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- (71) **Applicant** (for all designated States except US): **ELEMENT SIX LIMITED** [IE/IE]; Shannon Airport, Co. Clare (IE).
- (72) **Inventor; and**
- (75) **Inventor/Applicant** (for US only): **EGAN, David Patrick** [IE/IE]; Element Six Limited, Shannon Airport, Co. Clare (IE).
- (74) **Agents:** **REEVE, Anna Elizabeth** et al.; Element Six Limited, Group Intellectual Property, 3rd Floor, Building 4, Chiswick Park, 566 Chiswick High Road, London Greater London W4 5YE (GB).
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(54) **Title:** CUTTER CONSTRUCTIONS AND METHOD FOR MAKING SAME

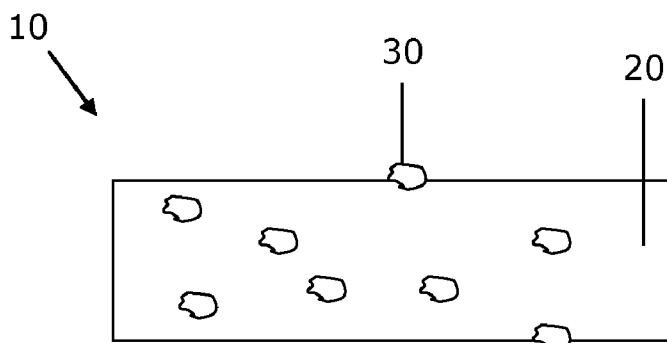


Fig. 1

(57) **Abstract:** A method for making a cutter construction comprising a cutter body joined to a carrier body, the method including providing the cutter body with a cutter coat structure, at least one of the carrier body and the cutter coat structure comprising a first material and the other comprising a second material, the first material having a lower melting point than the second material and being capable of wetting it, taking it into solution and reacting with it to produce a solid phase; heating the carrier body to above the melting point of the first material and contacting the cutter coat structure of the cutter body with the carrier body for a sufficient period for the first material to melt and for sufficient solid phase to form between the cutter body and the carrier body and join the cutter body to the carrier body; the heat being applied to the first and second materials via the carrier body.

CUTTER CONSTRUCTIONS AND METHOD FOR MAKING SAME

5 The invention relates generally to cutter constructions comprising cutter bodies and method for making cutter constructions, particularly but not exclusively cutter constructions in which the cutter bodies comprise super-hard material such as diamond or cubic boron nitride.

10 United States patent number 7,704,127 discloses an electrodeposited wire tool having a plurality of super-abrasive grains fixed by electro-deposition to the outer peripheral face of a long thin object, wherein the surface of the super abrasive grains is covered with a coating layer containing a metal, and the thickness of the coating layer is less than 0.1 micron or less than 10% of the mass of the super-abrasive grain.

15 Viewed from one aspect there is provided a method for making a cutter construction comprising a cutter body joined to a carrier body, the method including providing the cutter body with a cutter coat structure, at least one of the carrier body and the cutter coat structure comprising a first material and the other comprising a second material; 20 the first material having a lower melting point than the second material and being capable of wetting it, taking it into solution and reacting with it to produce a solid phase reaction product at a temperature greater than the melting point of the first material; the method further including heating the carrier body to the temperature and contacting the cutter coat structure of the cutter body with the carrier body for a 25 sufficient period for the first material to melt and for sufficient solid phase reaction product to form between the cutter body and the carrier body and join the cutter body to the carrier body; the heat being applied to the first and second materials via the carrier body.

30 Various combinations and variations of the method are envisaged by this disclosure, of which the following are non-limiting and non-exhaustive examples.

The method may include maintaining the temperature of the carrier body above the melting point of the first material for a period of at least about 10 seconds.

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The method may include heating the carrier body to a first temperature above the melting point of the first material and then contacting the cutter body with the carrier body.

- 5 In example variations of the method, the cutter coat structure may comprise the first material; the carrier body may comprise the first material; the cutter coat structure and the carrier body may comprise the first material; or the cutter coat structure and the carrier body may comprise the second material.
- 10 The carrier body may comprise a carrier coat structure disposed on a carrier core. The carrier coat structure may comprise the first material and the cutter coat structure comprising the second material, and or the cutter coat structure may comprise the first material and the carrier coat structure comprises the second material. The carrier coat structure may have thickness of at most about 100
- 15 microns, at most about 20 microns or at most about 10 microns.

- The first material may comprise an alloy including Cu and Zn, an alloy including Ni and P, or an element selected from Zn, Sn or Cu. In some examples, the second material may include Ni, Cu or W. In some examples, the first material may be
- 20 selected to have a relatively low melting point of at most about 1,200 degrees centigrade.

- The cutter coat structure may comprise an inner coat structure and an outer coat structure disposed over at least part of the inner coat structure; the inner coat
- 25 structure comprising a third material having a melting point greater than the melting point of the second material. The third material may be capable of being wet by the second material and of reacting with the second material to form a solid phase at a temperature greater than the melting point of the second material; the method further including heating the carrier body to a temperature greater than the melting point of
- 30 the second material for a period sufficient to allow the second and third materials to interact. The inner coat structure may comprise W or Ni in elemental or alloy form.

- Example cutter bodies may include abrasive grains such as diamond grains or cBN grains, polycrystalline bodies, sintered bodies, polycrystalline diamond (PCD)
- 35 structures, polycrystalline cubic boron nitride (PCBN) structures, chemical vapour

deposited (CVD) diamond, blades, saw segments, or inserts for machine tools or for drill tools. In some examples, the cutter body have mean size (such as mean diameter, equivalent circle diameter or side length) of at most about 5,000 microns, at most about 1,000 microns, at most about 100 microns, at most about 50 microns or at most about 25 microns. The size of the cutter body may be at least about 0.5 microns.

In some examples the cutter body may be a blade, a saw segment or an insert for machine tool. In some examples the cutter body may comprise an extended body such as a plate or other structure of CVD diamond, PCD or PCBN material.

Examples of carrier bodies for cutter constructions may include a wire for a wire saw, a wheel for a grinding or polishing, a segment for a saw, a wheel for a circular saw, a drill bit body, or a support body for a machine tool.

The method may include heating the carrier body by passing an electric current through it.

In some examples, the cutter coat structure may have a mean thickness of at least about 0.1 micron and at most about 100 microns, at most about 20 microns or at most about 10 microns. The mean thickness of the cutter coat structure may be selected such that the mass of the cutter coat structure is at least about 5 per cent and or at most about 50 per cent the mass of the cutter body. The cutter coat structure may be a coating layer that covers substantially the entire surface of the carrier body or part of the carrier body surface, and may have substantially uniform thickness or may have non-uniform thickness. The cutter coat structure may be a layer having mean thickness of at least about 1 micron.

In an example arrangement, the cutter coat structure may comprise an inner coat structure and an outer coat structure disposed over at least part of the inner coat structure. The inner coat structure may comprise a third material having a melting point greater than the melting point of the second material and the outer coat structure may comprise the second material or the first material. The inner coat structure may comprise sub-structures such as layers, which may comprise different materials. The inner coat may comprise material that is wettable by the second

material when the latter is in the liquid phase. In some versions, the inner coat structure may have thickness of at least about 0.1 micron and at most about 5 microns or at most about 3 microns. The outer coat structure may have a thickness of up to about 100 microns or up to about 10 microns.

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In an example arrangement, the cutter body may be a grain of diamond and the inner coat structure may comprise nickel, and a version of the method may include depositing nickel (Ni) on the grain surface by means of an electroplating process. In another particular example arrangement, the inner coat structure may comprise W, and a version of the method may include depositing W on the grain surface by physical vapour deposition (PVD) sputtering or chemical vapour deposition (CVD) involving hydrogen reduction of WF_6 . In one arrangement, the method may include depositing titanium (Ti) on the grain surface and then depositing a third material including Ni or W over the Ti material.

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In one version, the method may further including heating the carrier body to a temperature greater than the melting point of the outer coat structure for a period sufficient to allow the third material and the material of the outer cutter structure to interact, such wetting or reacting and form a solid phase.

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In one example, the inner coat structure may be bonded to the surface of the cutter body via a reaction product formed by reaction of material comprised in the inner coat structure and material comprised in the cutter body. For example, the cutter body may comprise carbon and the reaction product may be carbide material. In particular examples, the third material may include W or Ni in elemental or alloy form and the outer coat structure may comprise Cu, Sn or Zn.

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In some variations, the method may include providing a plurality of abrasive grains each coated with the second material and a carrier body comprising a carrier coat structure disposed on a carrier core, in which the carrier coat structure comprises the first material; combining the abrasive grains to form an unbonded agglomeration of the abrasive grains; heating the carrier body to a temperature high enough to melt the first material, and immersing the carrier body into the agglomeration of the abrasive grains. In some variations, the method may include providing a plurality of abrasive grains each coated with the second material and a carrier body comprising

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a carrier coat structure disposed on a carrier core, in which the carrier coat structure comprises the first material; heating the carrier body to a temperature high enough to melt the first material, and sprinkling the abrasive grains onto the carrier body.

- 5 An example method may include providing a plurality of diamond grains each comprising a respective grain coat structure, providing a carrier wire comprising a steel wire core and a wire coat structure disposed on the wire core; at least one of the wire coat structure or the grain coat structure comprising the first material and the other comprising the second material; heating the carrier wire to a temperature of at least the melting point of the first material and less than the melting point of the second material; contacting the diamond grains with the carrier wire for a sufficient period for the first material comprised in the wire coat structure or the grain coat structures to wet the other coat structure, to react with the second material comprised in the other coat structure and for reaction products in the solid phase to precipitate and form a solid bridge between the diamond grain and the wire core; and reducing the temperature of the carrier wire to a temperature less than the melting point of the first material.

Non-limiting examples are described with reference to the accompanying drawings, of which:

- Fig. 1 shows a schematic side view of a section of an example wire for a wire saw; Fig. 2A, Fig. 2B and Fig. 2C show a schematic cross section views through an example abrasive grain and an example carrier body at various stages of an example method for joining the abrasive grain to the carrier body;
- Fig. 3 shows a schematic cross section view through an example abrasive grain and an example carrier body at a stage of an example method for joining the abrasive grain to the carrier body; and
- Fig. 4 shows a schematic cross section view through an example abrasive grain and an example carrier body at a stage of an example method for joining the abrasive grain to the carrier body.

With reference to Fig. 1, an example cutter wire 10 for a wire saw comprises a wire 20 to which are joined a plurality of coated diamond grains 30.

In an example method described with reference to Fig. 2A, Fig. 2B and Fig. 2C, a diamond grain 32 provided with a grain coat 34 is joined to a carrier body 20 in the form of a wire comprising a steel core 22 and a wire coat 24. The wire coat 24 comprises a first material such as Sn or Zn and the grain coat structure 34 comprises a second material such as Cu, Ni or W. The wire 20 is heated to above the melting point of the first material to melt the wire coat 24 and form a layer in the liquid phase L, and the coated diamond grain 32 is placed in contact with the molten wire coat 24. The molten material of the wire coat 24 wets the surface of the grain coat 34, which is still substantially in the solid phase S, thereby increasing the area of contact with it and forming a surface tension bond between the wire coat 24 and the grain coat structure 34. The bond strength will be sufficient to hold the coated diamond grain 32 in place for a period sufficient to allow material from the grain coat 34 to go into solution in the molten wire coat 24 and diffuse through it substantially to the non-molten wire core 22, as indicated by the arrows. As the second material from the grain coat 34 diffuses through the molten first material of wire coat 24, the materials interact to form a solid phase S' in a region 26 between the coated diamond grain 32 and the wire core 22, resulting in a solid bridge between the diamond grain 32 and the wire core 22. The diamond grain 32 is thus joined to the wire 20. The temperature of the wire 20 is then reduced to less than the melting point of the first material, which consequently reverts to the solid phase.

In an example method described with reference to Fig. 3, a diamond grain 32 provided with a grain coat 34 is joined to a carrier body 20 in the form of a wire comprising a steel core 22 and a wire coat 24. The grain coat 34 comprises a first material such as Sn or Zn and the wire coat 24 comprises a second material such as Cu or Ni-P. The wire 20 is heated to above the melting point of the first material and the coated diamond grain 32 is placed in contact with the wire coat 24. On contact, the first material comprised in the grain coat 34 will begin to melt and wet the surface of the wire coat 24, which is still substantially in the solid phase, thereby increasing the area of contact with it and forming a surface tension bond between the wire coat 24 and the grain coat structure 34. The bond strength will be sufficient to hold the coated diamond grain 32 in place for a period sufficient to allow material from the wire coat 24 to go into solution in the molten grain coat 34 and diffuse through it substantially to the non-molten diamond grain 32, as indicated by the arrows. As the second material from the wire coat 24 diffuses through the molten first material of

grain coat 34, the materials interact to form a solid phase S' in a region 36 between the diamond grain 32 and the wire 20, resulting in a solid bridge between the diamond grain 32 and the wire 20. The diamond grain 32 is thus joined to the wire 20. The temperature of the wire 20 is then reduced to less than the melting point of the first material, which consequently reverts to its solid phase.

In an example method described with reference to Fig. 4, a diamond grain 32 provided with an inner grain coat 38 and an outer grain coat 34 is joined to a carrier body 20 in the form of a wire comprising a steel core 22 and a wire coat 24. The inner grain coat 38 is disposed on at least a part of the surface of the grain 32 and the outer coat 34 is disposed on at least a part of the inner grain coat 38. The outer grain coat 34 comprises a first material such as Sn or Zn and the wire coat 24 comprises a second material such as Cu or Ni-P. The inner grain coat 38 comprises a third material such as W or Ni (or more than one material, which may be arranged as sub-layers) which may be selected to have a higher melting point than the second material, to be capable of bonding to the grain 32 and to be capable of being wet by the second material (or the first material) when the latter is in the liquid phase. The wire 20 is heated to above the melting point of the first material and the coated diamond grain 32 is placed in contact with the wire coat 24. On contact, the first material comprised in the grain coat 34 will begin to melt and wet the surface of the wire coat 24, which is still substantially in the solid phase, thereby increasing the area of contact with it and forming a surface tension bond between the wire coat 24 and the grain coat structure 34. The bond strength will be sufficient to hold the coated diamond grain 30 in place for a period sufficient to allow material from the wire coat 24 to go into solution in the molten grain coat 34 and diffuse through it substantially to the non-molten diamond grain 32, as indicated by the arrows. As the second material from the wire coat 24 diffuses through the molten first material of grain coat 34, the materials interact to form a solid phase S' in a region 36 between the diamond grain 32 and the wire 20, resulting in a solid bridge between the diamond grain 32 and the wire 20. The diamond grain 32 is thus joined to the wire 20. The temperature of the wire 20 is then reduced to less than the melting point of the first material, which consequently reverts to the solid phase.

In a particular version of the example method described with reference to Fig. 4, the temperature of the wire may be further increased to greater than the melting point of

the second material but less than that of the third material to at least partially melt the outer coat 34. Reaction between the second and third material may result in at least part of the outer coat 34 transforming into a solid phase having a different composition than the second material, and may result in the diamond grain 32 becoming more strongly joined to the wire 20. The temperature of the wire 20 is then reduced to ambient temperature.

In one example, the method may include providing a plurality of abrasive grains coated with a second material and a carrier body coated with a first material, heating the carrier body to a temperature to melt the first material, and immersing the carrier body into a bed of the abrasive grains. Alternatively, the method may include sprinkling the abrasive grains onto the carrier body. In some versions, the carrier body may be heated in an oven or may be heated by passing an electric current through it.

Non-limiting example methods and arrangements are described in more detail below.

Example 1

A plurality of synthetic diamond grains having mean size of about 25 microns may be joined to a wire to provide a fixed-diamond wire for cutting silicon, silicon carbide, sapphire or quartz, for example. The diamond grains may be provided with a inner cutter coat of Ni by means of electroplating, the Ni coat covering substantially the entire surface of the grains and having a mean thickness of about 1 micron. A cutter coat layer comprising Cu and having a mean thickness of about 5 microns may then be deposited onto the Ni coat. A spring steel wire having a diameter of about 250 microns may be provided and a coating including Zn may be deposited onto the wire. The coated diamond grains may be placed in a vessel, the coated wire may be immersed in the diamond grains and an electric current may be passed through the wire to heat it to a temperature at least about 420 degrees centigrade to melt the Zn. The molten Zn would react with the Cu in the cutter coat structure to form a Zn-Cu alloy, which would be in a solid phase at the temperature. The wire may then be cooled and removed from the vessel to provide a wire comprising diamond grains joined to it. The wire may again be heated to melt the Cu of the cutter coating to bond the abrasive grains more robustly to the wire by wetting the Ni layer.

Example 2

A plurality of synthetic diamond grains having mean size of about 25 microns may be joined to a wire to provide a fixed-diamond wire for cutting silicon, silicon carbide, sapphire or quartz, for example. The diamond grains may be provided with a Ti or Cr coating on the surface, which may react with carbon at the diamond surface to form titanium carbide or chromium carbide. An inner cutter coat of Ni may be deposited over the Ti or Cr coat by means of electroplating, the Ni coat covering substantially the entire surface of the grains and having a mean thickness of about 1 micron. A cutter coat layer comprising Sn and having a mean thickness of about 5 micron may then be deposited onto the Ni coat. A spring steel wire having a diameter of about 250 microns may be immersed into a bed of the diamond grains and an electric current may be passed through the wire to heat it to a temperature at least about 250 degrees centigrade to melt the Sn, which may wet and bond to the wire material as well as the Ni layer on the grit. The wire may then be cooled and removed from the vessel to provide a wire comprising diamond grains joined to it.

Example 3

A plurality of synthetic diamond grains having mean size of about 25 microns may be joined to a wire to provide a fixed-diamond wire for cutting silicon, silicon carbide, sapphire or quartz, for example. The diamond grains may be provided with a Ti or Cr coating on the surface, which may react with carbon at the diamond surface to form titanium carbide or chromium carbide. An inner cutter coat of Ni may be deposited over the Ti or Cr coat by means of electroplating, the Ni coat covering substantially the entire surface of the grains and having a mean thickness of about 1 micron. A cutter coat layer comprising NiP and having a mean thickness of about 5 microns may then be deposited onto the Ni coat. A spring steel wire having a diameter of about 250 microns may be immersed into a bed of the diamond grains and an electric current may be passed through the wire to heat it to a temperature at least about 950 degrees centigrade to melt the NiP, which may wet and bond to the wire material. The wire may then be cooled and removed from the vessel to provide a wire comprising diamond grains joined to it.

Certain terms as used herein are briefly explained below.

As used herein, a material in the solid phase is wettable by material in the liquid phase if the liquid tends to move or become arranged to increase the contact area with the solid as a result of the surface interaction thermodynamic forces (i.e. to reduce the surface tension). The degree of wetting (i.e. the wettability) is determined by a force balance between adhesive and cohesive forces. Wetting may be important in the bonding or adherence of two materials and the surface forces that control wetting are also responsible for other related effects, including so-called capillary effects.

The cutter constructions according to this disclosure may also be referred to as tool elements.

Claims

1. A method for making a cutter construction comprising a cutter body joined to a carrier body, the method including providing the cutter body with a cutter coat structure, at least one of the carrier body and the cutter coat structure comprising a first material and the other comprising a second material; the first material having a lower melting point than the second material and being capable of wetting it, taking it into solution and reacting with it to produce a solid phase reaction product at a temperature greater than the melting point of the first material; the method further including heating the carrier body to the temperature and contacting the cutter coat structure of the cutter body with the carrier body for a sufficient period for the first material to melt and for sufficient solid phase reaction product to form between the cutter body and the carrier body and join the cutter body to the carrier body; the heat being applied to the first and second materials via the carrier body.
2. A method as claimed in claim 1, including heating the carrier body to a first temperature above the melting point of the first material and then contacting the cutter body with the carrier body.
3. A method as claimed in claim 1 or claim 2, including maintaining the temperature of the carrier above the melting point of the first material for a period of at least about 10 seconds.
4. A method as claimed in any of the preceding claims, in which the cutter coat structure comprises the first material.
5. A method as claimed in any of the preceding claims, in which the cutter coat structure and the carrier body comprise the first material.
6. A method as claimed in any of the preceding claims, in which the cutter coat structure and the carrier body comprise the second material.
7. A method as claimed in any of the preceding claims, in which the carrier body comprises a carrier coat structure disposed on a carrier core.

8. A method as claimed in any of the preceding claims, in which the carrier body comprises a carrier coat structure disposed on a carrier core, the carrier coat structure comprising the first material and the cutter coat structure comprising the second material.

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9. A method as claimed in any of the preceding claims, in which the first material comprises an alloy including Cu and Zn, an alloy including Ni and P, or an element selected from Zn, Sn or Cu.

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10. A method as claimed in any of the preceding claims, in which the cutter coat structure comprises an inner coat structure and an outer coat structure disposed over at least part of the inner coat structure; the inner coat structure comprising a third material having a melting point greater than the melting point of the second material.

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11. A method as claimed in claim 10, in which the third material is capable of being wet by the second material and of reacting with the second material to form a solid phase at a temperature greater than the melting point of the second material; the temperature to which the carrier body is heated being greater than the melting point of the second material and the period being sufficient to allow the second and third materials to interact.

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12. A method as claimed in claim 10 or claim 11, in which the inner coat structure comprises W or Ni in elemental or alloy form.

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13. A method as claimed in any of the preceding claims, in which the cutter body comprises a diamond grain or a cBN grain.

14. A method as claimed in any of the preceding claims, in which the carrier body is an abrasive grain having a size of at most about 5,000 microns.

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15. A method as claimed in any of the preceding claims, in which the cutter body comprises a polycrystalline diamond (PCD) structure, a polycrystalline cubic boron nitride (PCBN) structure or a CVD diamond structure.

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16. A method as claimed in any of the preceding claims, in which the cutter body is a blade, a saw segment or an insert for machine tool.
17. A method as claimed in any one of the preceding claims, in which the carrier
5 body is a wire for a wire saw or a wheel for a grinding wheel.
18. A method as claimed in any of the preceding claims, including heating the carrier body by passing an electric current through it.
- 10 19. A method as claimed in any one of the preceding claims, in which the cutter coat structure is a layer having mean thickness of at least about 1 micron.
20. A method as claimed in any of the preceding claims, including providing a plurality of abrasive grains each coated with the second material and a carrier
15 body comprising a carrier coat structure disposed on a carrier core, in which the carrier coat structure comprises the first material; combining the abrasive grains to form an unbonded agglomeration; heating the carrier body to a temperature high enough to melt the first material, and immersing the carrier body into the agglomeration of the abrasive grains.
- 20 21. A method as claimed in any of claims 1 to 19, including providing a plurality of abrasive grains each coated with the second material and a carrier body comprising a carrier coat structure disposed on a carrier core, in which the carrier coat structure comprises the first material; heating the carrier body to a
25 temperature high enough to melt the first material, and sprinkling the abrasive grains onto the carrier body.
22. A method as claimed in any of the preceding claims, the method including providing a plurality of diamond grains each comprising a respective grain coat
30 structure, providing a carrier wire comprising a steel core and a wire coat structure disposed on the steel core of the wire; at least one of the wire coat structure or the grain coat structure comprising the first material and the other comprising the second material; heating the carrier wire to a temperature greater than the melting point of the first material and less than the melting point of the
35 second material; contacting the diamond grains with the carrier wire for a sufficient period for the first material comprised in the wire coat structure or the grain coat structure to wet the other coat structure, to react with the second

material comprised in the other coat structure and for reaction products in the solid phase to precipitate and form a solid bridge between the diamond grain and the wire core; and reducing the temperature of the carrier wire to a temperature less than the melting point of the first material.

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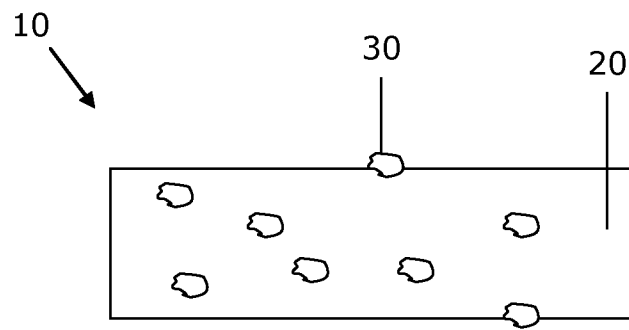


Fig. 1

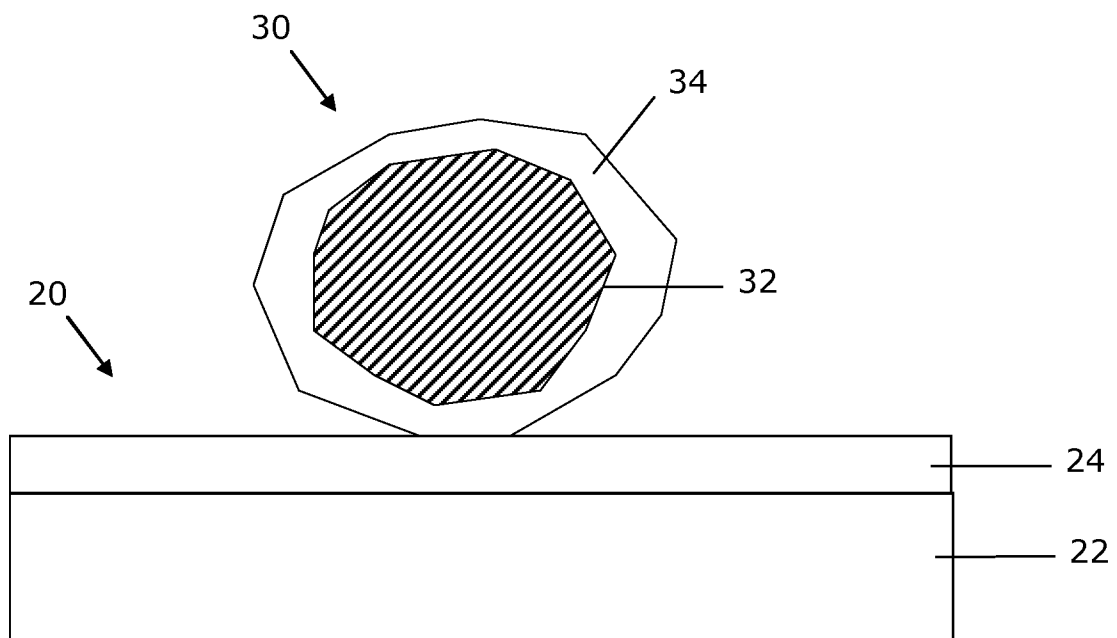


Fig. 2A

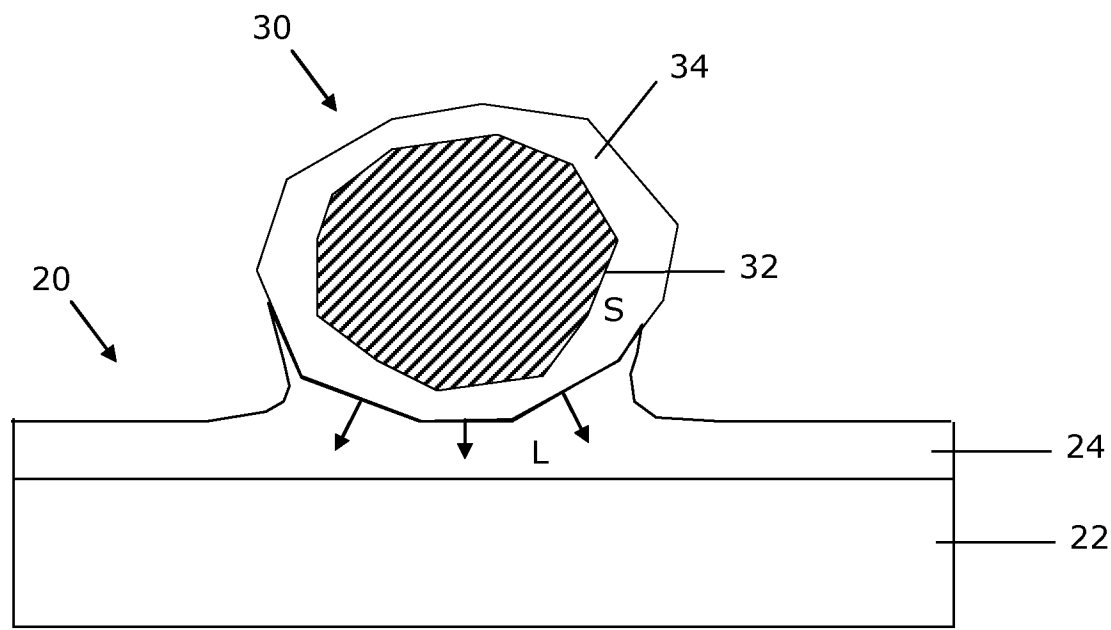


Fig. 2B

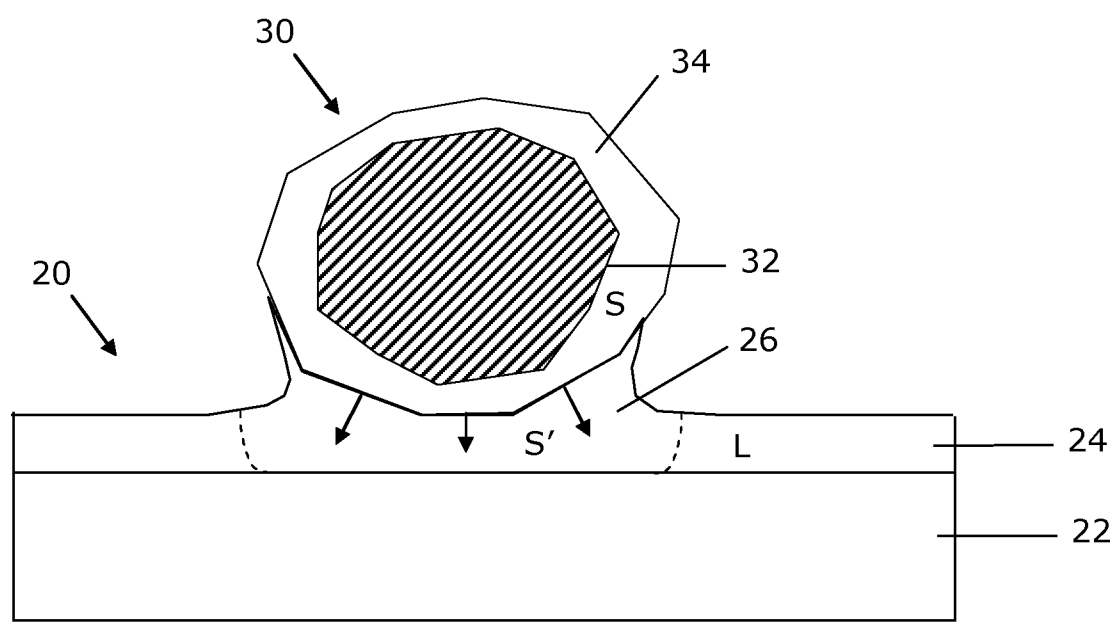


Fig. 2C

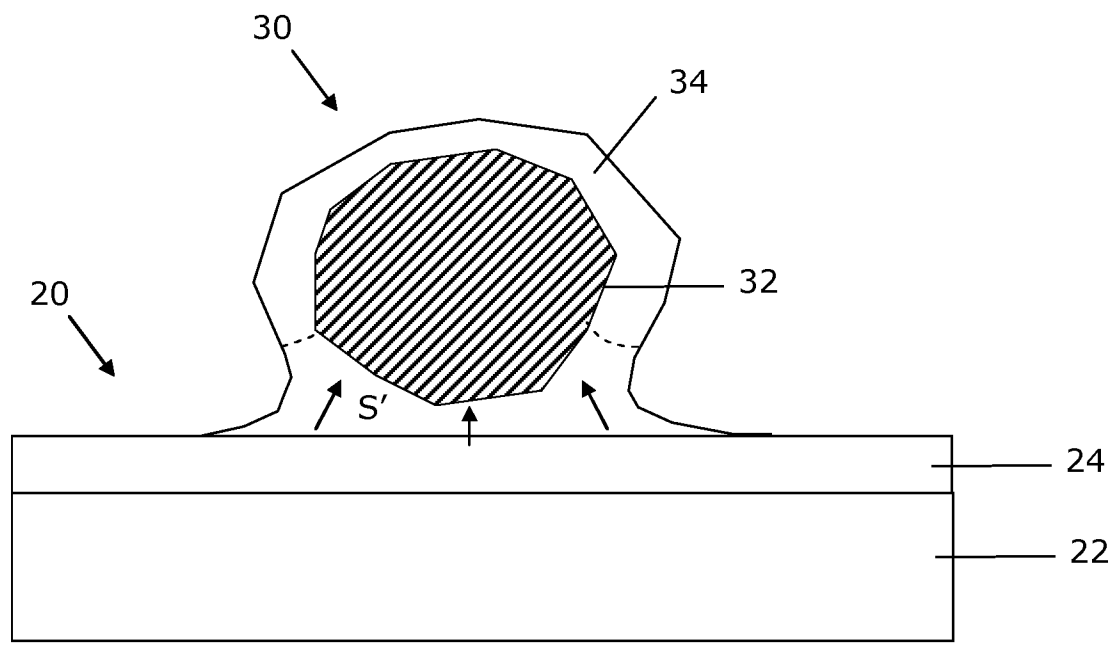


Fig. 3

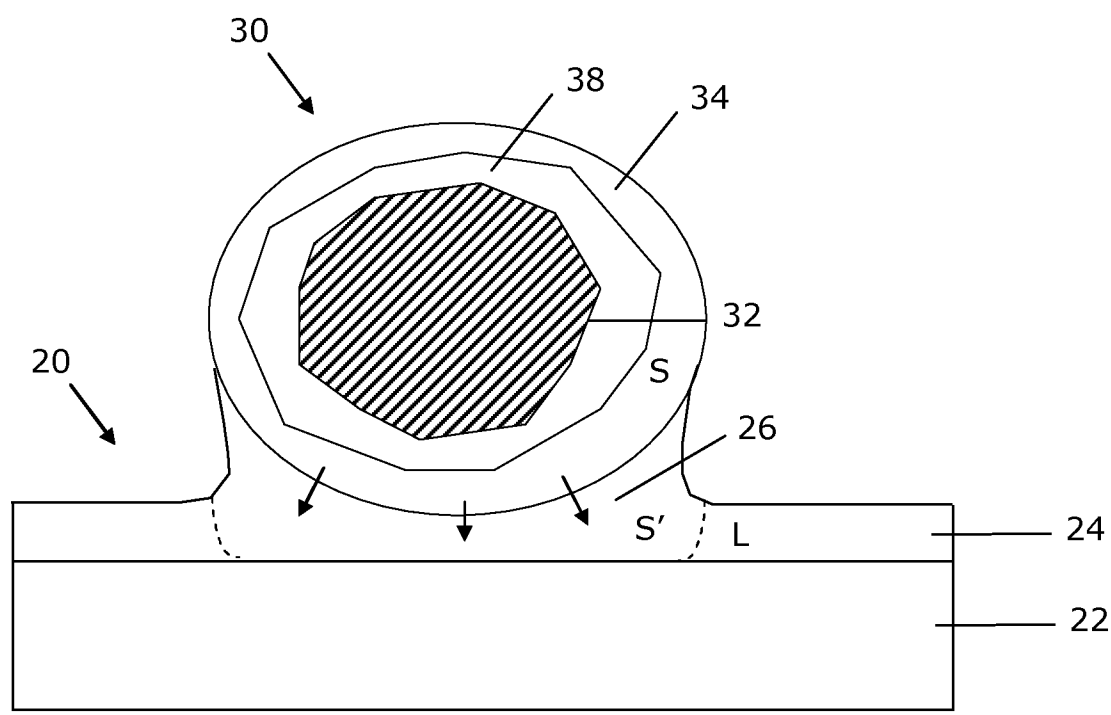


Fig. 4

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2012/059847

A. CLASSIFICATION OF SUBJECT MATTER INV. B24D3/06 B24D18/00 B24B27/06 ADD.		
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) B24D B24B		
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) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 7 704 127 B2 (TANIGUCHI KAZUAKI [JP] TANIGUCHI KAZUAKI [JP] ET AL) 27 April 2010 (2010-04-27) cited in the application the whole document	1-22
A	US 2007/151554 A1 (SONG MIN-SEOK [KR] ET AL) 5 July 2007 (2007-07-05) paragraphs [0042] - [0044]; figure 6	1-22
A	US 4 155 721 A (FLETCHER J LAWRENCE [US]) 22 May 1979 (1979-05-22) figures 2-4	1-22
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☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
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