ABSTRACT

Downhole tools include a component, at least a portion of which includes ternary boride cermet. A method of making a downhole tool including a ternary boride cermet includes obtaining a ternary boride cermet material and heating the ternary boride cermet material and a binder to form the downhole tool.
DOWNHOLE TOOLS INCLUDING TERNARY BORIDE-BASED CERMET AND METHODS OF MAKING THE SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Provisional Patent Application Ser. No. 61/801,484 filed on Mar. 15, 2013, entitled “COMPLEX TERNARY BORIDE-BASED CERMET AS ALTERNATIVE TO TUNGSTEN CARBIDE IN DOWNHOLE TOOL APPLICATIONS” to Cui et al., which is incorporated herein by reference in its entirety.

BACKGROUND

[0002] Tungsten carbide has good mechanical properties for drilling applications, and tungsten carbide-based cemented carbide is presently the predominant material used in forming downhole tools including drill bit bodies, drill inserts, reamers, bore-hole enlargement tools, stabilizers, wellbore departure millheads, roller cone bits, and thrust bearings for turbines used in drilling. However, the majority of the world’s supply of tungsten is found outside the United States, rendering a high cost for tungsten-based products. In addition, cobalt, which is a limited resource, is used in the manufacturing of tungsten carbide components, thereby further complicating the use of tungsten carbide in the manufacture of drilling components.

SUMMARY

[0003] This summary is provided to introduce a selection of concepts that are further described below in the detailed description. This summary is not intended to identify key or essential features of the claimed subject matter, nor is it intended to be used as an aid in limiting the scope of the claimed subject matter.

[0004] In some embodiments, a ternary boride cermet is disclosed for use in the manufacture of drilling components. In some embodiments, the ternary boride cermet is used in the manufacture of drilling components, including drill bit bodies, nozzles, drill inserts, diamond enhanced inserts, gage inserts, substrates for polycrystalline diamond (PCD) cutters or cutting elements, as well as hardfacing materials. In some embodiments, ternary boride cermets are used in making agglomerated pellets which are used in making a ternary boride matrix used in forming drilling tool and components.

[0005] In some embodiments, a method of making a ternary boride matrix includes sintering a mixture of boride particles to form a ternary boride cermet. The method may further include crushing the ternary boride cermet to obtain ternary boride cermet particles. To form a drilling component, the ternary boride cermet (e.g., the ternary boride particles) may be infiltrated with a binder to form at least a portion of a body of the component including a ternary boride matrix.

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] Embodiments of the present disclosure are described with reference to the following figures.

[0007] FIG. 1A shows a perspective view of a bit body, according to one or more embodiments.

[0008] FIG. 1B is a plan view of an ultra-hard material cutter.

[0009] FIG. 2 is a schematic showing ternary boride processing and formation.

[0010] FIG. 3A is a schematic disclosing methods for preparing a ternary boride cermet using a vacuum or under protective gas according to one or more embodiments.

[0011] FIG. 3B is a schematic showing a hot press sintering apparatus, according to one or more embodiments.

[0012] FIG. 3C is a schematic showing a microwave sintering apparatus, according to one or more embodiments.

[0013] FIG. 3D is a schematic showing a spark plasma sintering (SPS) apparatus, according to one or more embodiments.

[0014] FIG. 4 is a schematic disclosing methods for forming a cermet using self-propagating high temperature synthesis (SHS), according to one or more embodiments.

[0015] FIG. 5 is a schematic disclosing methods for preparing a ternary boride matrix bit body, according to one or more embodiments.

[0016] FIG. 6 is a schematic disclosing a pelleting apparatus for forming cermets pellets, according to one or more embodiments.

DETAILED DESCRIPTION

[0017] Ternary boride cermets have high strength, high hardness, good toughness, and excellent corrosion resistance. Ternary boride cermets have increased sinterability and mechanical properties compared to binary boride, and the wettability of ternary boride may be enhanced with a coating, such as a tungsten (W), chromium (Cr), titanium (Ti), and/or molybdenum (Mo) coating.

[0018] As used herein the term “cermet” refers to a sintered ceramic metal composition. In some embodiments, a ternary boride cermet as disclosed herein is used in the manufacturing of downhole tools and components. Non-limiting examples of these downhole tools and components include: drill bit bodies, cutting elements such as polycrystalline ultra-hard material cutters, for example PCD cutters or polycrystalline cubic boron nitride (PCBN) cutters, drill bit bodies including polycrystalline diamond compact (PDC) or PDC cutter drill bits and PDC “hybrid” drill bits having diamond impregnated blades, diamond impregnated drill bits, nozzles, drill inserts, diamond enhanced inserts, gage inserts, reamers, bore-hole enlargement tools including cutter blocks and bicenter bits, stabilizers, well-bore departure mill heads, roller cone bits, thrust bearings used in turbines, as well as hardfacing materials. The listed tools and components can be manufactured with a ternary boride cermet following manufacturing methods known in the art. For these components which are commonly made using a tungsten carbide cermet, the ternary boride cermet may be used in place of, or together with, tungsten carbide cermets, thereby reducing the amount of tungsten. Hard surface coatings may also be formed from ternary boride cermets.

[0019] A metal-matrix cermet (i.e., composite) used to form an earth boring drill bit body includes a hard particulate phase and a ductile metallic phase. The hard particulate phase includes refractory or ceramic compounds (e.g., nitrides and carbides, such as tungsten carbide), and the metallic phase may be a binder metal, such as a metal made of copper and other non-ferrous alloys. In some embodiments, the presently disclosed ternary boride cermet is substituted for, or combined with, tungsten or tungsten carbide. For example, the hard particulate phase may include from about 5 wt % to about 100 wt % ternary boride cermets with tungsten or tung-
sten carbide as a balancer. That is, for example, the hard particulate phase may include ternary boride cermet at 100 wt % and tungsten carbide at 0 wt %. In another example, the hard particulate phase may include ternary boride cermet at 90 wt % and tungsten carbide at 10 wt %. In another example, the hard particulate phase includes ternary boride cermet at 85 wt % and tungsten carbide at 15 wt %. In another example, the hard particulate phase includes ternary boride cermet at 80 wt % and tungsten carbide at 20 wt %.

[0020] FIG. 1A discloses an earth boring drill bit (5) having a bit body (7) and cutting elements or cutters (1) which contact the earth formation during drilling along the edges (9) of their cutting layers (18), also shown in FIG. 1B. In some embodiments, an earth boring bit body is made from a ternary boride cermet (e.g., at least a portion of an earth boring bit body is made with a ternary boride cermet).

[0021] Downhole drilling bits may include various “cutters” or “cutting elements” where such cutting elements include (but are not limited to): tungsten carbide inserts (TCIs), as well as PDC inserts, natural or synthetic diamond attached to the drill bit body; polycrystalline ultra-hard material cutters having a polycrystalline ultra-hard material cutting layers attached to substrates that are attached to the bit body, such as PDC cutters or PCD cutters; and/or combinations of these cutting elements. Ultra-hard materials may also be directly attached to the bit body forming cutting elements. For example, diamond grit hot-pressed inserts (GHIs), can be bonded to the bit body. In some embodiments, polycrystalline diamond may be coated on inserts which are incorporated or attached to the bit body to form diamond enhanced inserts (DEIs).

[0022] Currently, a drill bit body is formed by infiltrating tungsten carbide particles with a binder alloy in a mold. The tungsten carbide is placed in the mold, and the binder alloy may be placed on top of the tungsten carbide in the mold. During infiltrating, the binder alloy and tungsten carbide are heated in a furnace to a flow or infiltration temperature of the binder alloy so that the binder alloy can bond to the grains of tungsten carbide. Infiltration occurs when the molten binder alloy flows through the spaces between the tungsten carbide grains by means of capillary action. When cooled, the tungsten carbide matrix and the binder alloy form a hard, durable, strong framework or bit body to which cutting elements are bonded or otherwise attached. Methods of forming drill bit bodies using tungsten carbide including drill bit bodies having PDC inserts, GHIs, and DEIs using tungsten carbide are described in U.S. Pat. No. 5,593,474, U.S. Pat. No. 8,347,990, U.S. Patent Publication No. 2004/0244540, U.S. Pat. No. 7,625,521, WO 97/48874, and U.S. Pat. No. 6,725,953, the entire contents of all of which are herein incorporated by reference. Using known methodologies for forming bit bodies, tungsten carbide cermet may be substituted with or combined with the presently disclosed ternary boride cermet.

[0023] For some applications, cutting structures that include particulate diamond or diamond grit, impregnated in a supporting matrix are referred to as diamond impregnated. Methods of forming diamond impregnated cutting structures using a tungsten carbide cermet are described in U.S. Pat. No. 6,725,953, the entire contents of which are incorporated herein by reference. In embodiments, diamond impregnated cutting structures are formed using a ternary boride cermet in place of, or in addition to, a tungsten carbide cermet.

[0024] In some embodiments, cutting elements or cutters (1), as shown in FIG. 1B, are formed having a polycrystalline ultra-hard material cutting layer (18) bonded to a substrate (12) formed using ternary boride cermet in lieu of, or in addition to the tungsten carbide. Examples of cutting or cutting elements having a tungsten carbide substrate (without ternary boride), as well as examples of methods of forming the same are provided in U.S. Pat. Nos. 4,604,106, 4,311,490, and 5,351,772, the entire contents of all of which are incorporated herein by reference. These cutting elements are formed using a high pressure high temperature (HPHT) sintering process. A HPHT sintering process includes applying pressure of about 50 kbar or greater and even 70 kbar or greater at a temperature of about 1300°C or greater and often in the range of about 2000°C to 2500°C. Examples of such cutting elements brazed to a drill bit body (5) after the drill bit body is formed are shown in FIG. 1. In some embodiments, a ternary boride is substituted for, or used in addition to tungsten carbide cermet to form the cutting elements. In other embodiments, a ternary boride cermet insert is attached to a drill bit body. In some embodiments, the ternary boride cermet insert is attached to the drill bit body by brazing, press-fitting, and/or by infiltration. Methods for brazing, press-fitting (i.e., interference fitting) and infiltrating an insert to a drill bit body are described respectively in U.S. Pat. No. 8,360,176, Alan O. Lebeck (1991), Principles and design of mechanical face seals, Wiley-Interscience, p. 232, ISBN 978-0-471-51533-3; and U.S. Pat. No. 6,095,265, the entire contents of all of which are herein incorporated by reference.

[0025] Methods of forming drill bit bodies using tungsten carbide are described in U.S. Pat. No. 8,347,990 and U.S. Patent Publication No. 2004/0244540, the entire contents of both of which are herein incorporated by reference. In some embodiments, drill bit bodies may be formed using more than one matrix material. Drill bit bodies formed of multiple matrix materials are described in U.S. Pat. No. 8,109,177, the entire contents of which are herein incorporated by reference. Following disclosed methodologies, tungsten carbide may be substituted with or combined with the presently disclosed ternary boride cermet to form these drill bit bodies from ternary boride cermet or more than one matrix material.

[0026] In some embodiments, drill nozzles may be made from the presently disclosed ternary boride cermet in lieu or in addition to tungsten carbide. Methods for making drill nozzles are described in U.S. Pat. Nos. 5,927,410 and 8,047,308, the entire contents of both of which are herein incorporated by reference.

[0027] In some embodiments, a PCD cutting layer may be leached to remove or decrease the amount of metal catalyst or binder in the layer forming a thermally stable polycrystalline (TSP) ultra-hard cutting layer. For example, the ultra-hard cutting layer may be a TSP diamond material cutting layer. Other processes for forming TSP layers include using a non-metal catalyst during the HPHT sintering process of the diamond particles, and HPHT sintering diamond particles without the use of a catalyst. TSP materials are described in U.S. Pat. No. 8,328,891, the contents of which are fully incorporated herein by reference. In some embodiments, the TSP material layer is attached to a substrate made with a ternary boride cermet in lieu of, or in addition to the tungsten carbide cermet that may be used to form such a substrate. In some embodiments, the TSP material layer is attached to a substrate by any suitable method. In some embodiments, the TSP material layer is attached to the substrate made with ternary boride
cermet using high temperature high pressure (HTHP) processing or hot pressing. Hot pressing technology is further described herein.

[0028] A ternary boride cermet may also be used in lieu of, or in addition to, tungsten carbide cermets to form cutting elements which are mounted on downhole tools such as drag bits, roller cone bits, reamers, bore-hole enlargement tools including cutter blocks and bi-center bits, stabilizers, wellbore departure mill heads, and thrust bearings used in turbines used in drilling. Such cutting elements include tungsten carbide inserts, GHIs, and DEIs. Examples of such inserts formed from a tungsten carbide cermet are disclosed in U.S. Pat. Nos. 6,394,202 and 7,350,599, the contents of both of which are incorporated herein by reference.

[0029] The presently disclosed ternary boride cermet may also be used in hardfacing used on drill bits or other tools. Hardfacing (also referred to as hard surface coating) is the bonding of one or more metal carbides to the drill bit body using a metal alloy which provides a layer of hardness and wear resistance to the drill bit body. In some embodiments, a hard surface coating includes the presently disclosed ternary boride cermet in combination with or in lieu of tungsten carbide. Hard surface coating of drill bit bodies is described in U.S. Pat. No. 4,836,307, the entire contents of which are herein incorporated by reference. In some embodiments the hard surface coating including ternary boride cermet is applied by thermal spray of the ternary boride cermet particles. Thermal spray techniques are known and described in U.S. Pat. No. 5,535,838, the entire contents of which are herein incorporated by reference. In other embodiments, a hard surface coating including ternary boride cermet includes applying the coating using an oxyacetylene torch, tungsten inert gas (TIG) welding, and/or metal inert gas (MIG) welding.

[0030] FIG. 2 is a schematic outlining the formation of a sintered ternary boride cermet according to Takagi, 2006, J. of Solid State Chemistry, 179: 2809-2818, the entire contents of which are herein incorporated by reference. In some embodiments, a boron source (e.g. binary boride) (20) is mixed with a metal (22) to form a mixture (23) which forms ternary boride (24) through a solid state diffusional boronizing reaction. The boronizing reaction mixture (25) is then sintered to form a ternary boride cermet including ternary boride (24) and metal matrix (28). The ternary boride cermet includes a metal content from about 10 to about 60%. In some embodiments, the ternary boride cermet includes a metal content between about 25% and 30%. In some embodiments, a ternary boride is sintered with carbonyl nickel (Ni). Ternary boride may also be sintered with a copper, iron, and/or nickel alloy. In some embodiments, the ternary boride is vanadium (V) and chromium (Cr) modified Mo, Nb, B (nickel-molybdenum complex boride). In some embodiments, the ternary boride is vanadium (V) and chromium (Cr) modified Mo, Fe, B (iron-molybdenum complex boride). In some embodiments, when ternary boride is used to form any of the aforementioned components, the ternary boride particles are cemented together with iron, nickel, cobalt and/or copper.

[0031] In some embodiments, a method of preparing a ternary boride cermet includes the methods described above and shown in FIG. 3A. That is, in some embodiments, a method of preparing a ternary boride cermet includes mixing borides and metals to form a mixture. The borides may include vanadium boride (VB), chromium monoboride (CrB), and/or molybdenum monoboride (MoB). The metals may include nickel (Ni) and/or molybdenum (Mo). In some embodiments, each of Ni, Mo, MoB, VB, and CrB (23) is mixed in acetone or ethanol, and processed by ball milling to form a mixture (40) (block 38). In some embodiments, the mixed metal and boron sources are in acetone or ethanol (40) and then dried (block 42). The mixture (40) after drying is then pressed to form a green compact (45-1) (block 44). The green compact (45-1) is then sintered under vacuum or protective gas to form a ternary boride cermet (48) (block 46). The ternary boride cermet (48) may be used in the manufacture of downhole components (50), as disclosed herein.

[0032] In some embodiments, the boride (20) and metal (22) include materials having the following purity: 99.85% carbonyl Ni, 99.95% Mo, MoB having 89.52% Mo and 10.26% B, VB having 68.93% V and 29.84% B, and CrB having 82.99% Cr and 16.54% B. In some embodiments, the vacuum and heating occurs at a temperature of about 1200°C to about 1350°C. In some embodiments, the vacuum and heating occurs for about 20 to about 30 minutes.

[0033] In another embodiment, the ternary boride cermet is formed from a mixture (40), which is then sintered using a hot press (70), as shown schematically in FIG. 3B. In some embodiments, the hot press (70) includes a graphite punch (62) and graphite mold (60), surrounding the mixture (40). The graphite punch (62) applies a load (66) from at least one direction, thereby providing pressure, and the graphite mold conducts heat to the particle mixture from at least one heating element (64). In some embodiments, the pressure from the applied load is in a range of about 4,000 to about 5,000 psi. In some embodiments, the temperature from the heating element is in a range of about 1,000°C to about 1,500°C. As such, a hot press (70) combines pressure and heat for sintering of the particle mixture (40) to form the ternary boride cermet. The ternary boride cermet (48) may be used in the manufacture of downhole components (50), as disclosed herein.

[0034] In another embodiment, the ternary boride cermet is formed by microwave sintering of a green compact (45-1). As shown in FIG. 3C, the boride green compact (45-1) or 45-2 described later herein) is placed in a sintering chamber (78) and is then sintered using a system for microwaving (80) to form a ternary boride cermet that may be used as a substrate for a polycrystalline ultra-hard material cutting element or a cutting insert. The microwaves produced by a microwave generator (74) (e.g., HAMiLab-V3000 manufactured by Syntherm) are controlled and circulated using a circulation control (76) to sinter the green compact (45-1) in a sintering chamber (78). Pressure in the sintering chamber is controlled by a pressure controller (79) and flow rate controller (81). Microwave sintering can be faster and more energy efficient than liquid sintering using a conventional vacuum furnace. Microwave sintering is described in U.S. Pat. Nos. 5,848,348 and 6,004,505, the entire contents of both of which are herein incorporated by reference.

[0035] In another embodiment, the ternary boride cermet is formed using spark plasma sintering (SPS) of a mixture (40) using an SPS apparatus (90). As shown in FIG. 3D, the mixture (40) is surrounded by a graphite punch (62) and graphite mold (60). The graphite punch (62) receives an electrical pulse (68) from at least one direction from an electric pulse generator (92) and applies a load (66) from at least one direc-
tion which imparts pressure. Both the pressure and the heat generated from the electrical pulse pass through the graphite punch, to the mixture. The electrical pulse generator (92) is controlled by an SPS control unit (94). As such, the SPS (90) sinters the mixture to form a ternary boride cermet that may be used as a substrate for a polycrystalline ultra-hard material layer or as a cutting insert. SPS methods are described in U.S. Pat. No. 8,349,040, the entire contents of which are herein incorporated by reference. [0036] In another embodiment, ternary boride cermet particles are made by sintering to near net shape. Near net shape processing is useful as it can help reduce the overall manufacturing time. Near net shape processing produces less shrinkage after sintering, thereby requiring less grinding, which may be expensive and time consuming. Accordingly, the ternary boride cermet particles are made directly by forming agglomerates of the boride and metal mixture and binder alloy of appropriate size which are then sintered to near net shape. This enables one to determine the shape as well as the size of the particles. [0037] In some embodiments, the ternary boride cermet is formed using self-propagating high temperature synthesis (SHS). SHS is known and described in U.S. Pat. No. 3,726,643, the entire contents of which are herein incorporated by reference. [0038] For SHS, when a compact of the constituent elements is ignited by furnace heating or by a local heating source (e.g., a filament) at one end, the highly exothermic reaction propagates spontaneously and rapidly, converting the reactants into a refractory product. The reaction temperature can exceed 2500° C. In manufacturing, the SHS technique may have the advantage of high energy and time efficiency, and in some instances, high product purity due to the expulsion of volatile contaminates as a result of extreme high temperatures. The mixed particles are compacted (also referred to as “reactive compacts”), and act as a local heat source for joining many materials having high melting points. Using such reactive compacts, the joining process can be performed at room temperature without furnaces. The combustion temperature and propagating rate can also be controlled, for example, by pre-heating particle reactants to promote the reaction, and by adding diluents (such as oxide, boride and/or carbide) to lower the adiabatic combustion temperature and rate. SHS may also include conventional particle processing techniques, such as hot pressing, microwave heating and/or spark plasma sintering, as described herein. [0039] Using SHS, it is possible to synthesize binary boride by the direct reaction of the elements (e.g., Ti+2B, HF+2B, Mo+B, etc.) or by the reaction of a metal oxide with boron (e.g., Cr2O3, WO3, MoO3 and B). Because of the high adiabatic temperature (Tad) (e.g., of about 3000 K) and the volatility of B2O3, some addition of pure metal phase (e.g., Mo) may be used to form MoB. However, it is also possible to add binary boride (e.g., MoB, Mo3B) as a reaction modifier to lower the Tad. [0040] In some embodiments, ternary boride cermet is manufactured using an SHS technique, as schematically outlined in FIG. 4. In some embodiments, a cermet including Mo3Ni3B2(x−0−1) is made from a mixture of Mo, MoO3, and B with the addition of Ni (90.5%, −325 mesh). This elemental mixture may be mixed with acetone or ethanol and ball milling to form a mixture (41a) (block 39a) and then dried (block 42), or dry mixed (e.g., using a V-blender) to form a mixture (41b) (block 39b). The mixture (41a or 41b) is pressed to form a large scale green compact (45−2) (block 44). The large scale green packed compact (45−2) is then heated to 800° C. to 1350° C. under vacuum or under an inert gas (e.g., a protective gas such as Ar) to complete the SHS process (block 47). In some embodiments, a cermet including MoFeB3(x−0−1) is made from a mixture of Mo, MoO3, B with the addition of Fe(99.5%, −200mesh), green compacted and heated to 1000° C. to 1350° C. In both cases, SPS (FIG. 3D) and/or hot press (FIG. 3B) can also be included in the SHS process. In some embodiments, a small addition of binary boride (e.g., MoB and/or Mo3B) as diluents may be used to control the reaction temperature and propagating rate. In some cases, an addition of carbon (<0.5 wt %) may help to reduce oxidation during high temperature synthesis. [0041] In some embodiments, a method of manufacturing a ternary boride bit body or other cutting structures, as shown in FIG. 5, includes mechanically crushing a ternary boride cermet (48) in accordance with any one of the embodiments described and shown herein. The crushing of the sintered ternary boride cermet (48) forms crushed ternary boride cermet particles (53) (block 52). The crushed cermet particles (53) are then separated (54) to collect different sized ternary boride cermet particles (55) (block 54). In some embodiments, the cermet particles are separated to obtain particles having an average particle size in the range of about 1 μm to about 500 μm. In some embodiments, the selected particles have an average particle size in the range of about 45 μm to about 160 μm. The wettability of the selected ternary boride cermet particles (55) may be increased by applying a metal layer or coating by vapor deposition (block 56) or any other suitable coating method. The vapor deposition may be by chemical vapor deposition (CVD) or physical vapor deposition (PVD). The ternary boride cermet particles with or without a coating are then loaded into a bit mold and subjected to vibration (block 57). The loaded mold is then infiltrated under pressure or pressure-less conditions (block 58). In one embodiment, the separated, selected, and loaded ternary boride cermet particles are infiltrated with Cu-based, Fe-based, and/or Al-based alloys at about 850° C. to about 1250° C. to form a bit body (58) including ternary boride cermet. [0042] In some embodiments, the crushed ternary boride cermet particles are placed in a mold and infiltrated with a copper alloy to form a drill bit body, insert, and/or a plurality of blades. In some embodiments, the ternary boride cermet particles (55) are mixed with a metal (e.g., iron, nickel and/or copper alloys), and the metal and ternary boride cermet mixture is added to a drill bit mold forming at least a plurality of blades on a bit body, and is infiltrated with a copper alloy to form a drill bit body having a plurality of blades. In some embodiments, the plurality of blades include at least one cutting element attached thereto, the cutting element made from ternary boride cermet. In some embodiments, at least a portion of the drill bit including the plurality of blades may be made from ternary boride cermet in the absence of tungsten carbide. That is, a portion of the drill bit is substantially free of tungsten carbide, where substantially free of tungsten carbide is defined as including no more than 5 wt % tungsten carbide. In other embodiments, at least a portion of the drill bit including the plurality of blades is made from a mixture of ternary boride cermet and tungsten carbide cermet, as
described herein. In some embodiments, the cutting element including the substrate and/or the insert (optionally attached to the drill bit blades) is made from ternary boride cermet and is substantially free of tungsten carbide. In other embodiments, the cutting element (optionally attached to the drill bit blades) is made from a mixture of ternary boride cermet and tungsten carbide cermet, as described herein.

In another embodiment, ternary boride pellets can be manufactured by sintering pre-mixed boride green pellets (100), using the method discussed herein (e.g., FIGS. 3B-3D). As shown in FIG. 6, boride green pellets are formed by transforming the mixture (40) (FIG. 3A) into shaped green pellets by rotating the mixture with an organic binder (e.g., wax or polymer) in a pelletizing pan (105). The possible shapes of the pellets is controlled by the technique used in conjunction with the pelletizing pan, including but not limited to the tilt angle of the pan, the rotational speed of the pan, and the amount of wax or polymer added. As such, non-limiting examples of shapes of the pellets include spherical, semi-spherical, elliptical, and angular. This process is also referred to as disc type pelletizing. The boride green pellets (100) may be sintered thereafter for use in various downhole tool components and applications, e.g., hardfacing and in a drill bit body. In some embodiments, the green pellets may be sintered with a binder to form at least a portion of a downhole cutting tool. In other embodiments, the boride green pellets may be sintered to form sintered ternary boride pellets which may then be used to form at least a portion of a downhole cutting tool. In other embodiment, the sintered ternary boride pellets are crushed to form ternary boride particles which are used to form cutting tools as described herein.

Although a few embodiments have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the embodiments without materially departing from this disclosure. All such modifications are intended to be included within the scope of this disclosure. It is the express intention of the applicant not to invoke 35 U.S.C. §112, paragraph 6 for any limitations of any of the claims herein, except for those in which the claim expressly uses the words ‘means for’ together with an associated function.

What is claimed is:
1. A downhole tool comprising a component, wherein at least a portion of the component comprises ternary boride cermet.
2. The downhole tool of claim 1, wherein the component is selected from the group consisting of cutters, ultra-hard material cutters, drill bit bodies, nozzles, inserts, reamers, borehole enlargement tools, bits, stabilizers, well-bore departure mill heads, roller cone bits, and thrust bearings.
3. The downhole tool of claim 1, wherein the ternary boride cermet is made from at least one metal and at least one boride.
4. The downhole tool of claim 1, wherein the component is an earth boring drill bit body, at least a portion of which is made from the infiltration of the ternary boride cermet with a binder.
5. The downhole tool of claim 1, wherein the downhole tool is a cutting element comprising an ultra hard material cutting layer attached to a substrate, at least a portion of the substrate comprising the ternary boride cermet.
6. The downhole tool of claim 1, wherein the component is substantially free of tungsten.
7. The downhole tool of claim 1, wherein the component further comprises tungsten carbide.
8. The downhole tool of claim 7, wherein the ternary boride cermet is present at about 5 wt % to about 100 wt % and the tungsten carbide is present at most at about 95 wt %.
9. The downhole tool of claim 1, wherein the component comprising the ternary boride cermet is hardfacing.
10. A method of making a downhole tool comprising a ternary boride cermet, the method comprising: obtaining a ternary boride cermet material; and heating the ternary boride cermet material and a binder to form the downhole tool.
11. The method of claim 10, further comprising: mixing at least one metal and boron to form a boride metal mixture; and sintering the boride metal mixture to form the ternary boride cermet material.
12. The method of claim 11, wherein mixing further comprising adding a reaction modifier selected from the group consisting of mono-borides, di-borides, and combinations thereof.
13. The method of claim 11, wherein the at least one metal comprises nickel and molybdenum, and the boron comprises at least one selected from the group consisting of molybdenum monoboride, vanadium boride, chromium monoboride, and combinations thereof.
14. The method of claim 11, wherein the sintering comprises liquid sintering, hot press sintering, spark plasma sintering, or microwaving the boride metal mixture.
15. The method of claim 10, further comprising crushing the ternary boride cermet material to form ternary boride particles, and wherein heating comprises heating the ternary boride cermet particles and the binder.
16. The method of claim 15, further comprising: separating the ternary boride particles; selecting the ternary boride particles having an average particle size of about 1 μm to about 500 μm; and loading the selected ternary boride particles and the binder into a mold, wherein heating comprises heating the binder to infiltrate the ternary boride particles in the mold.
17. The method of claim 10, wherein heating comprises high pressure high temperature sintering the ternary boride cermet material adjacent to an ultra-hard material layer to form the downhole tool.
18. A method of making a downhole tool comprising a ternary boride matrix, comprising: mixing at least one metal and at least one boride with an organic binder in a pelletizing pan to form boride green pellets; sintering the boride green pellets to form a ternary boride material; and heating the ternary boride material to form the downhole tool comprising the ternary boride material.
19. The method of claim 18, wherein the at least one boride comprises at least one metal diboride and at least one metal monoboride.
20. A method for forming a cutting element comprising: high pressure high temperature sintering an assembly comprising a ternary boride cermet and an ultra-hard material to form the cutting element comprising a ternary boride cermet substrate attached to an ultra-hard material layer.
21. The method of claim 20, further comprising forming the substrate by heating ternary boride cermet particles with a binder.