion 208 and the hole 204. In yet other cases, the interference fit may be generated by a combination of heating the substrate 120 to a temperature above that of the expected range of drilling operating temperatures and cooling the diamond table 124.

[0045] In even further embodiments, the interference fit may be generated by heating both the substrate 120 the diamond table 124 to a temperature above that of the expected range of drilling operating temperatures. In such embodiments, because of the large difference in CTE between the substrate 120 the diamond table 124, the hole 204 will thermally expand at a rate much greater than that of the protrusion 208, thereby allowing the hole 204 to eventually be large enough to receive the protrusion 208. Cooling the cutter 200 will then result in an interference fit between the hole 204 and the protrusion 208.

[0046] With the interference fit successfully generated, there may be no need to braze the diamond table 124 to the substrate 120. In some embodiments, however, in addition to the interference fit, brazing may optionally be undertaken at the interface between the diamond table 124 to the substrate 120, without departing from the scope of the disclosure.

[0047] FIG. 2C is an isometric view of another embodiment of the diamond table 214. In the illustrated embodiment, the diamond table 124 may provide and otherwise define a plurality of protrusions 208, shown as a first protrusion 208a, a second protrusion 208b, and a third protrusion 208c. Each protrusion 208a-c protrudes or extends from the bottom surface 130 of the diamond table 124. Similar to the protrusion 208 of FIGS. 2A and 2B, each

protrusion 208a-c may be sized to be received within a corresponding hole defined in the first end 202a (FIGS. 2A-2B) of the substrate 120 (FIGS. 2A-2B). While three protrusions 208a-c are depicted in FIG. 2C, it will be appreciated that more than three (or two) protrusion 208a-c may protrude from the bottom surface 130 of the diamond table 124, without departing from the scope of the present disclosure. Moreover, while the protrusions 208a-c are depicted as exhibiting a generally circular cross-section, any one of the protrusions 208a-c may alternatively each exhibit other cross-sectional shapes including, but not limited to, oval, ovoid, polygonal (e.g., triangular, square, rectangular, pentagonal, etc.), or any combination thereof, without departing from the scope of the disclosure.

[0048] Referring now to FIGS. 3A and 3B, with continued reference to FIGS. 2A-2B, illustrated are cross-sectional side views of the cutter 200, according to one or more embodiments of the disclosure. Once the diamond table 124 is successfully coupled to the substrate 120 via brazing or an interference fit, or a combination of the two, as generally described above, the remaining open portions of the hole 204 defined through the substrate 120 may serve several purposes. As shown in FIG. 3A, for example, the hole 204 may be at least partially filled with a thermally conductive material 302. The thermally conductive material 302 may draw thermal energy 304 away from the cutter 200 and, more particularly, from the diamond table 124 during operation. The cutter 200 may be secured within a corresponding cutter pocket 118 (FIG. 1) provided on the drill bit 100 (FIG. 1) with the second end 202b of the substrate 120 in contact with or otherwise adjacent the cutter pocket 118. As a result, the thermally conductive material 302 may also be in thermal communication with the body 102 (FIG. 1) of the drill bit 100 and may be able to transfer thermal energy 304 from the cutter 200 to the bit body 102 during operation.

[0049] Suitable materials that may be used as the thermally conductive material 302 include, but are not limited to, a ceramic (e.g., oxides, carbides, borides, nitrides, silicides), a metal (e.g., aluminum, gold, copper, silver, steel, stainless steel, nickel, tungsten, titanium or alloys thereof), diamond, alumina, graphite, graphene, nanomaterials of the foregoing, and any combination thereof. Generally, the thermally conductive material 302 may comprise any material that exhibits thermal conductivity of 10^2 W/m·K or greater. Drawing thermal energy 304 away from the cutter 200 and using the bit body 102 (FIG.

1) as a heat sink may prove advantageous in mitigating or preventing graphitization of the diamond table 124, which would otherwise make the diamond table 124 less wear-resistant.

[0050] With reference to FIG. 3B, in some embodiments, the hole 204 may alternatively be at least partially filled with one or more temperature-sensitive materials 306, shown as a first temperature-sensitive material 306a and a second temperature-sensitive material 306b. The temperature-sensitive materials 306a,b may each comprise a material that undergoes a phase transformation and/or a crystalline structure change at a known or fixed temperature. By examining the temperature-sensitive materials 306a,b following operation of the drill bit 100 (FIG. 1), it can be ascertained whether the drill bit 100 operated in downhole conditions that exceeded the known temperature.

[0051] In one or more embodiments, for example, the first temperature-sensitive material 306a may comprise a powder material capable of passing through a phase change, such as from a solid state to a liquid or molten state, at a specific temperature. Upon returning the drill bit 100 (FIG. 1) back to the surface, the cutter 200 may be removed and the first temperature-sensitive material 306a may be analyzed. If the first temperature-sensitive material 306a is a solid mass, that may be an indication that the drill bit 100 operated in a downhole temperature that exceeded the known melting temperature of first temperature-sensitive material 306a, which melted the powder and resulted in the solid mass upon cooling. If, however, the first temperature-sensitive material 306a remains a powder, that may be an indication that drilling conditions at the drill bit 100 failed to exceed the melting temperature of first temperature-sensitive material 306a.

[0052] Suitable phase changing materials that may be used as the first temperature-sensitive material 306a include, but are not limited to, aluminum, copper, nickel, manganese, lead, tin, cobalt, silver, phosphorous, zinc, any alloys thereof, and any mixtures of the metallic alloys. Other suitable phase changing materials include salts of sodium and potassium (e.g., KOH, KNO₃, NaNO₃, NaOH) or a combination thereof, such as NaCl (26.8%) / NaOH or NaCl (42.5%) / KCl (20.5) / MgCl₂. As will be appreciated, a plurality of phase changing materials having known melting temperatures may be arranged in the hole 204 and post-analysis of the cutter 200 and the condition of the various

phase change materials may reveal specific operating temperatures that drill bit 100 experienced during operation.

[0053] In other embodiments, the second temperature-sensitive material 306b may comprise a material that changes crystalline structure upon reaching and exceeding a known crystalline transition temperature. Upon returning the drill bit 100 (FIG. 1) to the surface following operation, the cutter 200 may be removed and the second temperature-sensitive material 306b may be analyzed. If the crystalline structure of the second temperature-sensitive material 306b has changed, that may be an indication that the drill bit 100 operated in a downhole temperature that exceeded the known crystalline transition temperature of the second temperature-sensitive material 306b. If, however, the crystalline structure of the second temperature-sensitive material 306b remains the same, that may be an indication that drilling conditions at the drill bit 100 failed to exceed the known crystalline transition temperature of the second temperature-sensitive material 306b.

[0054] In at least one embodiment, for example, the second temperature-sensitive material 306b may comprise α -iron (i.e., alpha-iron or 'ferrite'), which undergoes a crystalline phase transition at around 912°C from body-centered cubic (BCC) to the face-centered cubic (FCC) configuration of γ -iron (i.e. gamma-iron or 'austenite'). This is commonly called an allotropic transformation. Other suitable temperature-sensitive materials that may undergo a crystalline allotropic phase transition include, but are not limited to, zirconium, titanium, and cobalt. Moreover, as will be appreciated, a plurality of materials that change crystalline structure upon reaching and exceeding a known crystalline transition temperature may be arranged in the hole 204 and post-analysis of the cutter 200 and the condition of the various materials may reveal specific operating temperatures that drill bit 100 experienced during operation.

[0055] Referring now to FIG. 4, illustrated is an exploded cross-sectional side view of a cutter assembly 400, according to one or more embodiments. The cutter assembly 400 may be installed on a portion of the drill bit 100 of FIG. 1 and, more particularly, within a cutter pocket 118 defined on a blade 104 of the drill bit 100. As illustrated, the cutter assembly 400 may include a cutter 402 and a post 404. The cutter 402 may be similar to or the same as the cutter 116 of FIG. 1B, and therefore may be best understood with

reference thereto. Similar to the cutter 116 of FIG. 1B, for example, the cutter 402 may include the substrate 120 and the diamond table 124.

[0056] As illustrated, the substrate 120 may provide a first end 406a and a second end 406b opposite the first end 406a. The first end 406a is the same as or similar to the top surface 128 of the substrate 120 depicted in FIG. 1B. At least one post receptacle 408 may be defined within the substrate 120 and extend at least partially between the first and second ends 406a,b. As will be appreciated, the post receptacle 408 may be the same as or similar to the hole 204 of FIGS. 2A-2B and 3A-3B. In some embodiments, as illustrated, the post receptacle 408 may extend all the way between the first and second ends 406a,b and thereby defining a corresponding elongate channel that extends through the entire length of the substrate 120. In some embodiments, at least one table post receptacle 410 may be defined within the diamond table 124 and extend at least partially between the working surface 126 and the bottom surface 130 of the diamond table 124. As illustrated, the table post receptacle 410 may generally align with the post receptacle 408. In other embodiments, however, the table post receptacle 410 may be omitted from the diamond table 124.

[0057] The post 404 may provide a first post end 412a and a second post end 412b opposite the first post end 412a. As illustrated, the second post end 412b of the post 404 may extend into the blade 104 and may otherwise be secured within a post orifice 414 defined in the bottom of the cutter pocket 118. The post 404 may be secured within the post orifice 414 by a variety of attachment means including, but not limited to, brazing, welding, industrial adhesives, threading, one or more mechanical fasteners (*e.g.*, snap rings, pins, screws, etc.), shrink-fitting, interference fitting, and any combination thereof. In some embodiments, however, the post 404 may comprise a molded portion that extends out of the cutter pocket 118. In yet other embodiments, the geometry and dimensions of the post 404 may be machined into the cutter pocket 118.

[0058] In some embodiments, as illustrated, the post 404 may provide and otherwise define an enlarged portion 416 (shown in dashed) at the second post end 412b. The enlarged portion 416 may take the form of any shape or configuration, and may prove advantageous in increasing the surface area of the post 404 within the blade 104. Such an increased surface area may provide

greater pull-out resistance and for the post 404 and increase the rigidity of the coupling engagement between the cutter 402 and the cutter pocket 118.

[0059] The post 404 may be sized and otherwise configured to be received within the post receptacle 408 of the substrate 120. While only one post 404 is depicted in FIG. 4, it will be appreciated that more than one post 404 may protrude from the cutter pocket 118, without departing from the scope of the present disclosure. In such embodiments, the plurality of posts 404 may be received within a corresponding plurality of post receptacles 408 defined in the second end 406b of the substrate 120.

[0060] In some embodiments, as illustrated, the post 404 may exhibit a generally circular cross-section and the post receptacle 408 (and the table post receptacle 410, if used) may correspondingly exhibit a circular cross-section. In other embodiments, however, the post 404 and the post receptacle 408 (and the table post receptacle 410, if used) may each exhibit other cross-sectional shapes including, but not limited to, oval, ovoid, polygonal (e.g., triangular, square, rectangular, pentagonal, etc.), or any combination thereof, without departing from the scope of the disclosure.

[0061] The post receptacle 408 may exhibit a first width 418a and the post 404 may exhibit a second width 418b. In embodiments where the post receptacle 408 and the post 404 are circular, as discussed above, the first and second widths 418a,b may comprise corresponding diameters for the post receptacle 408 and the post 404, respectively. In embodiments where the post receptacle 408 and the post 404 are polygonal, however, the first and second widths 418a,b may comprise the largest distance between opposing sides of each respective structure.

[0062] In some embodiments, the cutter 402, or at least the substrate 120, may be coupled to the cutter pocket 118 by brazing the post 404 into the post receptacle 408. In other embodiments, however, the cutter 402 may be coupled to the cutter pocket 118 by generating an interference fit between the post 404 and the post receptacle 408. As will be appreciated, an interference fit between the post 404 and the post receptacle 408 may optionally avoid the need for conventional joining techniques, such as brazing the cutter 402 into the cutter pocket 118. Rather, the respective geometries of the post 404 and the post receptacle 408 and the respective CTE of the substrate 120 and the post

404 may be selected such that the interference fit, alone, may be sufficient to maintain the substrate 120 coupled to post 404 during drilling operations.

[0063] In such embodiments, for instance, the first width 418a may be smaller than the second width 418b at standard temperature and may also be smaller over an expected range of drilling operating temperatures. In other words, in order to achieve a robust interference fit for drilling, the first width 418a is smaller than the second width 418b and will remain smaller even at temperatures exceeding the expected range of drilling operating temperatures.

[0064] Moreover, in such embodiments, the substrate 120 may be made of a material (e.g., WC) that exhibits a CTE that is greater than the CTE of the material of the post 404. The interference fit between the post 404 and the post receptacle 408 may be generated by various methods. In one embodiment, for instance, the interference fit may be generated by heating the substrate 120 to a temperature above that of the expected range of drilling operating temperatures. This will allow the post receptacle 408 to thermally expand and otherwise increase the size of the first width 418a to a dimension greater than that of the second width 418b. At that point, the post receptacle 408 may be large enough to receive the post 404. Once the post 404 is inserted into the post receptacle 408, the substrate 120 may then be cooled back to standard temperature, thereby allowing the post receptacle 408 to thermally contract as the size of the first width 418a decreases to standard temperature dimensions. At standard temperature, the post 404 may be secured within the post receptacle 408 via an interference fit that may withstand the expected range of drilling operating temperatures.

[0065] In other cases, the interference fit may be generated by cooling the post 404 such that the post 404 thermally contracts and the dimensions of the second width 418b otherwise become smaller than that of the first width 418a. At that point, the post receptacle 408 may be large enough to receive the post 404, or otherwise the post 404 may be small enough to be received within the post receptacle 408. Once the post 404 is inserted into the post receptacle 408, the post 404 may then be allowed to warm back up to standard temperature, whereby the post 404 thermally expands to second width 418b standard temperature dimensions and an interference fit is thereby generated at the interface between the post 404 and the post receptacle 408. In yet other cases, the interference fit may be generated by a combination of heating the

substrate 120 to a temperature above that of the expected range of drilling operating temperatures and cooling the post 404.

[0066] In even further embodiments, the interference fit may be generated by heating both the substrate 120 and the post 404 to a temperature above that of the expected range of drilling operating temperatures, without departing from the scope of the disclosure. In such embodiments, because of the large difference in CTE between the substrate 120 the post 404, the post receptacle 408 will thermally expand at a rate much greater than the post 404, thereby allowing the post receptacle 408 to eventually be large enough to receive the post 404. Cooling the cutter 402 will then result in an interference fit between the post receptacle 408 and the post 404.

[0067] With the interference fit successfully generated, there may be no need to braze the post 404 to the substrate 120. In some embodiments, however, in addition to the interference fit, brazing may optionally be undertaken at the interface between the post 404 to the substrate 120 or at the interface between the substrate 120 and the cutter pocket 118, without departing from the scope of the disclosure.

[0068] In some embodiments, the diamond table 124 may be coupled to the substrate 120 via conventional means, such as brazing or an HTHP process. In other embodiments, however, the length of the post 404 may be sufficiently long to extend through the post receptacle 408 and at least partially into the table post receptacle 410 and thereby allow an attachment point for the diamond table 124. In such embodiments, the diamond table 124 may be brazed to the substrate 120 via the post 404. In other embodiments, however, the diamond table 124 may be coupled to the substrate 120 via an interference fit with the post 404. More particularly, the table post receptacle 410 may exhibit a third width 418c, which may comprise a diameter if the table post receptacle 410 and the post 404 are each circular, or may otherwise comprise the largest distance between opposing sides of table post receptacle 410 in the event the table post receptacle 410 and the post 404 are each polygonal.

[0069] To generate an interference fit, the third width 418c may be smaller than the second width 418b at standard temperature and may also be smaller over an expected range of drilling operating temperatures. The interference fit may be generated as generally described above, such as by heating the diamond table 124 to a temperature above that of the expected

range of drilling operating temperatures, which allows the table post receptacle 410 to thermally expand and otherwise increase the size of the third width 418c to a dimension greater than that of the second width 418b. At that point, the table post receptacle 410 may be large enough to receive the post 404, and once it cools, the table post receptacle 410 thermally contracts to secure the post 404 via an interference fit that may withstand the expected range of drilling operating temperatures. In other cases, the interference fit may be similarly generated by cooling the post 404, or a combination of heating the diamond table 124 and cooling the post 404. In even further embodiments, the interference fit may be generated by heating both the diamond table 124 the post 404 to a temperature above that of the expected range of drilling operating temperatures, as discussed above.

[0070] With the interference fit successfully generated, there may be no need to braze the post 404 to the diamond table 124. In some embodiments, however, in addition to the interference fit, brazing may optionally be undertaken at the interface between the post 404 to the diamond table 124, without departing from the scope of the disclosure.

[0071] Referring now to FIG. 5, illustrated is an exploded cross-sectional side view of another cutter assembly 500, according to one or more embodiments. The cutter assembly 500 may be installed on a portion of the drill bit 100 of FIG. 1 and, more particularly, on a blade 104 of the drill bit 100. The cutter assembly 500 may include a cutter 502 and a post 504. Unlike the cutters 116, 200, and 400 of FIGS. 1A-1B, 2A-2B, 3A-3B, and 4, the cutter 502 may include only the diamond table 124. As illustrated, the diamond table 124 may provide the working surface 126 and a bottom surface 130 opposite the working surface 126. At least one table post receptacle 506 may be defined within the diamond table 124 and extend at least partially between the working surface 126 and the bottom surface 130 of the diamond table 124. In at least one embodiment, the table post receptacle 506 may extend entirely through the diamond table 124 between the working and bottom surfaces 126, 130.

[0072] The post 504 may provide a first post end 508a and a second post end 508b opposite the first post end 508a. As illustrated, the second post end 508b of the post 504 may extend into the blade 104 and may otherwise be secured within a post orifice 510 defined in the blade 104. In some embodiments, as illustrated, the post orifice 510 may be defined in a body

protrusion 512 extending from the outer surface of the blade 104. The body protrusion 512 may form an integral part of the bit body 102 (FIG. 1) and may otherwise be molded as a feature of the blade 104. The body protrusion 512 may provide a location to house the post 504 and may otherwise replace the substrate 120.

[0073] The post 504 may be secured within the post orifice 510 by a variety of attachment means including, but not limited to, brazing, welding, industrial adhesives, threading, one or more mechanical fasteners (*e.g.*, snap rings, pins, screws, etc.), shrink-fitting, interference fitting, and any combination thereof. In some embodiments, however, the post 504 may comprise a molded portion of the blade 104 that extends away from the body protrusion 512. In yet other embodiments, the geometry and dimensions of the post 504 may be machined into the body protrusion 512.

[0074] In some embodiments, as illustrated, the post 504 may provide and otherwise define an enlarged portion 514 (shown in dashed) at the second post end 508b. The enlarged portion 514 may take the form of any shape or configuration, and may prove advantageous in increasing the surface area of the post 504 within the blade 104. Such an increased surface area may provide greater pull-out resistance and for the post 504 and increase the rigidity of the coupling engagement between the cutter 502 and the body protrusion 512.

[0075] The post 504 may be sized and otherwise configured to be received within the table post receptacle 506 of the diamond table 124. While only one post 504 is depicted in FIG. 5, it will be appreciated that more than one post 504 may protrude from the body protrusion 512, without departing from the scope of the present disclosure. In such embodiments, the plurality of posts 504 may be received within a corresponding plurality of table post receptacles 506 defined in the bottom surface 130 of the diamond table 124.

[0076] In some embodiments, as illustrated, the post 504 may exhibit a generally circular cross-section and the table post receptacle 506 may correspondingly exhibit a circular cross-section. In other embodiments, however, the post 504 and the table post receptacle 506 may each exhibit other cross-sectional shapes including, but not limited to, oval, ovoid, polygonal (*e.g.*, triangular, square, rectangular, pentagonal, etc.), or any combination thereof, without departing from the scope of the disclosure.

[0077] The table post receptacle 506 may exhibit a first width 516a and the post 504 may exhibit a second width 516b. In embodiments where the table post receptacle 506 and the post 504 are circular, as discussed above, the first and second widths 516a,b may comprise corresponding diameters for the table post receptacle 506 and the post 504, respectively. In embodiments where the table post receptacle 506 and the post 504 are polygonal, however, the first and second widths 516a,b may comprise the largest distance between opposing sides of each respective structure.

[0078] In some embodiments, the diamond table 124 may be coupled to the body protrusion 512 by brazing the post 504 into the table post receptacle 506. In other embodiments, however, the diamond table 124 may be coupled to the body protrusion 512 by generating an interference fit between the post 504 and the table post receptacle 506. As will be appreciated, an interference fit between the post 504 and the table post receptacle 506 may optionally avoid the need for conventional joining techniques, such as brazing the diamond table 124 to the body protrusion 512. Rather, the respective geometries of the post 504 and the table post receptacle 506 and the respective CTE of the diamond table 124 and the post 504 may be selected such that the interference fit, alone, may be sufficient to maintain the diamond table 124 coupled to post 504 during drilling operations.

[0079] In such embodiments, for instance, the first width 516a may be smaller than the second width 516b at standard temperature and may also be smaller over an expected range of drilling operating temperatures. In other words, in order to achieve a robust interference fit for drilling, the first width 516a is smaller than the second width 516b and will remain smaller even at temperatures exceeding the expected range of drilling operating temperatures.

[0080] The interference fit between the post 504 and the table post receptacle 506 may be generated by various methods. In one embodiment, for instance, the interference fit may be generated by heating the diamond table 124 to a temperature above that of the expected range of drilling operating temperatures. This will allow the table post receptacle 506 to thermally expand and otherwise increase the size of the first width 516a to a dimension greater than that of the second width 516b. At that point, the table post receptacle 506 may be large enough to receive the post 504. Once the post 504 is inserted into the table post receptacle 506, the diamond table 124 may then be cooled back

to standard temperature, thereby allowing the table post receptacle 506 to thermally contract as the size of the first width 516a decreases to standard temperature dimensions. At standard temperature, the post 504 may be secured within the table post receptacle 506 via an interference fit that may withstand the expected range of drilling operating temperatures.

[0081] In other cases, the interference fit may be generated by cooling the post 504 such that the post 504 thermally contracts and the dimensions of the second width 516b otherwise become smaller than that of the first width 516a. At that point, the table post receptacle 506 may be large enough to receive the post 504, or otherwise the post 504 may be small enough to be received within the table post receptacle 506. Once the post 504 is inserted into the table post receptacle 506, the post 504 may then be allowed to warm back up to standard temperature, whereby the post 504 thermally expands to second width 516b standard temperature dimensions and an interference fit is thereby generated at the interface between the post 504 and the table post receptacle 506. In yet other cases, the interference fit may be generated by a combination of heating the diamond table 124 to a temperature above that of the expected range of drilling operating temperatures and cooling the post 504.

[0082] With the interference fit successfully generated, there may be no need to braze the diamond table 124 to the post 504. In some embodiments, however, in addition to the interference fit, brazing may optionally be undertaken at the interface between the post 504 to the diamond table 124 or at the interface between the diamond table 124 and the body protrusion 512, without departing from the scope of the disclosure.

[0083] Embodiments disclosed herein include:

[0084] A. A cutter for a drill bit that includes a substrate defining a hole at least partially through the substrate, a diamond table including a protrusion received within the hole such that a gap is defined between the protrusion and the substrate ranging between 0.001 and 0.010 inches when the substrate and diamond table are at standard temperature and pressure (STP), and a braze alloy coupling the diamond table to the substrate at an interface between the diamond table and the substrate, wherein at least a portion of the braze alloy is disposed in the gap in compression between the protrusion on the diamond and the hole in the substrate.

[0085] B. A cutter for a drill bit that includes a substrate defining a hole at least partially through the substrate, a diamond table, and a protrusion extending from the diamond table at least partially into the hole and in direct mechanical contact with the substrate via an interference fit between the protrusion and the substrate when at STP.

[0086] C. A drill bit that includes a bit body having one or more blades extending therefrom, and a plurality of cutters secured to the one or more blades, wherein at least one cutter of the plurality of cutters includes a substrate defining a hole at least partially through the substrate, a diamond table including a protrusion received within the hole such that a gap is defined between the protrusion and the substrate ranging between 0.001 and 0.010 inches when the substrate and diamond table are at standard temperature and pressure (STP), and a braze alloy coupling the diamond table to the substrate at an interface between the diamond table and the substrate, wherein at least a portion of the braze alloy is disposed in the gap in compression between the protrusion on the diamond and the hole in the substrate.

[0087] Each of embodiments A, B, and C may have one or more of the following additional elements in any combination: Element 1: wherein the interface between the diamond table and the substrate further comprises a planar face about the protrusion on the diamond table in close engagement with a corresponding planar face about the hole on the substrate, and wherein another portion of the braze alloy secures the planar face of the diamond table to the planar face of the substrate. Element 2: wherein the protrusion on the diamond table and the hole on the substrate are both circular, and the gap is a substantially constant-radial gap between the protrusion and the substrate. Element 3: wherein the diamond table has a first coefficient of thermal expansion (CTE) and the substrate has a second CTE greater than the first CTE. Element 4: wherein the diamond table comprises a plurality of protrusions. Element 5: wherein the braze alloy remains in compression up to at least a solidus temperature of the braze alloy. Element 6: further comprising one of a thermally conductive material and a temperature-sensitive material positioned in the hole at a location not occupied by the protrusion and the braze alloy. Element 7: wherein the thermally conductive material or the temperature-sensitive material is in direct mechanical contact with an end of the protrusion.

[0088] Element 8: wherein the diamond table defines the protrusion. Element 9: wherein the protrusion comprises a post extending all the way through the hole on the substrate and having one end coupled to the diamond table and another end opposite the diamond table for coupling to a cutter pocket of a drill bit. Element 10: wherein the diamond table comprises a hole aligned with the hole on the substrate, and wherein the post extends into the hole on the diamond table. Element 11: further comprising a braze alloy between a planar face about the protrusion on the diamond table and a corresponding planar face about the hole on the substrate, wherein the braze alloy secures the planar face of the diamond table to the planar face of the substrate.

[0089] Element 12: wherein the interface between the diamond table and the substrate further comprises a planar face about the protrusion on the diamond table in close engagement with a corresponding planar face about the hole on the substrate, and wherein a braze alloy at the interface secures the planar face of the diamond table to the planar face of the substrate. Element 13: wherein the protrusion on the diamond table and the hole on the substrate are both circular, and the gap is a substantially constant-radial gap between the protrusion and the substrate. Element 14: wherein the diamond table has a first coefficient of thermal expansion (CTE) and the substrate has a second CTE greater than the first CTE. Element 15: wherein the compression on the braze alloy is maintained up to at least a solidus temperature of the braze alloy. Element 16: further comprising one of a thermally conductive material and a temperature-sensitive material positioned in the hole at a location not occupied by the protrusion and the braze alloy. Element 17: further comprising a post extending from a cutter pocket on the one or more blades and secured within the hole of the substrate.

[0090] By way of non-limiting example, exemplary combinations applicable to A, B, and C include: Element 9 with Element 10.

[0091] Therefore, the disclosed systems and methods are well adapted to attain the ends and advantages mentioned as well as those that are inherent therein. The particular embodiments disclosed above are illustrative only, as the teachings of the present disclosure may be modified and practiced in different but equivalent manners apparent to those skilled in the art having the benefit of the teachings herein. Furthermore, no limitations are intended to the details of construction or design herein shown, other than as described in the claims

below. It is therefore evident that the particular illustrative embodiments disclosed above may be altered, combined, or modified and all such variations are considered within the scope of the present disclosure. The systems and methods illustratively disclosed herein may suitably be practiced in the absence of any element that is not specifically disclosed herein and/or any optional element disclosed herein. While compositions and methods are described in terms of "comprising," "containing," or "including" various components or steps, the compositions and methods can also "consist essentially of" or "consist of" the various components and steps. All numbers and ranges disclosed above may vary by some amount. Whenever a numerical range with a lower limit and an upper limit is disclosed, any number and any included range falling within the range is specifically disclosed. In particular, every range of values (of the form, "from about a to about b," or, equivalently, "from approximately a to b," or, equivalently, "from approximately a-b") disclosed herein is to be understood to set forth every number and range encompassed within the broader range of values. Also, the terms in the claims have their plain, ordinary meaning unless otherwise explicitly and clearly defined by the patentee. Moreover, the indefinite articles "a" or "an," as used in the claims, are defined herein to mean one or more than one of the elements that it introduces. If there is any conflict in the usages of a word or term in this specification and one or more patent or other documents that may be incorporated herein by reference, the definitions that are consistent with this specification should be adopted.

[0092] As used herein, the phrase "at least one of" preceding a series of items, with the terms "and" or "or" to separate any of the items, modifies the list as a whole, rather than each member of the list (*i.e.*, each item). The phrase "at least one of" allows a meaning that includes at least one of any one of the items, and/or at least one of any combination of the items, and/or at least one of each of the items. By way of example, the phrases "at least one of A, B, and C" or "at least one of A, B, or C" each refer to only A, only B, or only C; any combination of A, B, and C; and/or at least one of each of A, B, and C.

CLAIMS

What is claimed is:

1. A cutter for a drill bit, the cutter comprising:
a substrate defining a hole at least partially through the substrate;
a diamond table including a protrusion received within the hole such that a gap is defined between the protrusion and the substrate ranging between 0.001 and 0.010 inches when the substrate and diamond table are at standard temperature and pressure (STP); and
a braze alloy coupling the diamond table to the substrate at an interface between the diamond table and the substrate, wherein at least a portion of the braze alloy is disposed in the gap in compression between the protrusion on the diamond and the hole in the substrate.
2. The cutter of claim 1, wherein the interface between the diamond table and the substrate further comprises a planar face about the protrusion on the diamond table in close engagement with a corresponding planar face about the hole on the substrate, and wherein another portion of the braze alloy secures the planar face of the diamond table to the planar face of the substrate.
3. The cutter of claim 1, wherein the protrusion on the diamond table and the hole on the substrate are both circular, and the gap is a substantially constant-radial gap between the protrusion and the substrate.
4. The cutter of claim 1, wherein the diamond table has a first coefficient of thermal expansion (CTE) and the substrate has a second CTE greater than the first CTE.
5. The cutter of claim 1, wherein the diamond table comprises a plurality of protrusions.
6. The cutter of claim 1, wherein the braze alloy remains in compression up to at least a solidus temperature of the braze alloy.

7. The cutter of claim 1, further comprising one of a thermally conductive material and a temperature-sensitive material positioned in the hole at a location not occupied by the protrusion and the braze alloy.

8. The cutter of claim 7, wherein the thermally conductive material or the temperature-sensitive material is in direct mechanical contact with an end of the protrusion.

9. A cutter for a drill bit, the cutter comprising:
a substrate defining a hole at least partially through the substrate;
a diamond table; and
a protrusion extending from the diamond table at least partially into the hole and in direct mechanical contact with the substrate via an interference fit between the protrusion and the substrate when at STP.

10. The cutter of claim 9, wherein the diamond table defines the protrusion.

11. The cutter of claim 9, wherein the protrusion comprises a post extending all the way through the hole on the substrate and having one end coupled to the diamond table and another end opposite the diamond table for coupling to a cutter pocket of a drill bit.

12. The cutter of claim 11, wherein the diamond table comprises a hole aligned with the hole on the substrate, and wherein the post extends into the hole on the diamond table.

13. The cutter of claim 9, further comprising a braze alloy between a planar face about the protrusion on the diamond table and a corresponding planar face about the hole on the substrate, wherein the braze alloy secures the planar face of the diamond table to the planar face of the substrate.

14. A drill bit, comprising:
a bit body having one or more blades extending therefrom; and

a plurality of cutters secured to the one or more blades, wherein at least one cutter of the plurality of cutters includes:

a substrate defining a hole at least partially through the substrate;

a diamond table including a protrusion received within the hole such that a gap is defined between the protrusion and the substrate ranging between 0.001 and 0.010 inches when the substrate and diamond table are at standard temperature and pressure (STP); and

a braze alloy coupling the diamond table to the substrate at an interface between the diamond table and the substrate, wherein at least a portion of the braze alloy is disposed in the gap in compression between the protrusion on the diamond and the hole in the substrate.

15. The drill bit of claim 14, wherein the interface between the diamond table and the substrate further comprises a planar face about the protrusion on the diamond table in close engagement with a corresponding planar face about the hole on the substrate, and wherein a braze alloy at the interface secures the planar face of the diamond table to the planar face of the substrate.

16. The drill bit of claim 14, wherein the protrusion on the diamond table and the hole on the substrate are both circular, and the gap is a substantially constant-radial gap between the protrusion and the substrate.

17. The drill bit of claim 14, wherein the diamond table has a first coefficient of thermal expansion (CTE) and the substrate has a second CTE greater than the first CTE.

18. The drill bit of claim 14, wherein the compression on the braze alloy is maintained up to at least a solidus temperature of the braze alloy.

19. The drill bit of claim 14, further comprising one of a thermally conductive material and a temperature-sensitive material positioned in the hole at a location not occupied by the protrusion and the braze alloy.

20. The drill bit of claim 14, further comprising a post extending from a cutter pocket on the one or more blades and secured within the hole of the substrate.

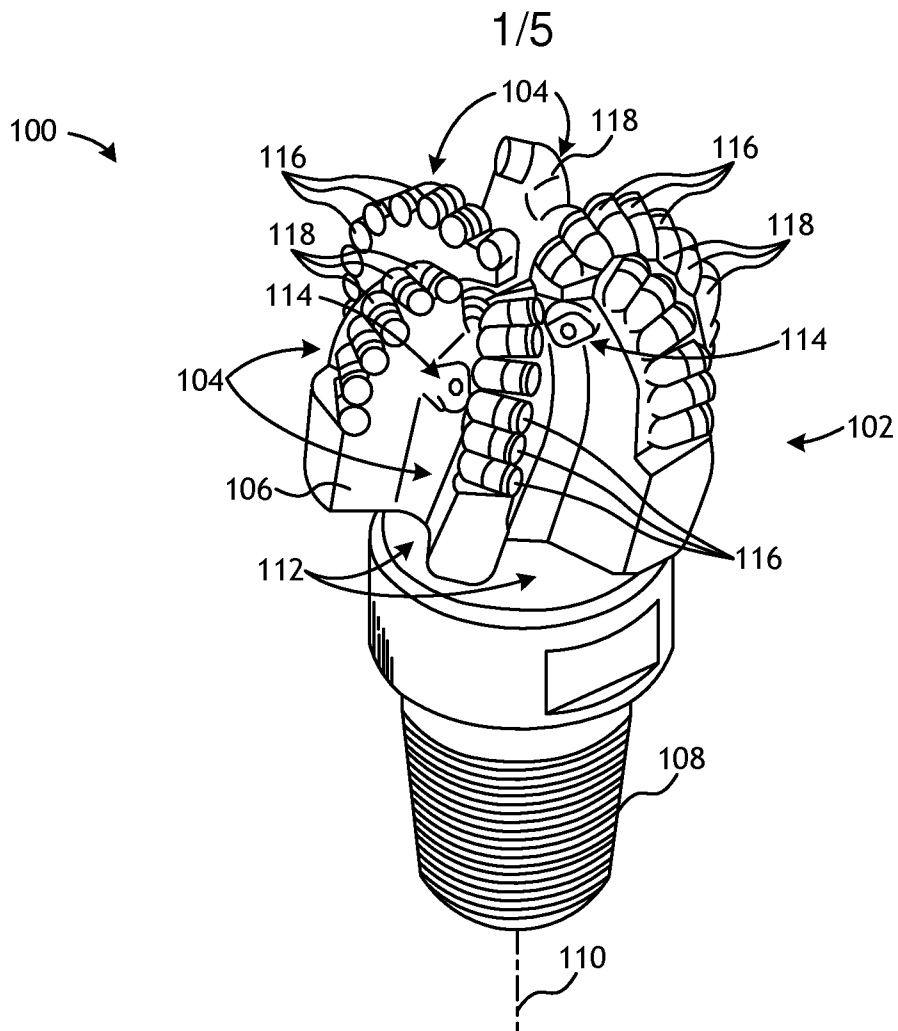


FIG. 1A

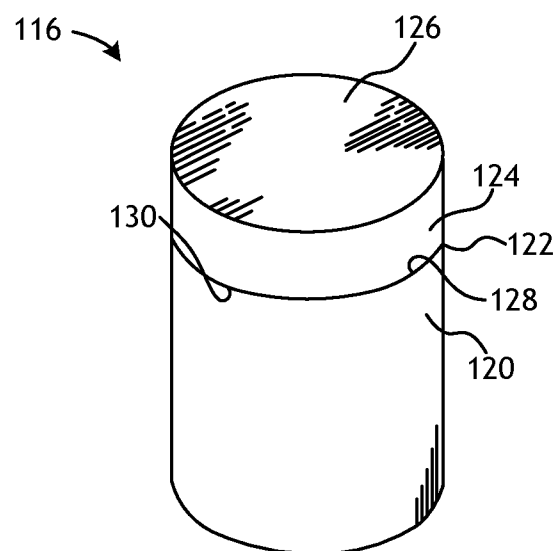


FIG. 1B

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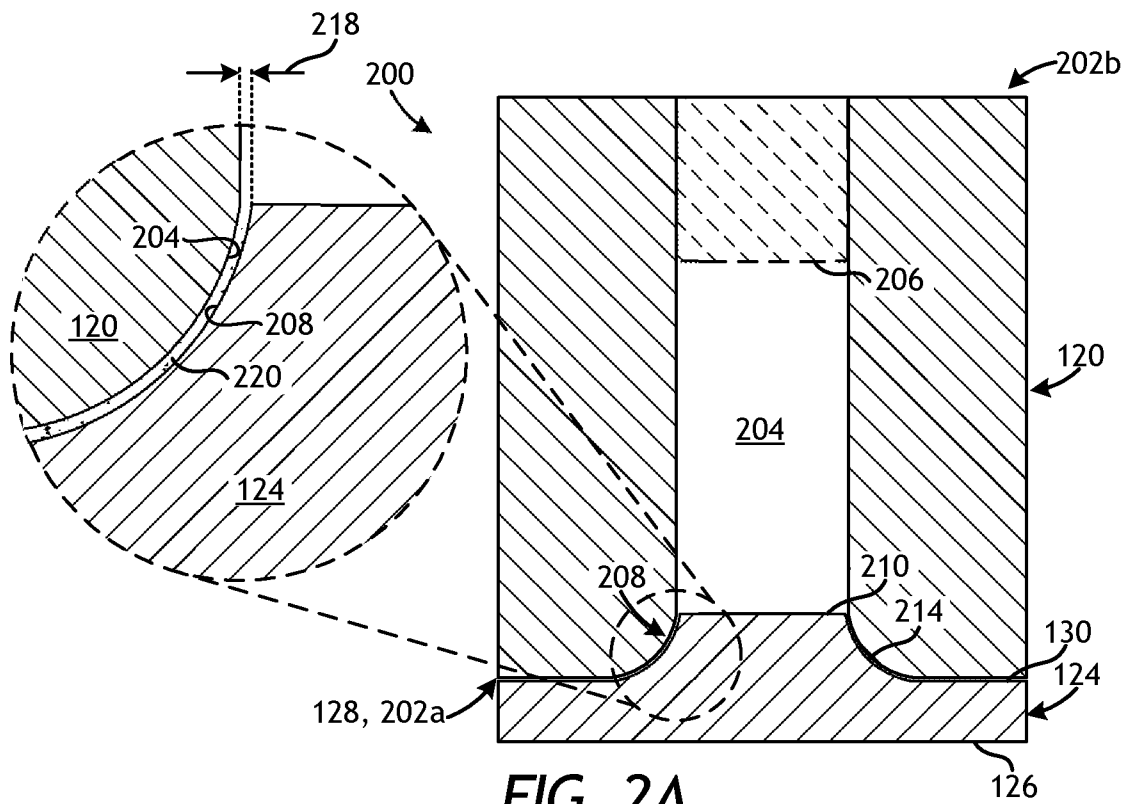


FIG. 2A

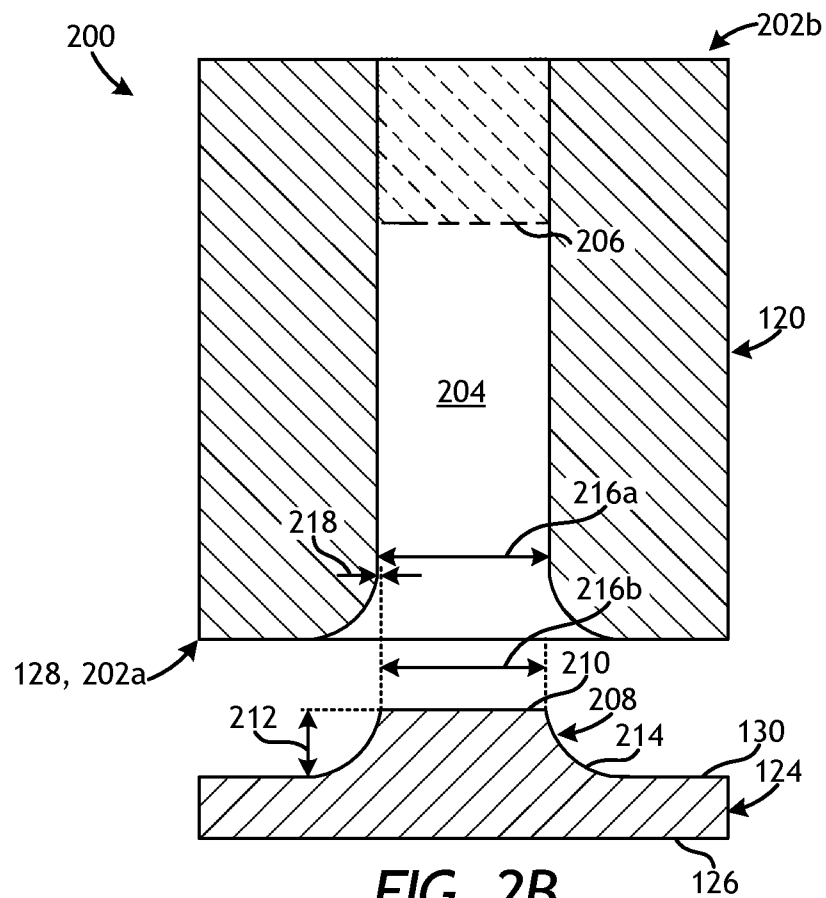


FIG. 2B

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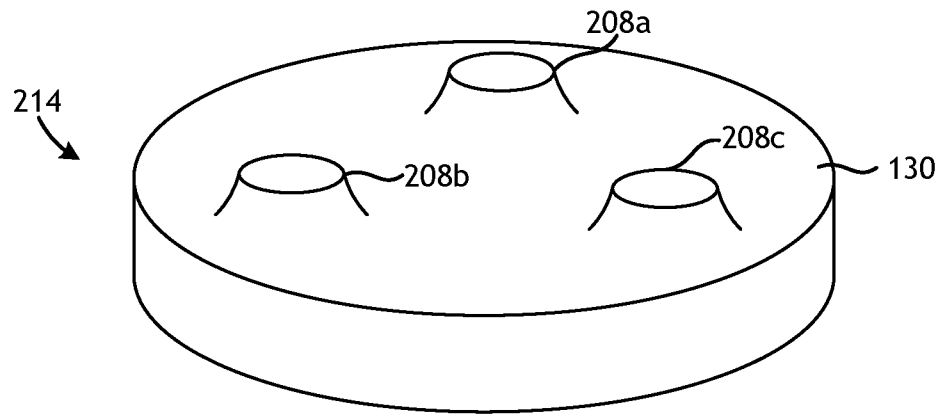
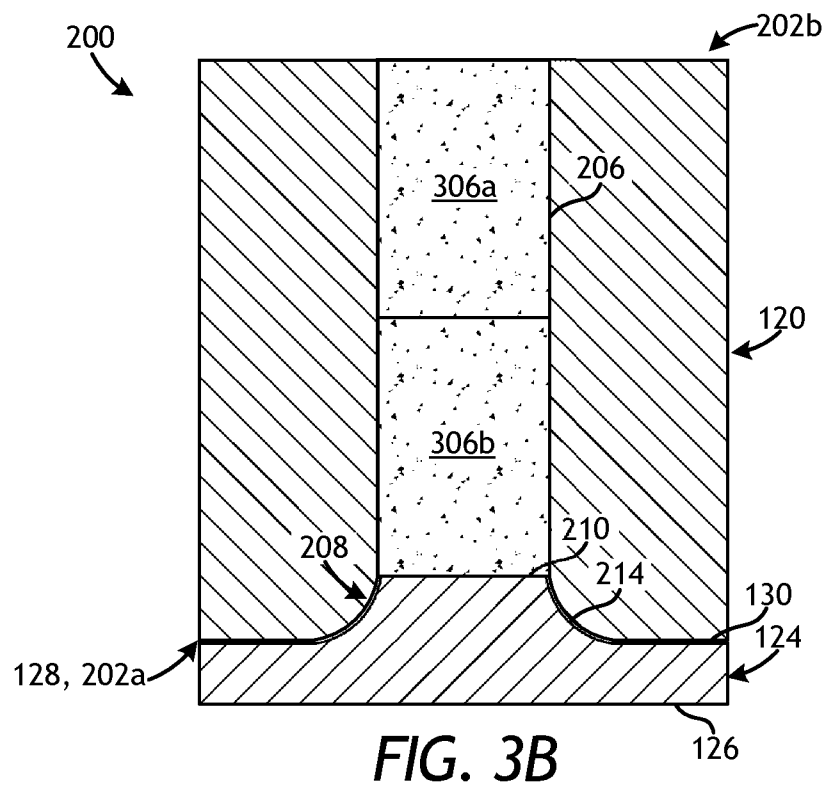
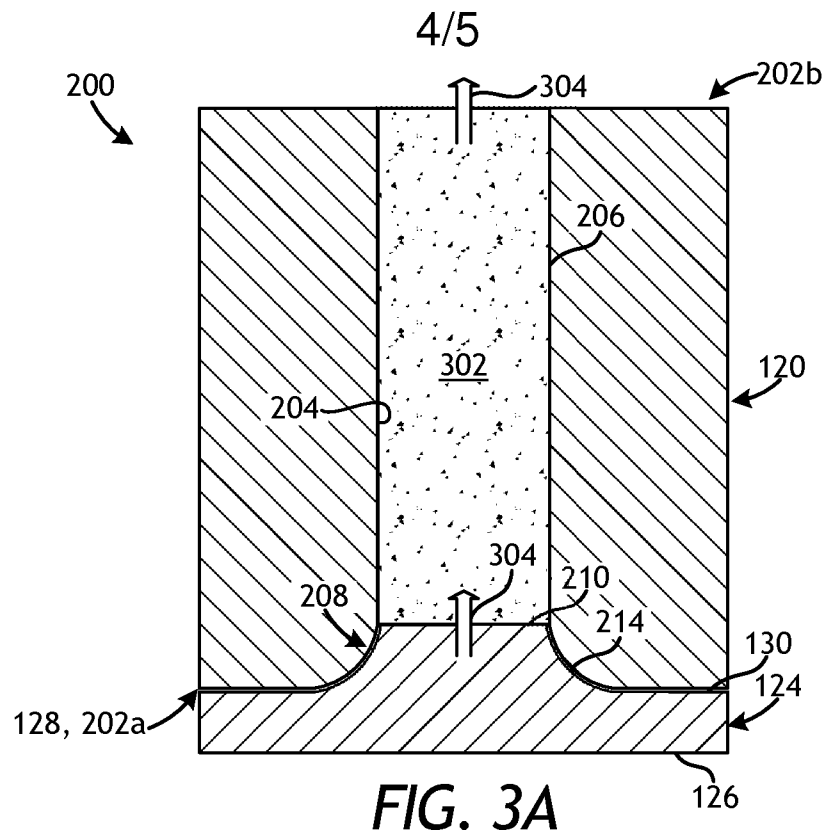


FIG. 2C



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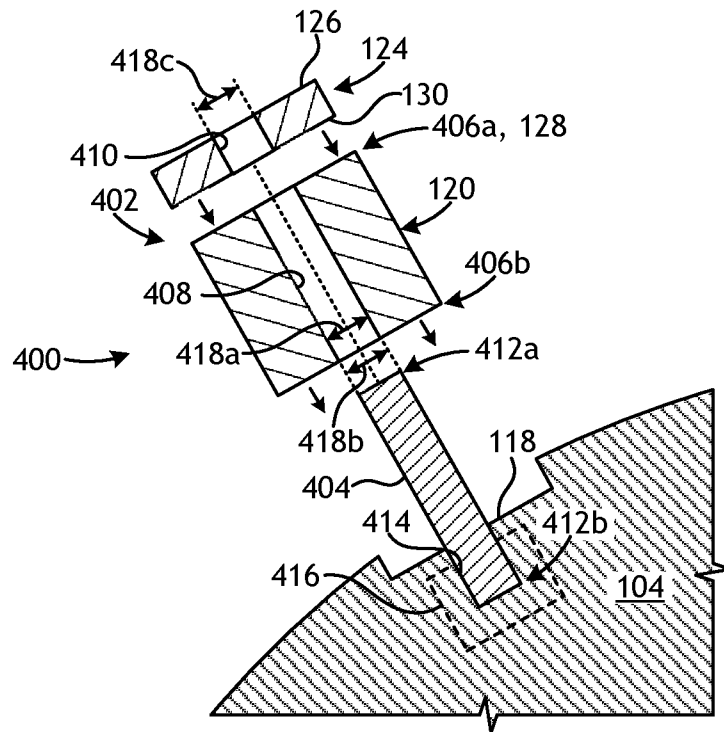


FIG. 4

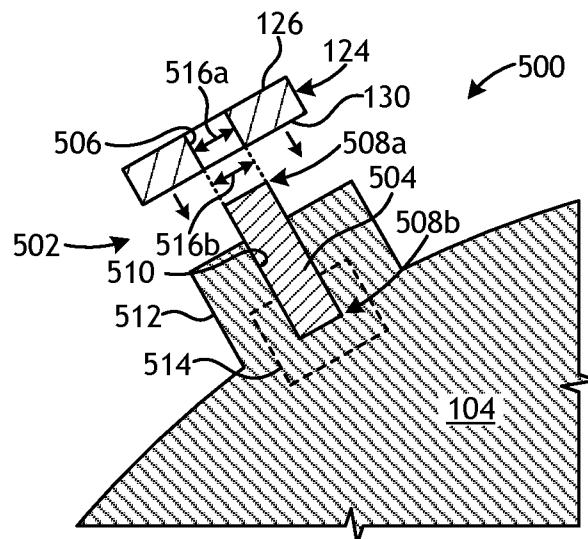


FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/037450**A. CLASSIFICATION OF SUBJECT MATTER****E21B 10/42(2006.01)i, E21B 10/54(2006.01)i, E21B 10/62(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)

E21B 10/42; E21B 7/00; B32B 37/16; G06F 17/50; E21B 10/36; E21B 10/46; E21B 10/54; E21B 10/55; B21K 5/04; E21B 10/62

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: wellbore, cutter, substrate, diamond, braze, alloy, hole, gap and protrusion

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013-0068539 A1 (VEMPATI et al.) 21 March 2013 See paragraphs [0008], [0026], [0037]-[0053] and figures 2-7.	1-10, 13-19
Y		11-12, 20
Y	US 2010-0319996 A1 (REESE, MICHAEL) 23 December 2010 See paragraphs [0031]-[0049], [0066] and figures 2-3.	11-12, 20
A	US 2013-0013267 A1 (CHEN et al.) 10 January 2013 See abstract, paragraph [0106] and figure 3C.	1-20
A	US 2008-0149398 A1 (AZAR, MICHAEL GEORGE) 26 June 2008 See abstract, paragraphs [0024]-[0027] and claim 14.	1-20
A	US 6003623 A (MIESS, DAVID P.) 21 December 1999 See abstract, claim 1 and figures 1-2.	1-20



Further documents are listed in the continuation of Box C.



See patent family annex.

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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

09 March 2016 (09.03.2016)

Date of mailing of the international search report

10 March 2016 (10.03.2016)

Name and mailing address of the ISA/KR

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/037450

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