METHOD FOR OPERATING A PULSED ARC SOURCE

Technical field

The invention relates to a method for operating an arc source~~, as claimed in the precharacterizing clauses of claims 1, 8 and 9,~~ and to an arc source ~~as claimed in the precharacterizing clauses of claims 34, 43 and 45~~.

Prior Art

The pulsing of arc sources has already been known for a relatively long time from the prior art, for example WO 02/070776 describes in a very general form the pulsing of spark sources in order to deposit various super-hard layers including TiSiN.

WO 03/057939 describes a spark source in which the spark is ignited via a pulsed high-voltage supply, and the spark is fed via a pulsed high-current supply. In this case, the spark is operated discontinuously. Initial materials are metallically conductive cathodes, conductive alloys and, in addition, carbon, and/or semiconductors which can be vaporized. The arc source described here is, however, difficult to manufacture and expensive to operate, particularly for cathode materials which are difficult to process, because of the highly complex geometry of the target body.

US 6, 361, 663 describes an arc source with a cathode composed of electrically conductive material, which is operated in a pulsed or modulated-pulsed form with peak currents of up to 5 kA and with a base current of, for example, 100 A. This source as well is difficult to manufacture and expensive to operate as a result of its design with a magnetic tunnel and an anode which is completely surrounded by the cathode.

Description of the invention

Embodiments~~One object~~ of the present invention ~~is therefore to~~ provide a method by means of which it is also possible to produce insulating layers using conventional arc sources, without any complex additional measures, and in stable process conditions.

~~This object is achieved by a method as claimed in~~ claims 1, 8 and 9 with an arc source as ~~claimed~~ in claims 34, 43 and 45. Further ~~inventive~~ embodiments are described in the ~~dependent~~ claims, which can be used individually or can be combined together, where this is ~~technically worthwhile.~~

In a first aspect, there is provided amethod for operating an arc source, in which an electrical spark discharge is ignited or operated on a surface of a target, with the spark discharge being fed at the same time with a direct current and with a pulsed or alternating current, characterized in that the surface of the target is at least partially covered by an insulating coating.

In a second aspect, there is provided an above method for etching with metal ions which are generated from the metal target by an arc source operated by a method, wherein a DC, a pulsed or an alternating-current bias is being applied to the at least one workpiece, in order to etch at least one workpiece.

In a third aspect, there is provided an arc source having a target and at least one opposing electrode and an electrical power supply unit which is connected to the target, whereas the electrical power supply unit feeds the target at the same time with a direct current and with a pulsed or alternating current, characterized in that the surface of the target is at least partially covered by an insulating coating.

Surprisingly, it has been possible to show that a stable arc process can be achieved by a simultaneous application of a direct current on which a pulsed current or alternating current is superimposed, even if the target surface is at least partially covered by an insulating coating.

By way of example, it has been possible to operate an aluminum target for several hours in a pure oxygen atmosphere without any further additional measures. During this process, a rise was observed in the voltage on the target, but this rise stabilized within minutes and did not lead to interruption or to instability of the arc process. The aluminum oxide layer which is deposited during this process on a substrate positioned directly in front of the target exhibited a completely unexpected considerable reduction in the surface flaws caused by adhering droplets, in comparison to a metallic aluminum layer deposited in the same conditions. Similar results were also achieved by operating chromium or titanium targets, and metallic targets composed of these materials with a high silicon content, even above 50%, in a pure oxygen or pure nitrogen atmosphere. In all cases, the target could be

PATENT CLAIMS

1. A method for operating an arc source, in which an electrical spark discharge is ignited or operated on a surface of a target, with the spark discharge being fed at the same time with a direct current and with a pulsed or alternating current, **characterized in that** the surface of the target is at least partially covered by an insulating coating.

2. The method as claimed in claim 1, **characterized in that** the insulating coating is produced by operating the source in an atmosphere containing reactive gas.

3. The method as claimed in claim 2, **characterized in that** the insulating coating results in an increase in the DC component of the source voltage by at least 10%, preferably by at least 20%, in comparison to operation with a surface without an insulating coating.

4. The method as claimed in claim 2, **characterized in that** the atmosphere containing reactive gas comprises at least one of the following components, a gas containing oxygen, nitrogen, silicon, boron or carbon, in particular oxygen, nitrogen, acetylene, methane, a silane, tetramethylsilane, tetramethylaluminum, diborane.

5. The method as claimed in claim 2, **characterized in that** the proportion of reactive gas is greater than that of the inert gas, preferably more than 70%, furthermore preferably more than 90% or approximately 100%.

6. The method as claimed in claim 1, **characterized in that** the target material comprises at least one of

the following materials: a transition metal from the IVth, Vth, VIth group in the periodic table or aluminum, boron, carbon or silicon, or an alloy or compound of the abovementioned materials, such as TiAl, CrAl, TiAlCr, TiSi, TaSi, CrSi, WC.

7. The method as claimed in claim 6, **characterized in that** the insulating coating is composed of an oxide, nitride, boride, silicide, carbide of the target material or of a mixture of the compounds of the target material mentioned.

8. A method for operating an arc source, in which an electrical spark discharge is ignited or operated on a surface of a target, with the spark discharge being fed at the same time with a direct current and with a pulsed or alternating current, **characterized in that** the DC component of the current flow is set in a range between 100% to 300% of a holding current, preferably between 100 and 200%.

9. A method for operating an arc source, in which an electrical spark discharge is ignited or operated on a surface of a target, with the spark discharge being fed at the same time with a direct current and with a pulsed or alternating current, **characterized in that** the DC component of the current flow is set in a range between 30 and 90 A, preferably between 30 and 60 A.

10. The method as claimed in one of claims 8 or 9, **characterized in that** reactive gas, inert gas, or reactive gas and inert gas is or are added.

11. The method as claimed in one of claims 8 or 9, **characterized in that** the target material comprises at least one of the following materials: a transition metal from the IVth, Vth, VIth group

in the periodic table or aluminum, boron, carbon or silicon, or an alloy or compound of the abovementioned materials, such as TiAl, CrAl, TiAlCr, TiSi, TaSi, CrSi, WC.

12. The method as claimed in one of claims 1, 8 or 9, **characterized in that** the target material is composed of a single crystallographic phase.

13. The method as claimed in one of the preceding claims, **characterized in that** the direct-current component is produced by a direct-current generator, and the pulsed- or alternating-current component is produced by a pulsed- or alternating-current generator, with the two generators being connected either in parallel or in series between an arc cathode and at least one anode or ground.

14. The method as claimed in one of claims 1 to 12, **characterized in that** the direct-current component and the pulsed-current component are produced by two pulsed- and alternating-current generators which are operated superimposed and synchronized, with the two generators either being connected in parallel or in series between an arc cathode and at least one anode or ground.

15. The method as claimed in one of claims 1 to 12, **characterized in that** the direct-current and the pulsed-current component are produced by a secondary-clocked current generator, with the generator being connected either in parallel or in series between an arc cathode and at least one anode or ground.

16. The method as claimed in one of claims 1 to 12, **characterized in that** the direct-current and the pulsed-current component are produced by a primary-clocked current generator, with the

generator being connected either in parallel or in series between an arc cathode and at least one anode or ground.

17. A coating method, **characterized in that** an arc source as claimed in one of the preceding claims is operated in order to deposit one or more layers on a workpiece.

18. The coating method as claimed in claim 17, **characterized in that** the layer is composed of at least one of the following materials: a transition metal from the IVth, Vth or VIth group in the periodic table and aluminum, and their compounds with oxygen, nitrogen, carbon, boron or silicon.

19. The coating method as claimed in claim 17, **characterized in that** the layer is composed of at least one of the following materials: aluminumoxide, aluminumnitride, aluminumoxynitride, chromiumoxide, chromiumnitride, chromiumoxynitride, aluminumchromiumoxide, aluminumchromiumnitride, aluminumchromiumoxynitride, aluminumchromiumoxycarbonitride, siliconoxide, siliconnitride, siliconoxynitride, siliconaluminumoxide, siliconaluminumnitride, siliconaluminumoxynitride, titaniumsiliconnitride, titaniumsiliconoxynitride, tantalumsiliconnitride, tantalumoxide, tantalumoxynitride, tungstensiliconnitride, tungstensiliconcarbide, niobiumsiliconnitride, titaniumcarbide, tungstencarbide or an alloy or compound of the abovementioned materials.

20. The coating method as claimed in claim 17, **characterized in that** a DC, a pulsed or an alternating-current bias is applied to the workpiece.

21. The coating method as claimed in claim 20, **characterized in that** a pulsed or alternating-current bias is applied, synchronized to the pulsed current or alternating current from the source.

22. The coating method as claimed in claim 17, **characterized in that** at least one inert gas or reactive gas is added at a first flow rate at least once, and at least one further reactive gas is then added at a second flow rate, or vice versa, in order to vary the layer composition.

23. The coating method as claimed in claim 22, **characterized in that** the first flow rate is reduced before, during or after setting the second flow rate, and the second flow rate is set from a low value to a higher value, or vice versa.

24. The coating method as claimed in claim 22, **characterized in that** the addition or setting process is carried out in the form of a ramp or a step, in order to produce a substantially constant or stepped variation in the layer composition.

25. The coating method as claimed in claim 22, **characterized in that** a layer with two or more layer elements is deposited by alternately increasing and decreasing the first and the second flow rate.

26. The coating method as claimed in claim 17, **characterized in that** a plurality of sources are operated at the same time, with identical or different target material.

27. An etching method for etching with **metal ions characterized in that** an arc source as claimed in one of claims 1 to 15 is operated with DC, a

pulsed or an alternating-current bias being applied, in order to etch at least one workpiece.

28. The etching method as claimed in claim 27, **characterized in that** a DC bias between -50 and -2000 V, preferably between -200 and -1500 V, is set on the workpiece.

29. The etching method as claimed in one of claims 27 or 28, **characterized in that** an additional etching gas is introduced.

30. The etching method as claimed in claim 29, **characterized in that** the etching gas contains at least one of the following components: helium, argon, crypton, oxygen, nitrogen, hydrogen, halogen (for example chlorine, fluorine, bromine, iodine) or a compound containing halogen.

31. The coating or etching method as claimed in one of claims 17 to 30, **characterized in that** the coating rate and the energy introduced into the workpiece are set by adjusting at least one of the following parameters: the pulse width of the current pulse, the magnitude of the current pulse, the duty ratio.

32. The coating or etching method as claimed in one of claims 17 to 31, **characterized in that** the workpiece is a tool or a component.

33. The coating or etching method as claimed in one of claims 16 to 28, **characterized in that** the workpiece is composed essentially of silicon or of some other semiconductive material.

34. An arc source having a target (5) and at least one opposing electrode (6, 20, 20') and an electrical power supply unit which is connected to the target

(5), **characterized in that** the electrical power supply unit comprises at least one first pulsed high-current supply (18, 18') and a further electrical power supply (13', 18'').

35. The arc source as claimed in claim 34, **characterized in that** the electrical power supply unit additionally comprises a DC current supply (13'), which is designed at least to maintain a holding current.

36. The arc source as claimed in claim 34, **characterized in that** the electrical power supply unit additionally comprises a DC current supply (13') which is designed at least to maintain a holding current.

37. The arc source as claimed in claim 34, **characterized in that** the electrical power supply unit additionally comprises a second, pulsed high-current supply (18''), which can be synchronized with the first pulsed arc source such that a holding current with a superimposed pulsed signal can be set.

38. The arc source as claimed in claim 36, **characterized in that** the pulsed arc sources (18', 18'') can be synchronized such that the holding current has one or more holding-current pauses in individual pulse pauses or in all of the pulse pauses, in which no voltage is applied to the target or to the electrode, in which case the holding-current pauses can be set to be so short that the arc plasma is not quenched in the pauses.

39. The arc source as claimed in claim 37, **characterized in that** the holding-current pauses can be set between 1 ns and 1 µs, in particular between 1 and 100 ns.

40. The arc source as claimed in claim 34, **characterized in that** the first pulsed high-current supplies (18, 18') and the further electrical power supply (13', 18'') are connected in parallel or in series.

41. The arc source as claimed in claim 34, **characterized in that** the first pulsed high-current supplies (18, 18') and the further electrical power supply (13', 18'') are connected in parallel or in series.

42. The arc source as claimed in claim 34, **characterized in that** at least the first pulsed high-current supplies (18, 18') or at least the further electrical power supply (13', 18'') is connected between the target (5) and an electrode (6) which comprises the target, or further electrodes (20, 20').

43. An arc source having a target (5) and at least one opposing electrode (6, 20, 20') and an electrical power supply unit which is connected to the target 5, **characterized in that** the electrical power supply unit is a secondary-clocked electrical power supply (21, 21'), by means of which the signal of the secondary-clocked electrical power supply (21, 21') is modulated such that a DC holding current is produced, with a pulsed signal or AC signal superimposed on it.

44. The arc source as claimed in claim 42, **characterized in that** the secondary-clocked electrical power supply is in the form of a step-down converter (21') or a step-up converter (21).

45. An arc source having a target (5) and at least one opposing electrode (6, 20, 20') and an electrical

power supply unit which is connected to the target (5), **characterized in that** the electrical power supply unit is a primary-clocked electrical power supply (22), by means of which the signal of the primary-clocked electrical power supply (22) is modulated such that a DC holding current is produced, with a pulsed signal or AC signal superimposed on it.

Claims

1. A method for operating an arc source, in which an electrical spark discharge is ignited or operated on a surface of a target, with the spark discharge being fed at the same time with a direct current and with a pulsed or alternating current, characterized in that the surface of the target is at least partially covered by an insulating coating.

2. The method as claimed in claim 1, characterized in that the insulating coating is produced by operating the source in an atmosphere containing reactive gas.

3. The method as claimed in claim 2, characterized in that a proportion of the reactive gas is chosen so that the generated insulating coating results in an increase in the DC component of the source voltage by at least 10% in comparison to operation with a surface without an insulating coating.

4. The method as claimed in claim 2, characterized in that the atmosphere containing reactive gas comprises at least one of the following components, a gas containing oxygen, nitrogen, silicon, boron or carbon.

5. The method as claimed in claim 2, characterized in that the proportion of reactive gas in the atmosphere is greater than that of an inert gas.

6. The method as claimed in claim 1, characterized in that the target material comprises at least one of the following materials: a transition metal from the IVth, Vth, VIth group in the periodic table or aluminum, boron, carbon or silicon, or an alloy or compound of the abovementioned materials.

7. The method as claimed in claim 6, characterized in that the insulating coating is composed of an oxide, nitride, boride, silicide, carbide of the target material or of a mixture of the compounds of the target material mentioned.

8. The method as claimed in claim 1, characterized in that the DC component of the current flow of the electrical spark discharge is set in a range between 100% to 300% of a holding current which is the smallest DC current at which the electrical spark discharge is possible to be operated.

9. The method as claimed in claim 1, characterized in that the DC component of the current flow of the electrical spark discharge is set in a range between 3.0 and 90 A.

10. The method as claimed in one of claims 8 or 9, characterized in that reactive gas, inert gas, or reactive gas and inert gas is or are added.

11. The method as claimed in one of claims 8 or 9, characterized in that the target material comprises at least one of the following materials: a transition metal from the

IVth, Vth, VIth group in the periodic table or aluminum, boron, carbon or silicon, or an alloy or compound of the abovementioned materials.

12. The method as claimed in one of claims 1, 8 or 9, characterized in that the target material is composed of a single crystallographic phase.

13. The method as claimed in one of the preceding claims, characterized in that the direct-current component is produced by a direct-current generator, and the pulsed- or alternating-current component is produced by a pulsed- or alternating-current generator, with the two generators being connected either in parallel or in series between an arc cathode and at least one anode or ground.

14. The method as claimed in any of claims 1 to 13, characterized in that a coating is deposited in one or more layers on a workpiece.

15. The method as claimed in claim 14, characterized in that the layer is composed of at least one of the following materials: a transition metal from the IVth, Vth or VIth group in the periodic table and aluminum, and their compounds with oxygen, nitrogen, carbon, boron or silicon.

16. The method as claimed in claim 14, characterized in that the layer is composed of at least one of the following materials: aluminumoxide, aluminumnitride, aluminum-oxynitride, chromiumoxide, chromiumnitride,

chromiumoxynitride, aluminumchromiumoxide, aluminumchromiumnitride, aluminumchromium-oxynitride, aluminumchromiumoxycarbonitride, siliconoxide, siliconnitride, siliconoxynitride, siliconaluminumoxide, siliconaluminumnitride, siliconaluminumoxynitride, titaniumsiliconnitride, titaniumsiliconoxynitride, tantalumsiliconnitride, tantalumoxide, tantalumoxynitride, tungstensiliconnitride, tungstensiliconcarbide, niobiumsiliconnitride, titaniumcarbide, tungstencarbide or an alloy or compound of the abovementioned materials.

17. The method as claimed in claim 14, characterized in that a DC, a pulsed or an alternating-current bias is applied to the workpiece.

18. The method as claimed in claim 17, characterized in that a pulsed or alternating-current bias is applied, synchronized to the pulsed current or alternating current from the source.

19. The method as claimed in claim 14, characterized in that at least one inert gas or reactive gas is added at a first flow rate at least once, and at least one further reactive gas is then added at a second flow rate in order to vary the layer composition.

20. The method as claimed in claim 19, characterized in that the first flow rate is reduced before, during or after setting the second flow rate, and the second flow rate is set from a low value to a higher value.

21. The method as claimed in claim 19, characterized in that the addition or setting process is carried out in the form of a ramp or a step of the flow rate change from the first flow rate to the second flow rate, in order to produce a constant or stepped variation in the layer composition.

22. The method as claimed in claim 19, characterized in that a layer with two or more layer elements is deposited by alternately increasing and decreasing the first and the second flow rate.

23. The method as claimed in claim 14, characterized in that a plurality of sources are operated at the same time, with identical or different target material.

24. A method for etching with metal ions which are generated from the metal target by an arc source operated by a method according to any of claims 1 to 13, wherein a DC, a pulsed or an alternating-current bias is being applied to the at least one workpiece, in order to etch at least one workpiece.

25. The method as claimed in claim 24, characterized in that a DC bias between -50 and 2000 V is set on the workpiece.

26. The method as claimed in one of claims 24 or 25, characterized in that an additional etching gas is introduced.

27. The method as claimed in claim 26, characterized in that the etching gas contains at least one of the following components: helium, argon, crypton, oxygen, nitrogen, hydrogen, halogen or a compound containing halogen.

28. The method as claimed in one of claims 14 to 23, characterized in that a coating rate is set by adjusting at least one of the following parameters: the pulse width of the current pulse, the magnitude of the current pulse, the duty ratio.

29. The method as claimed in one of claims 14 to 23, characterized in that the workpiece is a tool or a component of a tool.

30. The method as claimed in one of claims 14 to 23, characterized in that the workpiece is composed essentially of silicon or of some other semiconductive material.

31. An arc source having a target (5) and at least one opposing electrode (6, 20, 20') and an electrical power supply unit which is connected to the target (5), whereas the electrical power supply unit feeds the target (5) at the same time with a direct current and with a pulsed or alternating current, characterized in that the surface of the target is at least partially covered by an insulating coating.

32. The arc source as claimed in claim 31, characterized in that the electrical power supply unit comprise at least

one first pulsed high-current supply (18, 18') and a further electrical power supply (13', 18") for feeding the target (5).

33. The arc source as claimed in claim 32, characterized in that the further electrical power supply is a DC current supply (13'), which is designed at least to maintain a holding current which is the smallest DC current at which the electrical spark discharge is possible to be operated.

34. The arc source as claimed in claim 33, characterized in that the first pulsed high-current sources (18', 18") can be synchronized such that the holding current has one or more holding-current pauses in individual pulse pauses or in all of the pulse pauses, in which no voltage is applied to the target or to the electrode, in which case the holding-current pauses can be set to be so that the arc plasma is not quenched in the pauses.

35. The arc source as claimed in claim 34, characterized in that the holding-current pauses can be set between 1 ns and 1 µs.

36. The arc source as claimed in claim 32, characterized in that the first pulsed high-current supplies (18, 18') and the further electrical power supply (13', 18") are connected in parallel or in series.

37. The arc source as claimed in claim 32, characterized in that at least the first pulsed high-current supplies (18,

18') or at least the further electrical power supply (13', 18") is connected between the target (5) and an electrode (6) which comprises the target, or further electrodes (20, 20').

38. The arc source as claimed in claim 31, characterized in that the electrical power supply unit is in the form of a step-down converter (21') or a step-up converter (21).

39. The method as claimed in one of claims 24 to 27, characterized in the energy introduced into the workpiece is set by adjusting at least one of the following parameters: the pulse width of the current pulse, the magnitude of the current pulse, the duty ratio.

40. The method as claimed in one of claims 24 to 27, characterized in that the workpiece is a tool or a component of a tool.

41. The method as claimed in one of claims 24 to 27, characterized in that the workpiece is composed essentially of silicon or of some other semiconductive material.