

TOOL BITS HAVING PLASMA DEPOSITED METAL CARBIDE COATINGS

Technical Field

The present invention generally relates to coated
5 tool bits and in particular to metal carbide coated tool
bits used in the manufacture of printed circuit boards
(here called "PCB").

Background

10 Machining operations on PCB'S must be precise and
match very close tolerances. For boring operations using a
drill bit or other similar rotary boring device, the
tolerances are measured in respect of bore diameter, axial
straightness, and depth of bore.

15 The substrates of PCB's are usually made from
materials that are difficult to drill (ie fiberglass) and
which impart high demands on drill bits and other rotary
boring tools that are used during PCB manufacture.
Materials such as fiberglass can be very abrasive and tend
20 to dull the drill bit ends relatively quickly. This
results in the drill bits failing to meet tolerance
standards, which results in dimensional faults arising in
the manufacture of the PCB board.

To overcome the problems associated with high wear
25 rates of the drill bits, it is known to coat the drill
bits with a hard coating, such as hardened carbide steel,
to prevent the rates at which the drill bits are dulled.
However, due to the abrasiveness of the PCB board
material, most hardened carbide PCB drill bits have a life
30 of between about 500 and 2,000 cycles out of each drill
bit before it is so dull that it is spent and must be
replaced.

There is a need to provide tool bits that overcome, or at least ameliorate, one or more of the disadvantages described above.

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Summary

According to a first aspect, there is provided a tool bit comprising a tool bit comprising:

- a cylindrical body having a longitudinal axis;
- 10 a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;
- a working end on an opposite end of said body to said tool engagement end; and
- 15 a plasma deposited metal carbide coating layer provided on said working end, wherein in use, said coated working end bores a hole into a work piece as said cylindrical body is rotated about its longitudinal axis.

Advantageously, when the tool bits are used to bore
20 holes in PCB material, the plasma deposited metal carbide coating layer significantly extends the cycle life of the tool bit relative to known hard coating layers.

The hard coating layer may have a thickness selected from the group consisting of 250 nm to 3000 nm, 250 nm to
25 2500 nm, 250 nm to 2000 nm, 250 nm to 1500 nm, 250 nm to 1000 nm, 500 nm to 3000 nm, 500 nm to 2500 nm, and 1000 nm to 2000 nm.

The hard coating layer may have a hardness of at least 10 GPa. Optionally, the hard coating layer has a
30 hardness of 10 GPa to 35 GPa or 15 GPa to 25 GPa.

In one embodiment, the hard coating layer comprises a primary layer provided on said working end and a secondary layer provided on said primary layer, wherein the hardness of said secondary layer is higher than said primary layer.

Optionally, the primary layer has a hardness of 5 GPa to 10 GPa and said secondary layer has a hardness of 10 GPa to 35 GPa. In one embodiment, the primary and secondary layers have respective thickness within the range of
5 250 nm to 1500 nm, 500 nm to 1500 nm, and 800 nm to 1500 nm.

The metal of the metal carbide may be a transition metal. The transition metal of said transition metal carbide may be selected from the group consisting of Ti,
10 Zr, Hf, V, Nb, Ta, Cr, Mo, W, Fe, Ru, Os, and combinations thereof.

In one embodiment, the transition metal carbide is tantalum carbide.

The hard coating layer may have been deposited using
15 a plasma sourced from a filtered cathodic vacuum arc.

In one embodiment, the tool bit is a printed circuit board (PCB) drill bit. In another embodiment, the tool bit is a printed circuit board (PCB) router bit.

The cylindrical body may have a diameter selected
20 from the group consisting of 0.05 mm to 3 mm; 0.05 mm to 2 mm; 0.05 mm to 1 mm; 0.05 mm to 0.5 mm and 0.05 mm to 0.25 mm.

In one embodiment, the tool bit comprises a metal layer disposed between said working end and said hard
25 coating layer. The thickness of the metal layer may be 250 nm to 1500 nm.

In one embodiment, the cylindrical body comprises tungsten carbide and cobalt.

In one embodiment, there is provided a tool bit
30 comprising:

- a cylindrical body having a longitudinal axis;
- a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;

a working end on an opposite end of said body to said tool engagement end;

a plasma deposited metal layer provided on said working end;

5 a plasma deposited primary metal carbide coating layer provided on said metal layer;

a plasma deposited secondary metal carbide coating layer provided on said primary metal carbide coating layer, wherein the hardness of said secondary metal
10 carbide coating layer is harder relative to said primary metal carbide coating layer;

wherein in use, said coated working end bores a hole into a work piece as said cylindrical body is rotated about its longitudinal axis.

15 The plasma deposited metal carbide coating layer may exhibit Raman intensity values of between about 0.3 to about 1 or about 0.5 to about 0.8.

According to a second aspect, there is provided a method of coating a tool bit comprising a cylindrical body
20 having a longitudinal axis, a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis, and a working end on an opposite end of said body to said tool engagement end, the method comprising the step
25 of (a) depositing plasma metal ions and carbon ions onto said working end to form a metal carbide layer thereon.

Advantageously, the plasma metal ions and carbon ions are substantially free of macroparticles.

The method may, before step (a), the steps of: (b)
30 generating a plasma beam comprising metal ions and carbon ions in an inert atmosphere, or under vacuum, from a cathodic vacuum arc source; and

(c) filtering said plasma beam to substantially remove all macroparticles therefrom.

The method may comprise, during step (a), the step of:

(d) applying an alternating bias pulse to said working end of said tool bit, said bias pulse alternating
5 between a relatively high negative bias pulse and a low negative bias pulse.

The method may comprise the step of (d1) selecting said high negative bias pulse from the group consisting of the range -1800 V to -4,500 V and -2000 V to -2500 V.

10 The method may comprise the step of (d2) selecting said low negative bias pulse from the group consisting of the range -50 V to -500 V and -100 V to -200 V.

The method may comprise the step of (e) pulsing the bias on the substrate at a frequency of up to 10 kHz. The
15 pulsing step (e) may comprise the step of (e1) selecting the frequency from the range of 1 kHz to 3 kHz.

The pulsing step (e) may comprise the step of (e2) selecting the pulse duration from the group consisting of 1 μ s to 50 μ s, 1 μ s to 25 μ s, and 5 μ s to 10 μ s.

20 According to a third aspect, there is provided use of a tool bit for printed circuit board (PCB) manufacture, the tool bit comprising:

a cylindrical body having a longitudinal axis;

a tool engagement end on one end of said body for
25 engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;

a working end on an opposite end of said body to said tool engagement end; and

a plasma deposited metal carbide coating layer
30 provided on said working end,

wherein in use said coated working end bores a hole into said PCB as said cylindrical body is rotated about its longitudinal axis.

According to a fourth aspect, there is provided a method of making a tool bit comprising the steps of:

(a) providing a tool bit comprising a cylindrical body having a longitudinal axis, a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis, and a working end on an opposite end of said body to said tool engagement end; and

(b) depositing plasma metal ions and carbon ions onto said working end to form a metal carbide layer thereon.

According to a fifth aspect, there is provided a printed circuit board (PCB) drill bit or router bit comprising:

a cylindrical body having a longitudinal axis;
a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;

a working end on an opposite end of said body to said shank end; and

a plasma metal carbide deposited coating layer on said working end for boring a hold into said PCB as said cylindrical body is rotated about its longitudinal axis.

According to a sixth aspect, there is provided use of a tool bit for boring a hole into a board during the manufacture of a printed circuit board (PCB), the tool comprising:

a cylindrical body having a longitudinal axis;
a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;

a working end on an opposite end of said body to said shank end; and

a tantalum carbide coating layer on said working end having a thickness of about 1.5 μ m or less,

wherein in use, said coating layer bores a hole into said PCB as said cylindrical body is rotated about its longitudinal axis.

According to a seventh aspect, there is provided a
5 printed circuit board (PCB) having one or more holes that have been bored with a tool bit as claimed in the first aspect.

According to an eighth aspect, there is provided a method of boring a hole into the substrate of a printed
10 circuit board (PCB) comprising the step of:

(a) drilling a drill or router tool bit into the PCB board substrate, the end of said tool bit comprising a plasma deposited metal carbide coating layer thereon.

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Definitions

The following words and terms used herein shall have the meaning indicated:

The term "tool bit", in the context of this
20 specification, refers to a tool bit used for axial boring and includes within its scope drill bits, end mills and router bits, for boring holes into work pieces. In one embodiment, the tool bits are used in the electronics industry for PCB fabrication and particularly, where the
25 tool bits are used to axially bore holes into the substrate of PCBs.

The term "working end", in the context of this specification, refers to the end of the tool bit on which the plasma deposited metal carbide coating layer is coated
30 and which does the actual boring into the work piece.

The term "tool engagement end", in the context of this specification, refers to the end of the tool bit that is engageable with a tool capable of rotating the tool bit about its longitudinal axis. For example, the tool

engagement end may comprise a shank portion that is capable of being inserted into, and lockingly engaged by, a chuck of a drill.

5 The term 'hard coating layer', in the context of this specification, refers to a coating layer that has a hardness that is harder relative to the hardness of the working end of the tool bit. Typically, the hardness of the coating layer is at least 10 GPa, more typically the hardness of the coating layer is between 10 GPa to 35 GPa.

10 Unless specified otherwise, the terms "comprising" and "comprise", and grammatical variants thereof, are intended to represent "open" or "inclusive" language such that they include recited elements but also permit inclusion of additional, unrecited elements.

15 As used herein, the term "about", in the context of concentrations of components of the formulations, typically means $\pm 5\%$ of the stated value, more typically $\pm 4\%$ of the stated value, more typically $\pm 3\%$ of the stated value, more typically, $\pm 2\%$ of the stated value, 20 even more typically $\pm 1\%$ of the stated value, and even more typically $\pm 0.5\%$ of the stated value.

Throughout this disclosure, certain embodiments may be disclosed in a range format. It should be understood that the description in range format is merely for 25 convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosed ranges. Accordingly, the description of a range should be considered to have specifically disclosed all the possible sub-ranges as well as individual numerical values within 30 that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed sub-ranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6 etc., as well as individual numbers within that range, for

example, 1, 2, 3, 4, 5, and 6. This applies regardless of the breadth of the range.

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Brief Description Of Drawings

The accompanying drawings illustrate a disclosed embodiment and serves to explain the principles of the disclosed embodiment. It is to be understood, however, that the drawings are designed for purposes of illustration only, and not as a definition of the limits of the invention.

Fig. 1 is a schematic side view of a coated tool bit in accordance with one disclosed embodiment;

Fig. 2 is a schematic cross-sectional view of one coating embodiment applied to the working end of the tool bit of Fig. 1; and

Fig. 3 is a schematic cross-sectional view of another coating embodiment applied to the working end of the tool bit of Fig. 1.

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Detailed Description of Embodiments

Referring to Fig. 1 there is shown a schematic side view of a tool bit in the form of drill bit 10. Although the following description will describe the drill bit 10, it should be realized that this is for convenience only and that the following description could equally apply to other tool bits such as end mills and router bits.

The drill bit 10 includes a cylindrical body 12 having a longitudinal axis extending therethrough as represented by dashed line 14. The body 12 is made from a tungsten carbide and cobalt alloy (WC-Co). WC-Co tool bits are known in the art and are commercially available

from a number of manufacturers such as SFS Carbide Tool, Inc. of Saginaw, Michigan, United States of America and SGS Carbide Tool (UK) Ltd, Wokingham, Berkshire, United Kingdom.

- 5 The body 12 includes a tool engagement end in the form of shank end 16 and a working end in the form of end 18, which is on an opposite end of the body 12 to the shank end 16. The body also includes spiral formations extending from the end 18 to the middle of the body 12.
- 10 The spiral formations assist in boring a hole into a PCB board as will be explained further below.

 The shank end 16 has a dimension and a shape configuration that allows it to be engaged by a chuck (not shown) of a drilling tool so that the body 12 can be

15 rotated about the longitudinal axis 14 in use.

 The working end 18 is coated with a hard coating layer 20. The hard coating layer 20 comprises metal carbide, particularly tantalum carbide (TaC) (CAS Registry Number: 12070-06-3), which has been deposited onto the

20 working end 18 by a plasma beam consisting of metal ions and carbon ions.

 The plasma beam is generated from a TaC target using a Filtered Cathodic Vacuum Arc (FCVA) apparatus developed by Nanofilm Technologies International Pte Ltd (NTI) of

25 Singapore and described in published International patent application WO 96/26531, which is incorporated herein in its entirety for reference. TaC powder is available from a number of commercial suppliers such as Johnson Matthey Management GmbH & Co KG of Karlsruhe Germany and Chemos

30 GmbH of Regenstauf, Germany.

 The FCVA apparatus generates a plasma beam from a cathodic arc source that is "filtered" in that it is substantially free of macroparticles comprising particles of neutral multi-atom clusters.

A bias is applied to the end 18 using a power supply. Any number of power supplies can be used such as a "high voltage pulse generator" (HVPG) available from NTI. The power unit has a control panel on which the parameters can be manually set. Also employed is a switching device insulated gate bipolar transistor (IGBT) which is protected against current overloads and short circuits. The generator assembly is also equipped with an output fuse.

10 The output range of the pulse generator is up to -10,000 V, preferably -5,000 V, and more preferably -2,000 V to -4,000 V, with the pulses lasting from between 1-50 μ s; for direct arc sources preferably from between 1-20 μ s, more preferably from between 5-10 μ s, and for FCVA
15 sources preferably from between 10-40 μ s, more preferably 15-25 μ s; and at a frequency of up to 10 kHz, preferably from 1-3 kHz, more preferably from 1.5-2.5 kHz.

 The HVPG is associated with the FCVA apparatus, and connected to the drill bit 10. During operation of the
20 FCVA apparatus, the HVPG is set to deliver pulses of large negative voltage to the drill bit 10. The HVPG is started and stopped either manually or via remote

 The thickness of the hard coating layer 20 of TaC is between about 0.1-1 μ m. Hence, the coating layer 20 is
25 very thin and cannot be seen by the naked eye, but its thickness, as shown in Fig. 1, is exaggerated for the purposes of demonstration.

 It has surprisingly been found by the inventors that the hard coating layer 20 deposited by the FCVA apparatus
30 provides a longer cycle life than known metal carbide coatings deposited by other deposition methods. Without being bound by theory, it is thought that the plasma deposited metal and carbon ions ensures very tight adherence of the coating layer to the end 18, thereby

increasing the cycle life of the drill bit 10. Furthermore, because layer upon layer of metal and carbon ions are deposited on each other to form the coating, it is thought that an extremely tight coating layer builds up
5 providing very high hardness. Furthermore, the plasma beam, being filtered, ensures a smooth coating devoid of macroparticles. The inventors have surprisingly found that, in PCB manufacture requiring the boring of a PCB board, the drill bit 10 has significantly increased cycle
10 life relative to drill bits coated with known deposition methods.

Referring to Fig. 2, there is shown a schematic cross-sectional view of one embodiment of a coating 20A that can be applied to the end 18 of the tool bit 10. The
15 coating 20A consists of a first metal layer 22A that is formed from a filtered plasma beam, generated by the FCVA apparatus, which is deposited onto the end 18 of the tool bit 10. The metal of metal layer 18 is Tantalum (Ta) and has a thickness (t_M) is between 0.05 μ m to 0.8 μ m.

20 A primary TaC layer 24A is applied to the metal layer 22A. The primary TaC layer 24A is deposited by the plasma beam during which the tool bit end 18 is biased with a with a bias of -2800V to -3500V. The relatively low bias produces a relatively soft primary TaC layer 24A having a
25 relatively low softness in the range 15-25 GPa. The thickness (t_{Ls}) of the primary TaC layer 24A is between 0.05 μ m to 0.8 μ m.

After the primary TaC layer 24A is formed, the filtered plasma beam continues to be applied to form a
30 secondary TaC layer 26A, however the bias is lowered to -1500V to -2500V. The larger negative bias increases the hardness of the secondary TaC layer 26A to about 15-35 GPa. The thickness (t_{Lh}) of the secondary TaC layer 26A is between 0.05 μ m to 0.8 μ m.

Accordingly, the metal layer 22A between the tool bit end 18 and the primary layer 24A, promotes adhesion between the successive layers. Furthermore, the increasing hardness between the primary layer 24A and the secondary layer 26A results in an increasing hardness in the coating 20A in the direction from the metal layer 22A to the top secondary layer 26A. The increasing hardness ensures that the portion of the coating 20A that is most exposed to a workpiece during a boring operation is the hardest layer, thereby increasing the drill bit 10 cycle life in PCB manufacture.

Furthermore, the successively increasing hard layers from the tool bit end 18 to the top secondary coating layer 26A ensures excellent adhesion so that the coating is held firmly onto the end 18.

Although the layers 24A and 26A are shown in Fig. 2 as two discrete layers, it should be realized that this is for illustrative purposes only. In practice, many layers of increasing hardness from the metal layer to the top coat may be formed successively increasing the negative bias during deposition of the TaC coating by the plasma. Hence, the layers may increasing hardness are not necessarily discretely formed layers as shown in Fig. 2 but may consist of layers of increasing hardness towards the periphery of the coating.

Referring to Fig. 3, there is shown the same coating as Fig. 2 in which the primary layer 24A of Fig. 2 corresponds to primary layer 24B, the secondary layer 26A of Fig. 2 corresponds to secondary layer 26B and the metal layer 22A is absent.

Example

WC-Co drill bits with a diameter of 200 μ m were coated with hard coatings using the FCVA apparatus as described above. The hard coatings consisted of two groups, 5 "Coating A" where the total coating layer was about 0.1 μ m and "Coating B" where the total coating layer was about 0.3 μ m.

The hard coatings A and B consisted of a first metal coating of (Ta) of 0.02 μ m for coating A and 0.1 for 10 coating B, during which no bias was applied to the drill bit.

A filtered plasma beam of Ta ions and carbon ions was then applied to the metal layer to form a primary layer of TaC having a thickness of 0.04 μ m for coating A and 0.1 for 15 coating B. During formation of the primary layer, pulses of -3200V with a duration of 10 μ s and a frequency of 3kHz was applied to the drill bit. After formation of the primary layer, a top secondary layer of TaC was formed having a thickness of 0.04 μ m for coating A and 0.1 for 20 coating B. During formation of the secondary layer, pulses of -1600V with a duration of 10 μ s and a frequency of 3kHz was applied to the drill bit.

The primary layer of both coatings had a hardness of about 15-25 GPa while the secondary layer was about 25-35 25 GPa.

A number of drill bit coatings were subjected to Raman spectroscopic analysis wherein the peak intensities of each sample coating were obtained. It was found that the peak intensity (I_D/I_G) of the sample coatings had 30 relatively hard Raman intensity value of about 0.3 to about 0.5 indicating a relatively hard coating.

The coated drill bits of coatings A and B were then used to drill into a stack of fiberglass board having a total thickness of 5 mm of the type used in PCB

manufacture and the number of cycles were recorded before drill bits became dull and needed to be replaced. For comparison, non-coated WC-Co drill bits were also subjected to the same drilling operation and the cycles
5 recorded before these non-coated drill bits needed to be replaced.

A sample set of 2000 drill bits were tested for Coating A, Coating B and non-coated drill bits and the results given in table 1 below.

10

TABLE 1

Drill Bit Coating	Average Cycle Life
Non-coated drill bits (Comparative Example)	1983
Coating A (0.1 μ m)	8215
Coating B (0.3 μ m)	7353

Accordingly, it can be seen from the data that the coated drill bits exhibited an almost four-fold increase in the cycle life compared to non-coated WC-Co drill bits.
15 Hence, it will be appreciated that the hard coatings significantly increase the cycle life of the drill bits in PCB manufacture.

The plasma deposited coatings also exhibited excellent adhesion to the drill bits, thus increasing
20 their cycle life compared to known coating methods.

The disclosed coatings therefore overcome the problems associated with high wear rates of the drill bits

It will be apparent that various other modifications and adaptations of the invention will be apparent to the
25 person skilled in the art after reading the foregoing disclosure without departing from the spirit and scope of the invention. For example, although the disclosed drill bits, their method of manufacture and their use are particularly useful in PCB manufacture, it will be

appreciated that the coatings for the drill bits can be used in other applications such as masonry drill bits. Hence, it is intended that all such modifications and adaptations come within the scope of the appended claims.

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Claims

1. A tool bit comprising:
 - a cylindrical body having a longitudinal axis;
 - a tool engagement end on one end of said body for
 - 5 engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;
 - a working end on an opposite end of said body to said tool engagement end; and
 - a plasma deposited metal carbide coating layer
 - 10 provided on said working end, wherein in use, said coated working end bores a hole into a work piece as said cylindrical body is rotated about its longitudinal axis.
2. A tool bit as claimed in claim 1, wherein said hard
- 15 coating layer has a thickness selected from the group consisting of 250 nm to 3000 nm, 250 nm to 2500 nm, 250 nm to 2000 nm, 250 nm to 1500 nm, 250 nm to 1000 nm, 500 nm to 3000 nm, 500 nm to 2500 nm, and 1000 nm to 2000 nm.
- 20
3. A tool bit as claimed in claim 1, wherein said hard coating layer has a hardness of at least 10 GPa.
4. A tool bit as claimed in claim 3, wherein said hard
- 25 coating layer has a hardness of 10 GPa to 35 GPa or 15 GPa to 25 GPa.
5. A tool bit as claimed in claim 1, wherein said hard coating layer comprises a primary layer provided on said
- 30 working end and a secondary layer provided on said primary layer, wherein the hardness of said secondary layer is higher than said primary layer.

6. A tool bit as claimed in claim 5, wherein said primary layer has a hardness of 5 GPa to 10 GPa and said secondary layer has a hardness of 10 GPa to 35 GPa.

5 7. A tool bit as claimed in claim 5, wherein said primary and secondary layers independently have respective thicknesses within the range of 250 nm to 1500 nm, 500 nm to 1500 nm, and 800 nm to 1500 nm.

10 8. A tool bit as claimed in claim 1, wherein said metal of said metal carbide is a transition metal.

9. A tool bit as claimed in claim 8, wherein said transition metal of said transition metal carbide is
15 selected from the group consisting of Ti, Zr, Hf, V, Nb, Ta, Cr, Mo, W, Fe, Ru, Os, and combinations thereof.

10. A tool bit as claimed in claim 8, wherein said transition metal carbide is tantalum carbide.

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11. A tool bit as claimed in claim 1, wherein said hard coating layer has been deposited using a filtered plasma.

12. A tool bit as claimed in claim 11, wherein said
25 filtered plasma has been generated from a cathodic vacuum arc.

13. A tool bit as claimed in claim 1, wherein said tool bit is a printed circuit board (PCB) drill bit.

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14. A tool bit as claimed in claim 1, wherein said tool bit is a printed circuit board (PCB) router bit.

15. A tool bit as claimed in claim 1, wherein said cylindrical body has a diameter selected from the group consisting of 0.05 mm to 3 mm; 0.05 mm to 2 mm; 0.05 mm to 1 mm; 0.05 mm to 0.5 mm and 0.05 mm to 0.25 mm.

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16. A tool bit as claimed in claim 1, comprising a metal layer disposed between said working end and said hard coating layer.

10 17. A tool bit as claimed in claim 16, wherein the thickness of the metal layer is 250 nm to 1500 nm.

18. A tool bit as claimed in claim 1, wherein the cylindrical body comprises tungsten carbide and cobalt.

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19. A tool bit as claimed in claim 1, characterized in that the coating layer exhibits Raman intensity values of between about 0.3 to about 1.

20 20. A tool bit as claimed in claim 1, wherein the hardness of said coating layer generally increases in hardness a direction from said working end to the periphery of said coating layer.

25 21. A tool bit as claimed in claim 1, wherein the work piece is the substrate of a printed circuit board (PCB).

22. A method of coating a tool bit comprising a cylindrical body having a longitudinal axis, a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis, and a working end on an opposite end of said body to said tool engagement end, the method comprising the step of:

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(a) depositing plasma metal ions and carbon ions onto said working end to form a metal carbide layer thereon.

5 23. A method as claimed in claim 22, comprising before step (a), the steps of:

(b) generating a plasma beam comprising metal ions and carbon ions in an inert atmosphere, or under vacuum, from a cathodic vacuum arc source; and

10 (c) filtering said plasma beam to substantially remove all macroparticles therefrom.

24. A method as claimed in claim 22, comprising, during step (a), the step of:

15 (d) applying an alternating bias pulse to said working end of said tool bit, said bias pulse alternating between a relatively high negative bias pulse and a low negative bias pulse.

20 25. A method as claimed in claim 24, comprising the step of:

(d1) selecting said high negative bias pulse from the group consisting of the range -1800 V to -4,500 V and -2000 V to -2500 V.

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26. A method as claimed in claim 24, comprising the step of:

(d2) selecting said low negative bias pulse from the group consisting of the range -50 V to -500 V and -100 V
30 to -200 V.

27. A method as claimed in claim 24, comprising the step of:

(e) pulsing the bias on the substrate at a frequency of up to 10 kHz.

28. A method as claimed in claim 27, wherein said
5 pulsing step (e) comprises the step of:

(e1) selecting the frequency from the range of 1 kHz to 3 kHz.

29. A method as claimed in claim 27, wherein said
10 pulsing step (e) comprises the step of:

(e2) selecting the pulse duration from the group consisting of 1 μ s to 50 μ s, 1 μ s to 25 μ s, and 5 μ s to 10 μ s.

15 30. Use of a tool bit for printed circuit board (PCB) manufacture, the tool bit comprising:

a cylindrical body having a longitudinal axis;

a tool engagement end on one end of said body for engagement with a tool capable of rotating said
20 cylindrical body about said longitudinal axis;

a working end on an opposite end of said body to said tool engagement end; and

a plasma deposited metal carbide coating layer provided on said working end,

25 wherein in use, said coated working end bores a hole into the substrate of a PCB as said cylindrical body is rotated about its longitudinal axis.

31. A method of making a tool bit comprising the steps
30 of:

(a) providing a tool bit comprising a cylindrical body having a longitudinal axis, a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal

axis, and a working end on an opposite end of said body to said tool engagement end; and

(b) depositing plasma metal ions and carbon ions onto said working end to form a metal carbide layer thereon.

32. A printed circuit board (PCB) drill bit or router bit comprising:

a cylindrical body having a longitudinal axis;

10 a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;

a working end on an opposite end of said body to said shank end; and

15 a plasma metal carbide deposited coating layer on said working end for boring a hold into said PCB as said cylindrical body is rotated about its longitudinal axis.

33. Use of a tool bit for boring a hole into the substrate of a printed circuit board (PCB) during PCB manufacture, the tool comprising:

a cylindrical body having a longitudinal axis;

20 a tool engagement end on one end of said body for engagement with a tool capable of rotating said cylindrical body about said longitudinal axis;

a working end on an opposite end of said body to said shank end; and

a tantalum carbide coating layer on said working end having a thickness of about 1.5 μ m or less,

30 wherein in use, said coating layer bores a hole into said PCB substrate as said cylindrical body is rotated about its longitudinal axis.

34. A printed circuit board (PCB) having one or more holes that have been bored with a tool bit as claimed in claim 1.

5 35. A method of boring a hole into the substrate of a printed circuit board (PCB) comprising the step of:

(a) drilling a drill or router tool bit into the PCB board substrate, the end of said tool bit comprising a plasma deposited metal carbide coating layer thereon.

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