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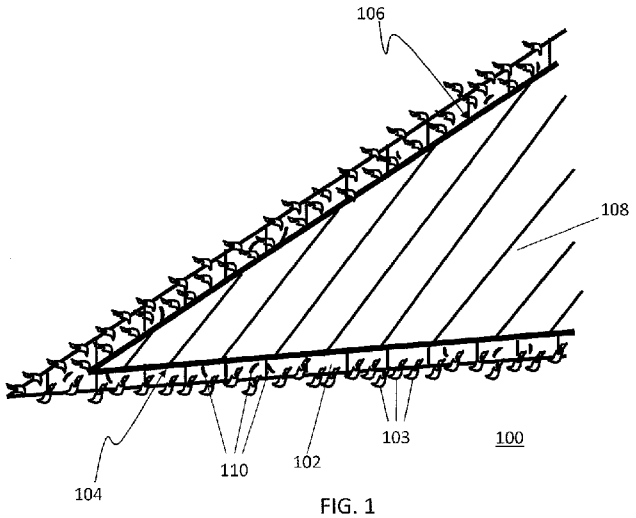


FIG. 1

(57) Abstract: A MAX-phase material is provided for a cutting tool and other applications.

CUTTING TOOL AND METHOD OF MANUFACTURE

CROSS REFERENCE TO RELATED APPLICATIONS

This application claims priority from U.S. Provisional Patent Application S.N. 61/363,813, filed July 13, 2010 and incorporated herein by reference in its entirety.

FIELD OF THE INVENTION

The present invention generally relates to cutting tools, and in particular to drill bits used for drilling through geological formations.

BACKGROUND OF THE INVENTION

Drilling or cutting tools are prone to failure when cutting into very hard material compressed to high pressures and/or heated to high temperatures or when used in corrosive environments, such as those found in deep well oil drilling environments. Conventional cutting tools are comprised of a metal amalgam applied to a hard metal bit head, most often a titanium bit head. The metal amalgam is impregnated with diamond shards, which are the tool's actual cutting elements. A principal failure mode is caused by the temperature differential generated between the amalgam's cutting surface and the bit head to which it is attached. Friction induced by cutting into hard material, cutting into highly pressurized materials, or cutting into hot materials will frequently generate sufficient heat differentials between the cutting surface and the bit head to crack the tool. These conditions are quite often present when drilling for fossil fuels at greater depths. In these instances, mechanical failures have high carrying costs due to longer periods lost time encumbered in replacing the drill bit.

In view of the above discussion, it would be beneficial to have a cutting tool that is less prone to failure when cutting through hard materials, highly pressurized materials, or materials heated to elevated temperatures.

1. Definition of Terms

The term "amorphous material" is herein understood to mean a material that does not comprise a periodic lattice of atomic elements, or lacks mid-range (over distances of 10's of nanometers) to long-range crystalline order (over distances of 100's of nanometers).

The terms "chemical complexity", "compositional complexity", "chemically complex", or "compositionally complex" are herein understood to refer to a material, such as a metal or superalloy, compound semiconductor, or ceramic that consists of three (3) or more elements from the periodic table.

The term "LCD" is herein understood to mean a method that uses liquid precursor solutions to fabricate materials of arbitrary compositional or chemical complexity as an amorphous laminate or free-standing body or as a crystalline laminate or free-standing body that has atomic-scale chemical uniformity and a microstructure that is controllable down to nanoscale dimensions.

The term "liquid precursor solution" is herein understood to mean a solution of hydrocarbon molecules that also contains soluble metalorganic compounds that may or may not be organic acid salts of the hydrocarbon molecules into which they are dissolved.

The term "MAX phase material" is herein understood to define a chemically complex intermetallic ceramic material having the general chemical formula $M_{(n+1)}AX_n$, wherein M is first row transition-metal element, A is an "A-group" element found in columns III-VI of the periodic table, and X is either carbon (C) or nitrogen (N).

The term "microstructure" is herein understood to define the elemental composition and physical size of crystalline grains forming a material substance.

The term "nanoscale" is herein understood to define physical dimensions measured in lengths ranging from 1 nanometer (nm) to 100's of nanometers (nm).

The term "solid solution" is herein understood to be an amorphous material.

In view of the above discussion, it would be beneficial to improve the useful life of cutting tools and operational efficiency of drilling systems, particularly those systems deployed in extreme or harsh environments. The present invention instructs methods to fabricate a cutting tool that has a surface consisting of diamond shards (teeth) embedded within a mechanically strong, corrosion-resistant, thermal shock-resistant laminate.

SUMMARY OF THE INVENTION

One embodiment of the present invention provides a cutting tool, comprising: a support substrate; and a complex ceramic cutting surface laminate formed on the support substrate and including hard shards, a first row transition-metal element, an element from columns III-VI of the periodic table and carbon and/or nitrogen.

The laminate may include an $M_{(n+1)}AX_n$ (MAX) phase material; where M is the first row transition-metal element, where A is an element from columns III-VI of the periodic table and where X is carbon and/or nitrogen. The MAX-phase material may have micro-Vickers hardness greater than 1 GPa. The MAX-phase material may have micro-Vickers hardness greater than 4 GPa. The MAX-phase material may further include particles embedded within it that include carbide, carbon fiber, coated-carbon fiber, and/or nitride particles. The hard shards may have hardness in the range of 8-10.

The laminate may have a polycrystalline structure or fully crystalline structure except for the hard shards. The hard shards may comprise diamond. The substrate may be a drill bit. The laminate may be formed on the substrate by liquid chemical deposition of a colloidal solution of nanoparticles in dissolved metal-organic precursors.

Another embodiment of the present invention provides a MAX-phase material, comprising $M_{(n+1)}AX_n$ (MAX) phase material; where M is the first row transition-metal element, where A is an element from columns III-VI of the periodic table and where X is carbon and nitrogen.

The material may have atomic scale crystalline uniformity. The material may further comprise hard material shards and/or carbon fibers, coated carbon fibers, or carbon, carbide or nitride nanoparticles. The laminate may be formed by liquid chemical deposition of a colloidal solution of nanoparticles in dissolved metal-organic precursors

Yet another embodiment of the present invention provides a method of forming a MAX-phase material, comprising the steps of: forming a stoichiometric colloidal suspension of metal-organic precursors in solution along with carbon, carbide and/or nitride nanoparticles; spraying the colloidal suspension onto a heated substrate to deposit the suspension and to simultaneously decompose the precursors and leave an amorphous ceramic

material with embedded carbon, carbide, and/or nitride nanoparticles on the substrate; and rapid plasma annealing the amorphous ceramic material to create crystalline structure with carbon and/or nitrogen integrated from the carbon, carbide, and/or nitride nanoparticles.

The method may further comprise the step of repeating the steps of spraying and rapid plasma annealing to form a MAX-phase material having multiple layers. The method may still further comprise the step of repeating the step of forming to create different compositional mixtures in two or more of the multiple layers.

The colloidal suspension may include a super-stoichiometric relationship of the carbon, carbide and/or nitride nanoparticles to A-group elements for the MAX-phase material. The colloidal suspension may have a stoichiometry that produces a crystalline structure with a super stoichiometry of X group elements to A group elements. The colloidal suspension may have a super stoichiometry of X group elements of 1.1x to 3x to A group elements

The colloidal suspension may also include hard material shards, carbon or carbide nanoparticles, carbon fibers, coated carbon fibers, and/or nitride nanoparticles. The shards may be diamond.

In still another embodiment, the present invention provides a cutting tool that minimizes crack-forming differentials by embedding hardened shards, preferably diamond shards, in an ablative ceramic adhered to the bit head.

In still a further embodiment, the present invention provides means to fabricate chemically complex MAX phase materials on the surface of another material, or as a free-standing body.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention is illustratively shown and described in reference to the accompanying drawings, in which:

Figure 1 shows a cross-sectional depiction of a cutting tool constructed in accordance with one embodiment of the invention.

Figures 2A through 2C are sectional views of material constructed in accordance with one or more embodiments of the present invention.

Figure 3 is a sectional view of material constructed in accordance with amother embodiment of the present invention.

DETAILED DESCRIPTION OF THE EMBODIMENT

The present invention is introduced using examples and particular embodiments for descriptive purposes. Although a variety of examples are presented to show how various configurations can be employed to achieve the desired improvements, these particular embodiments are only illustrative and not intended in any way to restrict the inventions presented.

The current application incorporates by reference all matter contained in de Rochemont and Kovacs, U.S. Ser. No. 12/843,112 filed July 26, 2010, "LIQUID CHEMICAL DEPOSITION PROCESS APPARATUS AND EMBODIMENTS", (de Rochemont et al. '112), and de Rochemont and Farmer U.S. No. 5,707,715, entitled "METAL CERAMIC COMPOSITES WITH IMPROVED INTERFACIAL PROPERTIES AND METHODS TO MAKE SUCH COMPOSITES", filed August 29, 1996, issued January 13, 1998 (de Rochemont et al. '715), and de Rochemont and Farmer, U.S. No. 6,143,432, entitled "CERAMIC COMPOSITES WITH IMPROVED INTERFACIAL PROPERTIES AND METHODS TO MAKE SUCH COMPOSITES", filed January 9, 1998, issued November 7, 2000 (de Rochemont et al. '432).

Cutting tools generally locate shards of a very hard material, such as diamond, on the cutting surface of a bit head. The bit head is usually a mechanically hard substance, such as titanium, and is used to mechanically support the cutting surface. The hard material shards are located on the bit head cutting surface by impregnating them into a metal amalgam that is bonded to the bit head. The cutting process scrapes the hardened shards over the material to be cut. Repetitively scraping the surface with the hardened shards digs into and tears away the material through the application of frictional forces. Principal failure modes include the corrosive erosion of the metal amalgam and heat differentials generated between the bit head and the cutting surface that produce shear forces strong enough to crack the amalgam and/or the bit head itself. Shear forces are created when the heat differential causes unbalanced thermal expansion within the cutting tool that is greater than its tensile strength.

As shown in **FIG. 1**, a preferred embodiment of the invention uses the liquid chemical deposition (LCD) process to produce a cutting tool **100** that consists of a MAX-phase ceramic laminate **102** impregnated with shards of a very hard material **103**, preferably materials such as diamond that have hardness values in the range of 8-10, on the cutting surfaces **104,106** of a bit head **108**. The bit head **108** may be any material, but preferably is a hard, shape-formable material, such as titanium. MAX-phase ceramics are mechanically hard, oxidation/corrosion-resistant, damage tolerant materials that have excellent high-temperature properties, and will typically exhibit micro-Vickers hardness in the range of 1 GPa – 4 GPa at elevated temperatures up to 700 °C. This combination of physical and chemical properties makes MAX-phase materials ideal for use in harsh environments, such as those found in deep well oil exploration, when formed as a laminate on a cutting surface. The MAX-phase ceramic laminate may optionally have additional elements **110** embedded within it to improve its ablative properties. Ablative ceramics are characterized by their ability to prevent the creation of strong thermal gradients (heat differentials) sufficient to crack the cutting tool by allowing tiny particles with high heat capacities to carry thermal energy from the laminate body as they are dislodged from its surface. Rather, heat generated by frictional forces on the surface of the ceramic is dissipated through surface particles ablated off of the heated surface. While ablative ceramics will wear, as the metal amalgams do, they can withstand significantly higher temperatures found in harsh environments. Additional elements **110** may consist of carbon-fibers, coated carbon fibers, or aluminum nitride particles or nanoscale particles consisting either of carbon or aluminum nitride.

MAX-phase ceramics are impervious to many corrosive elements found in deep oil drilling environments, such as carbon dioxide and hydrogen sulfide gas. Previous fabrication techniques for MAX-phase ceramics consist of sintered powder preparations containing stoichiometric proportions of the desired elemental chemistry. Better results are achieved when the powder preparations are sintered using pulsed plasma discharges. The powder preparations are only used to make free-standing bodies, which are either machined or slip-cast to form a desired geometric shape. While it is possible to embed secondary phase components in powder-prepared MAX-phase materials, they cannot be applied to the surface of a pre-existing body as a laminate. Chemical vapor deposition (CVD) techniques have been

used to form MAX-phase laminates on the surface, but vapor delivery systems preclude the integration of shards of very hard material **103** needed to form a cutting surface, or the integration of additional elements **110** in the laminate to improve the cutting surface's ablative properties.

Reference is now made to **FIG. 2A,2B,2C & 3** to illustrate embodiments of the invention that relate to the synthesis of MAX-phase materials by LCD processes, and the integration of shards of very hard material **103** and additional elements **110** within the formed body. As detailed in de Rochemont et al. '112, the LCD process forms a compositionally complex laminate **120** having atomic-scale chemical uniformity from a liquid precursor solution that is sprayed on a substrate **122** heated to 250-450 °C. Atomic-scale chemical uniformity is endowed to the laminate through the molecular-level subdivision of the metalorganic precursors that are achieved in solution, and their simultaneous decomposition on the substrate surface. The laminate initially forms an amorphous solid due to the low deposition temperatures (250-450 °C). The LCD laminate will form an elemental solid solution if it is deposited in reducing or oxygen-free atmospheres, i.e., consisting of a chemically inert gas, hydrogen, or an oxidizing partial pressure ratio of carbon dioxide/carbon monoxide. Similarly, the LCD laminate will form a metal oxide solid solution when it is formed in oxidizing atmospheres. As detailed in de Rochemont et al. '715 and '432, secondary phase materials **124**, which may comprise shards of very hard material **103** and additional elements **110**, are embedded into the compositionally complex laminate **120** by forming a colloidal suspension that uniformly mixes the secondary phase materials **124** with the liquid precursor solution immediately prior to the spray deposition step. The amorphous deposit is rendered into a fully crystallized laminate **126** or poly-crystalline laminate **128** having uniform microstructure controllable down to nanoscale levels, by plasma annealing steps applied intermittently with the liquid precursor sprays. LCD allows a free-standing body that is amorphous, fully crystalline, or polycrystalline by optionally removing substrate **122** once the compositionally complex laminate(s) **120,126,128** have been formed to a thickness(es) that is (are) sufficient to mechanically support its (their) own weight. The surface adhesion of an LCD laminate to the substrate **122** is stronger than the tensile strength of most ceramics. The low deposition temperatures (250 °C to 450 °C) are insufficient to

anneal any tempering applied to the bit head **108**, thereby allowing cutting tool **100** to have higher intrinsic mechanical strength and not otherwise interfere with any prior heat treatments or tempering of the bit head **108**.

As noted above, MAX-phase materials are attractive for use a laminate in these applications because they are elastically stiff, resistant to chemical and thermal shock, damage tolerant, have relatively low coefficients of thermal expansion, and have high corrosion resistance. The most basic form of MAX-phase materials are binary carbides or nitrides and maintain the following compositional relationship:

$$M_{(n+1)}AX_n \quad (1)$$

where M is selected from the following transition-metal elements:

M = Sc, Ti, V, Cr, Mn, Fe, Ni, Cu, Zn

where A is selected from the following "A-group" elements:

A = Al, Si, Ga, Ge, In, Sn, Sb

where X is either nitrogen (N) or carbon (C),

and, n = 1, 2, or 3.

LCD enables the fabrication of higher order MAX-phase materials that have wider ranging or tailor-made physical, chemical, or electro-chemical properties. Higher order MAX-phase materials maintain higher complexity compositional relationships, for instance:

$$M^{(I)}_{(a)}M^{(II)}_{(b)}M^{(III)}_{(c)}M^{(IV)}_{(d)}A^{(I)}_{(1-x-y-z)}A^{(II)}_{(x)}A^{(III)}_{(y)}A^{(IV)}_{(z)}X_n \quad (2)$$

where the molar fractions $a + b + c + d = (n+1)$,

$x + y + z \leq 1$,

with, $M^{(X)}$ elements (X = I, II, III, IV) selected from the group of M elements listed above,

$A^{(Y)}$ elements (Y = I, II, III, IV) selected from the A-group elements listed above,

where X is nitrogen (N), carbon (C), or a mixture of nitrogen and carbon,

and n = 1,2, or 3

It is often necessary to specifically optimize the physical, chemical, or electro-chemical properties of a material for specific applications. Physical property optimization enabled by the inclusion or substitution of a plurality of transition-metal or A-group elements would include (micro) Vicker's hardness, Young's modulus, tensile strength, coefficient of thermal expansion, sound velocity, electrical and thermal conductivity. For instance, substituting

transition-metal elements that form strong bonds with A-group elements will improve the finished MAX-phase material's hardness. However, a plurality of substitutions and additions are generally required to achieve specific optimization of one property without comprising the integrity of another desirable physical, chemical or electro-chemical property. Partial substitution of a nitride element for a carbide would be made to improve or alter thermal conductivity.

The MAX-phase material is formed by first depositing an amorphous elemental pre-form material **150** on a substrate **152** heated to 250 – 450 °C using LCD processes, preferably in a reducing gas environment as noted above. The liquid precursor solution is prepared to endow the amorphous pre-form material **150** with the desired stoichiometric relationship between transition-metal elements (M group) and group-A elements. X-group nanoparticles **154** are incorporated into the amorphous elemental pre-form material **150** by forming a colloidal suspension in the liquid precursor solution prior to the spray deposition. Carbon nanoparticles, or nanoparticles comprising one or more desirable A-group elements with carbon, for instance, silicon carbide, aluminum carbide, are embedded into the amorphous element pre-form material **150** as X-group nanoparticles **154** when it is desirable to form a MAX-phase material consisting of carbide material, i.e., X = C. Nitride nanoparticles, comprising one or more desirable A-group elements, for instance, aluminum nitride (AlN), or gallium nitride (GaN), are embedded into the amorphous pre-form material **150** as X-group nanoparticles **154** when it is desirable to form a MAX-phase material consisting of nitride material, i.e., X = N. A combination of carbide and nitride nanoparticles are embedded into the amorphous perform material **150** as x-group nanoparticles **154** when it is desirable to form a MAX-phase material consisting of carbide and nitride material, i.e., X = C and N. The X-group nanoparticles **154** are the elemental source for the X-group element in the stoichiometry equations (1) and (2). It is preferred that the total weight of X-group nanoparticles **154** have a super-stoichiometric relationship to the group-A elements, such that the total weight of X-group nanoparticles **154** incorporated into the amorphous elemental pre-form material **150** comprise 1.1x – 3x the total number of moles A-group elements incorporated therein after spray deposition. A bake-out step that heats the amorphous elemental pre-form material to temperatures in the range of 450 °C – 600 °C is used to remove any undecomposed residual

metalorganic precursor material from the amorphous elemental pre-form material **150** prior to subsequent processing steps.

The X-group nanoparticles **154** are then reacted with the amorphous elemental pre-form material **150** by plasma annealing the deposit for 5-60 seconds at RF powers in the range of 10-300 W in gas mixtures that may contain argon, helium, and/or xenon at atmospheric pressures ranging between 1.5 to 5 Torr (1500 to 5000 mTorr), with partial pressures of carbon dioxide and carbon monoxide to prevent the evolution of carbon by-products from the laminate during processing. Nitrogen may be added to the ionized plasma when in it is desirable to use nitrogen (N) and an elemental component (X material) in the finished deposit. The substrate **152** is heated to a temperature in the range of 50 °C to 500 °C prior to initiating the plasma annealing steps. Shorter plasma annealing times, in the range of 5 seconds to 30 seconds, are used to form polycrystalline **128** laminates. Longer plasma annealing times, in the range of 30 seconds to 60 seconds, are used to form fully crystalline laminates **126**, except for hard material **103**. Any excess X-group nanoparticles **154** remaining in the laminate may be used as an additional element **110** that improves the ablative properties of the formed MAX-phase material. Additional elements **110** may also comprise carbon fiber, coated-carbon fiber, aluminum nitride particles, and very hard material **103**, comprising diamond shards or dust, are introduced into the amorphous pre-form material **150** as a colloidal suspension in the liquid precursor solution immediately prior to the deposition step. Greater thicknesses, including thicknesses sufficient to support the weight of the laminate as a free-standing body when the substrate **152** is optionally removed, are achieved by repeating the spray deposition, bake-out, and annealing steps a plurality of times. Additional, multi-layer MAX-phase material structures may formed with varied composition in different layers by sequentially depositing and plasma annealing a plurality of different MAX-phase compositions

The present invention is illustratively described above in reference to the disclosed embodiments. Various modifications and changes may be made to the disclosed embodiments by persons skilled in the art without departing from the scope of the present invention. For example, various sizes of diamond shards may be used including diamond dust. The process is also applicable to various types of cutting tools.

WHAT IS CLAIMED IS:

1. A cutting tool, comprising:
   a support substrate; and
   a complex ceramic cutting surface laminate formed on the support substrate and including hard shards, a first row transition-metal element, an element from columns III-VI of the periodic table and carbon and/or nitrogen.

2. The tool of claim 1, wherein the laminate has a polycrystalline structure or fully crystalline structure except for the hard shards.

3. The tool of claim 1, wherein the laminate includes an $M_{(n+1)}AX_n$ (MAX) phase material; where M is the first row transition-metal element, where A is an element from columns III-VI of the periodic table and where X is carbon and/or nitrogen.

4. The tool of claim 3, wherein the MAX-phase material has micro-Vickers hardness greater than 1 GPa.

5. The tool of claim 4, wherein the MAX-phase material has micro-Vickers hardness greater than 4 GPa.

6. The tool of claim 3, wherein the MAX-phase material further includes particles embedded within it that include carbon fiber, coated-carbon fiber, and/or aluminum nitride particles.

7. The tool of claim 1, wherein the hard shards comprise diamond.

8. The tool of claim 1, wherein the substrate is a drill bit.

9. The tool of claim 1, wherein the laminate is formed on the substrate by liquid chemical deposition of a colloidal solution of nanoparticles in dissolved metal-organic precursors.

10. A MAX-phase material, comprising $M_{(n+1)}AX_n$ (MAX) phase material; where M is the first row transition-metal element, where A is an element from columns III-VI of the periodic table and where X is carbon and nitrogen.

11. The material of claim 10, wherein the material has a atomic scale crystalline uniformity.

12. The material of claim 10, further comprising hard material shards or carbon fibers, coated carbon fibers, or carbon nanoparticles.

13. The material of claim 10, wherein the laminate is formed by liquid chemical deposition of a colloidal solution of nanoparticles in dissolved metal-organic precursors

14. A method of forming a MAX-phase material, comprising the steps of:

forming a stoichiometric colloidal suspension of metal-organic precursors in solution along with carbon, carbide and/or nitride nanoparticles;

spraying the colloidal suspension onto a heated substrate to deposit the suspension and to simultaneously decompose the precursors and leave an amorphous ceramic material with embedded carbon, carbide, and/or nitride nanoparticles on the substrate; and

rapid plasma annealing the amorphous ceramic material to create crystalline structure with carbon and/or nitrogen integrated from the carbon and/or nitride nanoparticles.

15. The method of claim 14, further comprising the step of repeating the steps of spraying and rapid plasma annealing to form a MAX-phase material having multiple layers.

16. The method of claim 15, further comprising the step of repeating the step of forming to create different compositional mixtures in two or more of the multiple layers.

17. The method of claim 14, wherein the colloidal suspension includes a super-stoichiometric relationship of the carbon, carbide and/or nitride nanoparticles to A group elements for the MAX-phase material.

18. The method of claim 14, wherein the colloidal suspension has a super stoichiometry of X group elements of 1.1x to 3x to A group elements

19. The method of claim 14, wherein the colloidal suspension also includes hard material shards, carbon nanoparticles, carbon fibers, coated carbon fibers, and/or nitride nanoparticles.

20. The method of claim 14, wherein the shards are diamond.

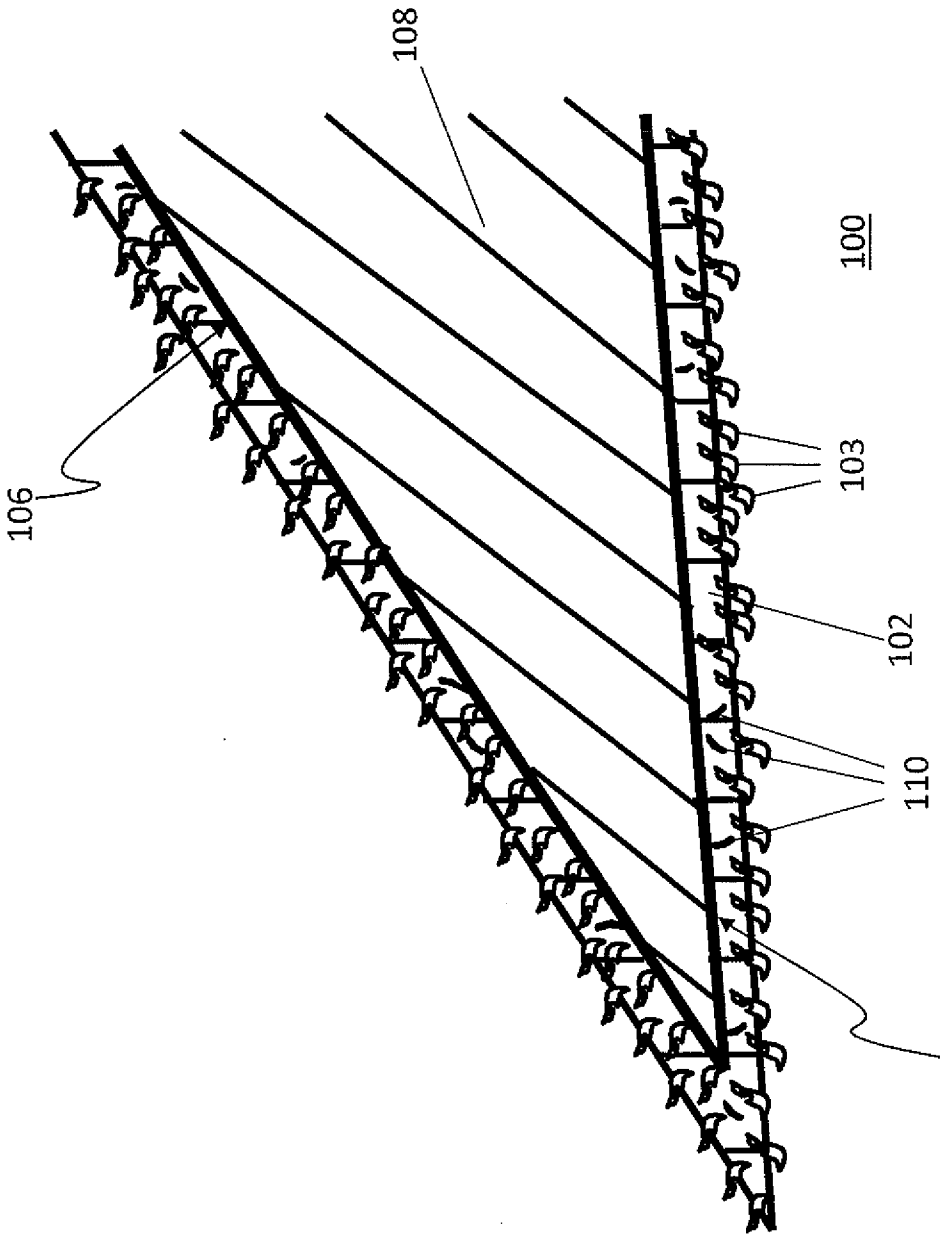


FIG. 1

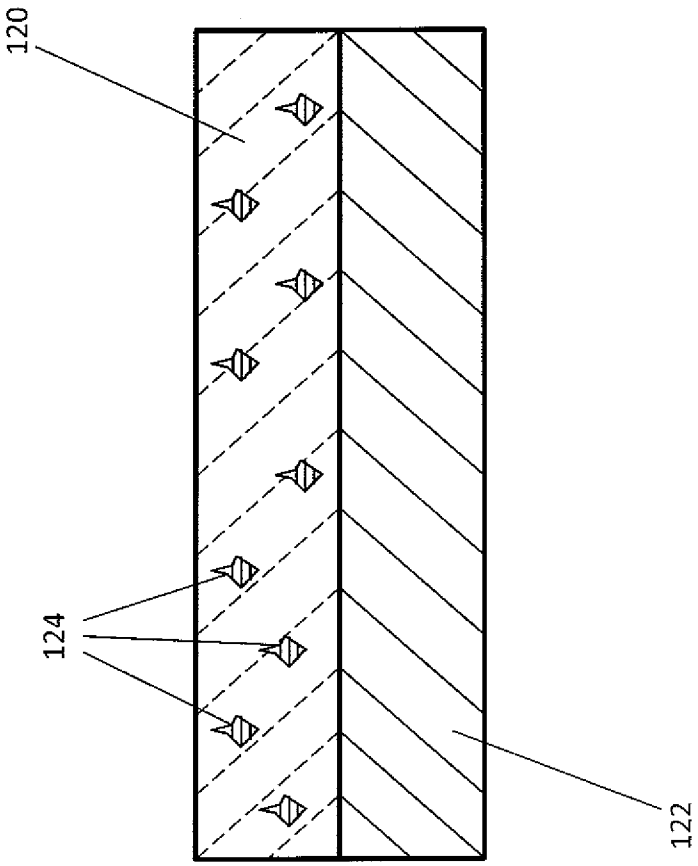


FIG. 2A

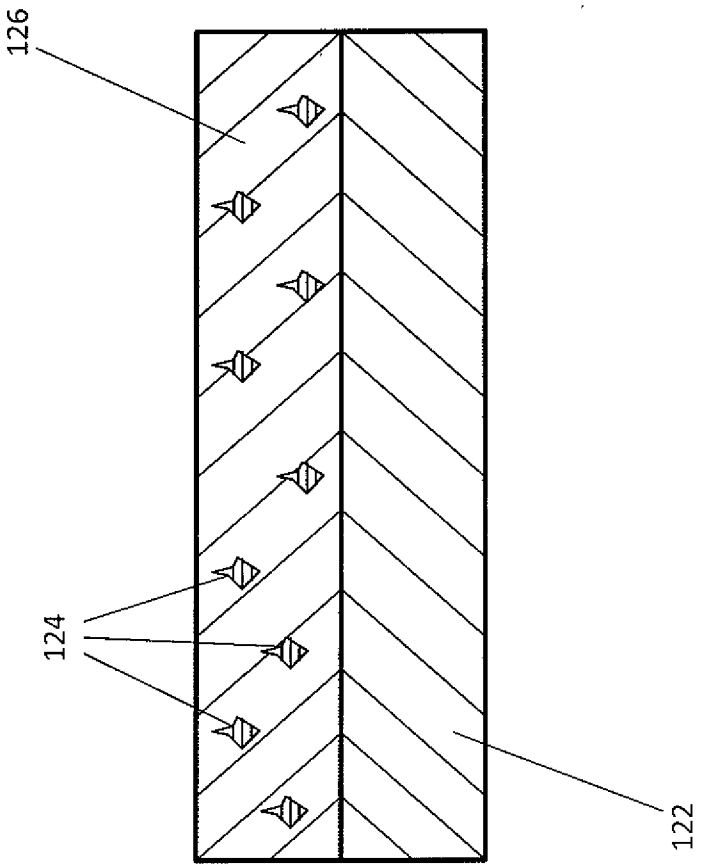


FIG. 2B

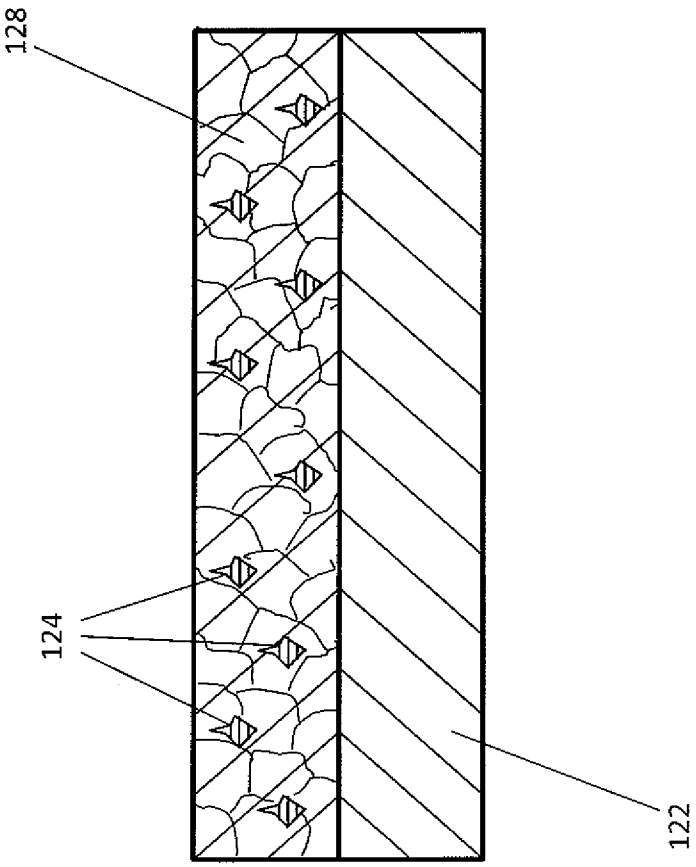


FIG. 2C

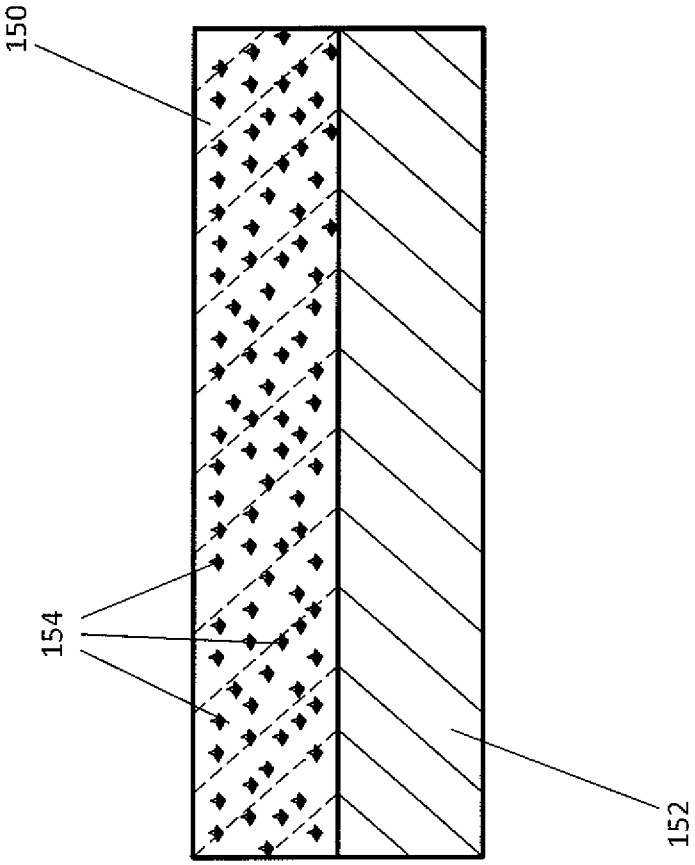


FIG. 3

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US 11/61315

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - B23B 27/14 (2012.01)
USPC - 51/309; 428/698
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)
IPC -- B23B 27/14 (2012.01)
USPC -- 51/309; 428/698

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
PubWEST (USPT, PGPB, JPAB, EPAB); Google
Search Terms: Drill bit, cutting tool, laminate, substrate, support, carbon, nitride, carbide, diamond, polycrystalline, nickel, tungsten, titanium, carbon fiber, plasma, spray, coating

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X ---------- Y	US 6,742,611 B1 (Illerhaus et al.) 01 Jun 2004 (01.06.2004), entire document especially Abstract, col 8, ln 44-55, col 26, ln 63 to col 27, ln 5, col 8, ln 55 to col 9, ln 5, col 15, ln 5-11 and col 26, ln 48-55	1-3, 7-13 ---------- 4-6, 14-20
Y	US 6,227,188 B1 (Tankala et al.) 08 May 2001 (08.05.2001), entire document especially Abstract, col 7, ln 30-45	4-6, 14-20
A	US 5,503,912 A (Setoyama et al.) 2 April 1996 (02.04.1996), entire document especially Abstract; col 2 ln 25-39; col 3 ln 61-67; col 5 ln 37-39; col 8 ln 32-50	1-20
A	US 5,656,561 A (Rogers et al.) 12 Aug 1997 (12.08.1997), entire document	1-20

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

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
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Date of the actual completion of the international search	Date of mailing of the international search report
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