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(54) ELECTRODE ATTACHMENT TO ANODE ASSEMBLY

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(57) ABSTRACT

The invention relates to electroplating. In particular, the invention relates to an improved anode for electroplating metals onto substrates, and to a method of electroplating metals onto substrates utilizing the anode. The anode has a solid metal portion, and a metal electrode shaft having one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft. The barbs are fixed through the body extend a distance therethrough.

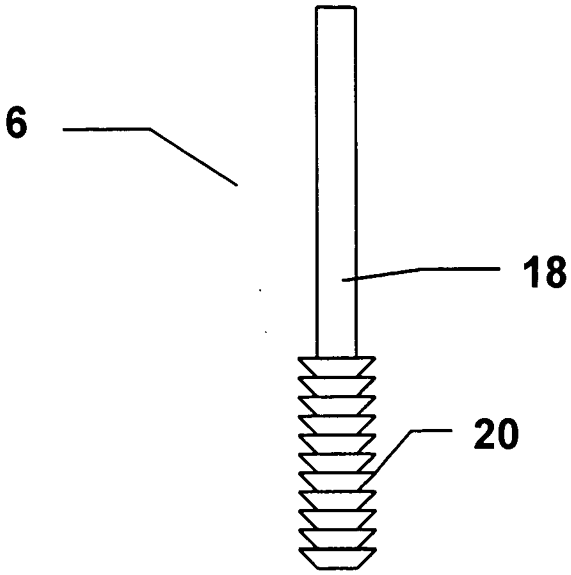

FIG.1

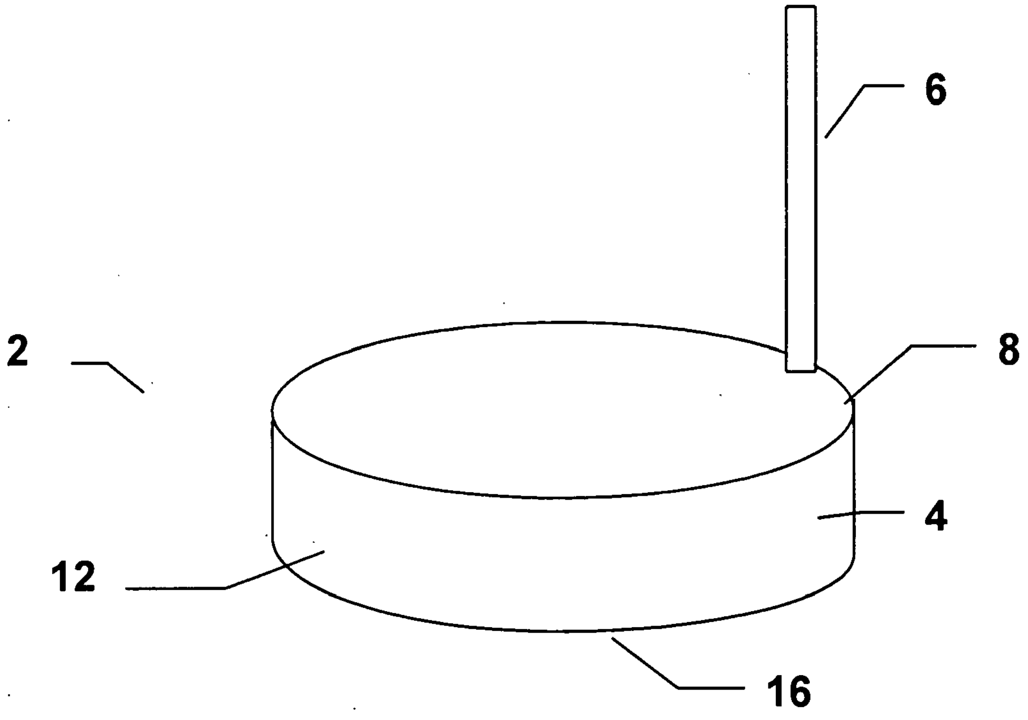

FIG. 2

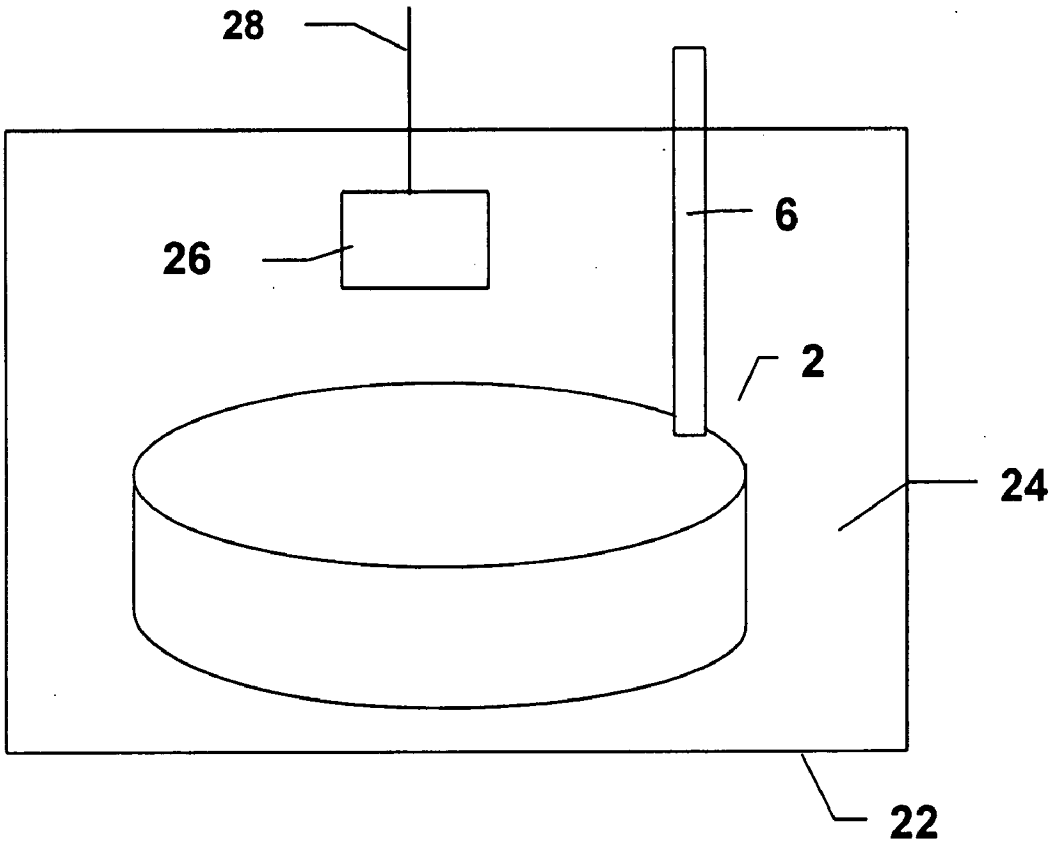

FIG. 3

ELECTRODE ATTACHMENT TO ANODE ASSEMBLY

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The invention relates to electroplating. In particular, the invention relates to an anode for electroplating metals onto substrates, and to a method of electroplating metals onto substrates utilizing the anode.

[0003] 2. Description of the Related Art

[0004] In the production of microelectronic devices, a metal may be plated onto a substrate for a variety of purposes. Typically, metal is plated onto a substrate in a cell or reservoir that holds a plating solution which is a metal ion containing bath for plating the metal onto the substrate surface.

[0005] In the manufacture of semiconductor chips, printed circuit boards and other circuit components and devices, the conductors of the devices are electroplated with a solder material comprising tin and/or lead to improve solderability of the device. The step of electroplating is typically performed while several semiconductor devices are mounted on a lead frame suspended by hooks on a cathode rack placed in an electroplating bath or before devices have been singulated (i.e, in wafer form). The bath contains an anode which conducts an electrical current that passes to the cathode and lead frames to deposit metal on the leads of the devices. After electroplating, the lead frames are severed and the individual semiconductor chips are separated.

[0006] The uniformity of the deposited metal is a function of the current density, the purity of the plating bath and the purity of the anode. Composition of plating baths and conditions within the plating bath must be carefully controlled to produce deposition of a desired quality of desired metal(s) on a substrate. Plating rate, uniformity, and deposit quality may be affected by a variety of factors. For example, among the parameters that may affect rate, uniformity, and deposit quality of plating are concentration of chemicals in the plating bath, nature and distribution of electrical contacts and voltage within the plating system. The physical design of an electroplating system may affect the conditions within the system and the plating carried out in the system.

[0007] The anode in the plating bath conducts the current into the plating solution and produces an electric field between the anode and the cathode workpiece. During routine plating operations, as electroplating proceeds, the anode is consumed, and any anode impurities may generate particles called anode fines. As the amount of anode fines increases, they form a sludge. As electroplating continues and the anode continues to be consumed, the anode sludge continues to thicken. A number of problems are associated with anode sludge. For example, the anode sludge may cause a voltage drop in the electroplating cell because ions migrate through the sludge to the plating solution and the plating voltage may rise. A rising plating voltage may effect the deposit uniformity. The effects of the anode sludge depend on cell design and plating parameters, among other factors. Additionally, the anode sludge can be incorporated into the structure of the plated metal and contaminate a workpiece being plated.

[0008] As a result of anode sludge formation and the degradation in plating, such as degraded plating uniformity that may result, anode maintenance typically is required in electroplating systems. Anode maintenance may include removal of the anode from the cell, removal of excess sludge by scraping, etching in a suitable solution to remove remaining sludge and then be subjecting to one or more lengthy anode reconditioning steps. The reconditioning steps may last for about 5 to about 16 hours. Impurities may also form gas bubbles, such as air bubbles, which may interfere with electric field lines between the anode and the wafer or workpiece. Interference with the electrical field within the electroplating system may result in overpotential. The overpotential may cause the plating voltage to rise in an erratic manner until the power supply reaches its set compliance voltage and shuts off. Disturbance in the electrical operation caused by gas bubbles may also effect the uniformity of electrodeposits. The thickness of plated films tends to be thinner in the region adjacent to the bubbles. A concentration gradient of plating ions may develop in the anode assembly. The concentration of plating ions may be high close to the anode and low in the vicinity of the wafer or workpiece being plated. The concentration gradient may result in a concentration polarization. The polarization may also cause the plating voltage to rise. While the concentration gradient may affect not only uniformity of wafers plated under such conditions, the concentration gradient may cause plating voltage to rise and reach its compliance value, again resulting in shut down of the plating cell. The air or gas bubbles may not only cause undesirable cell polarization, but may also distort the uniformity of the plated film. This is because the electric field has to bend around the air or gas bubbles before the field arrives at the workpiece. This causes distortion from the preferred parallel field lines and produces undesirable metal deposit uniformly on the workpiece.

[0009] To make plating more uniform across the workpiece, it is necessary to produce a plating bath which is substantially free of extraneous impurities. The improved solution purity helps to eliminate the concentration gradient, concentration polarization, and improving plating and the overall operation of the plating cell. The present invention also makes it possible to dramatically improve plating cell productivities. One source of plating bath impurities is the anode assembly. Typically the anode comprises the anode structure itself plus a metal handle which is used to introduce and maintain the anode in the plating solution. Typically, the handle is soldered to the anode. A joint is typically formed using a solder composition, however, the solder composition itself tends to introduce metal impurities into the plating bath. It would be desirable to fixedly attach an anode to a handle without the need for a solder joint. The present invention provides an improved anode and holder. Among the features of an anode and holder according to the present invention are at least one barbed end to the holder. A mechanical joint may allow for preferential corrosion and intermittent or inconsistent electrical contact. The barbed end is fixed through a hole in the anode, thus eliminating or reducing the need for a solder composition therebetween.

[0010] The present invention also includes methods of electroplating a metal on a substrate. A substrate may be arranged in the electroplating composition and current supplied to the substrate from the improved anode, resulting in the plating of the metal from a purer plating solution onto the substrate.

SUMMARY OF THE INVENTION

[0011] The invention provides an anode comprising a shaped, substantially solid, metal body; a metal electrode shaft having one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft; the one or more barbs being fixed within the body.

[0012] The invention also provides an anode comprising a metal electrode shaft and a shaped, substantially solid metal body cast around one end of the shaft.

[0013] The invention further provides a method for producing an anode which comprises:

[0014] a) providing a metal electrode shaft having one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft;

[0015] b) providing a shaped, substantially solid, metal body;

[0016] c) fixing the one or more barbs through the side wall of the body.

[0017] The invention still further provides a method for producing an anode which comprises:

[0018] a) providing a metal electrode shaft;

[0019] b) casting a molten metal around one end of the shaft and cooling the molten metal to thus form an anode comprising a solid metal body enveloping said end of the shaft; and

[0020] c) subsequently removing the anode from the mold.

[0021] The invention also provides an electrolytic arrangement which comprises:

[0022] a) a vessel containing an electrically conductive fluid; and

[0023] b) the anode of claim **1** in the electrically conductive fluid, which anode is connected to an electric circuit; and

[0024] c) a cathode in the electrically conductive fluid, which cathode is connected to an electric circuit.

BRIEF DESCRIPTION OF THE DRAWINGS

[0025] **FIG. 1** shows metal electrode shaft having barbs projecting outwardly from a periphery of the shaft at one end of the shaft.

[0026] **FIG. 2** shows an anode according to the invention having a metal body and the metal electrode shaft with the barb end fixed through the side wall of the metal body.

[0027] **FIG. 3** is a schematic representation of the anode and a workpiece wafer cathode suspended within an electroplating bath.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0028] **FIG. 2** shows an anode **2** according to the invention. It has a metal body **4** and a metal electrode shaft **6** fixed through a side wall **8** of the metal body **4**. It has a top edge **8**, an outside wall surface **12**, and a lower edge **16**. The upper edge **8** and the lower edge **16** are preferably in parallel planes. Although the anode portion **4** has been shown to have a disc shape, it may have any shape or cross section suitable for forming an anode. Such include those which are rectangular, square, cubic, circular, oval, trapezoidal, wedged, tubular, triangular, ring shaped, irregular shaped, spherical, cylinders among others. They may be solids or have apertures.

[0029] As better seen in **FIG. 1**, the metal electrode **6** comprises a shaft **18** having one or more barbs **20** projecting radially outwardly from a periphery of the shaft at one end of the shaft. In the construction of the anode **2**, the barbs **20** are fixed through the top edge **8** of the metal body **4** and extending a distance through the top edge **8** toward the lower edge **16** such that the barbs are positioned in the body **4**. In the preferred embodiment, all of the barbs are within the body of the anode. In one embodiment of the invention, the shaft portion within the body does not have any barbs.

[0030] The metal body comprises a metal or metal alloy capable of conducting electricity and dissociating into ionic species under electrolytic plating conditions. Non-exclusive examples of such metals include tin, lead, copper, aluminum, silver, bismuth, indium, antimony, or combinations thereof. Preferred body metals non-exclusively include tin, tin-lead alloys, tin-silver-copper alloys, silver-bismuth alloys, and combinations thereof.

[0031] In a more preferred embodiment, the metal body comprises from about 0% to about 100% tin and from about 0% to about 100% lead and still more preferably an alloy which comprises from about 5% to about 63% tin and from about 37% to about 95% lead.

[0032] The shaft **18** and barbs **20** preferably comprise a metal or metal alloy capable of conducting electricity but not significantly dissociating into ionic species under the electrolytic plating conditions which cause the metal body to dissociate into ionic species. Non-exclusive examples of such metals include titanium, copper, silver, platinum, tantalum, stainless steel, gold and combinations thereof. More preferably, the shaft and one or more barbs comprise nickel plated titanium.

[0033] The metal electrode **6** may be formed by machining a shaft **18** with a suitable tool, such as a lathe to provide one or more barbs **20** projecting radially outwardly from a periphery of the shaft at one end of the shaft. Any suitable method of producing such a shaft with barbs, such as casting, may be used.

[0034] The anode may be produced by providing the metal electrode shaft having one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft; providing a metal body and then fixing the one or more barbs through the metal body. One way of assembling the anode may be by drilling a hole into the metal body and then pressing the barbed end into the body. However, the preferred method is by casting the body metal around the barbed end of the shaft.

[0035] One may produce the anode by providing the metal electrode shaft having one or more barbs; applying a flux composition to the one or more barbs; placing the barbs of the electrode into a fixture; placing the fixture and the electrode into a casting mold; casting a molten metal into the casting mold and cooling the molten metal to thus form the anode with subsequent removing of the anode from the mold. Such casting methods are well known to the skilled artisan. In this embodiment it is preferred that the selection of the metal for the shaft and body is such that they are compatible for casting one around the other for a true metallurgical bond. Alternatively the shaft may have its end plated with a metal which easily wets both the shaft and the solid body metals during casting.

[0036] In another aspect of the invention, there is also provided a method of electroplating a workpiece. A cathode workpiece and the anode are immersed in an electroplating bath, and current flow from the anode to the cathode deposits the anode material on the workpiece.

[0037] **FIG. 3** shows an electrolytic arrangement which comprises a vessel **22** containing an electrically conductive fluid **24**. The anode **2** is disposed in the electrically conductive fluid. The anode is connected to an electric circuit via shaft **6**. A cathode workpiece **26** is also disposed in the electrically conductive fluid **24**. The cathode **26** is connected to an electric circuit via a suitable support **28**.

[0038] The cathode workpiece **26** is conveniently a wafer, on which materials, such as at least one metal or and or at least one alloy are to be electroplated. It may conveniently comprise a material such as semiconductors, ceramics, silicon and combinations thereof. Any cathode which can be plated using prior art baths may be coated in accordance with the present invention. For example, good deposits may also be produced upon articles of copper, nickel, iron, steel, etc. The best results are obtainable with these baths if relatively pure anodes of the metals are employed, and either tin/lead alloy anodes or separate tin anodes and lead anodes may be used. It should be noted that the composition of the anode has a significant effect upon the composition of the deposit, and that it is generally desirable to employ an anode having a proportion of metals approximating that desired in the plated alloy. The composition of the deposit may also be controlled by use of separate anodes of tin and lead, to which the current may be proportioned appropriately.

[0039] The electrically conductive fluid may be comprised of water and at least one ionic species, preferably an ionic species derived from the dissociation of the anode material. Typical plating baths are known from U.S. Pat. Nos. 4,118,289 and 4,440,608. Electrodeposited tin/lead alloys of different compositions are especially valuable in a number of applications including the provision of bearing contact surfaces for which a 7/93 tin/lead alloy is typically used and the provision of surfaces for soldering such as on printed circuit boards and the like for which alloys of 60/40 tin/lead are desired. Suitable aqueous acid plating baths for the electrodeposition of tin/lead alloys comprise about 5 to 80, and preferably about 45 to 65 grams per liter of stannous ion; about 85 to 10, and preferably about 35 to 15 grams per liter of lead ion; and at least about 100, and preferably at least about 150, grams per liter of radical selected from the group consisting of fluoborate, fluosilicate, and sulfamates. When the bath utilizes the fluoborate radical, as is preferred, it desirably also contains at least about 50 grams per liter of free fluoboric acid and at least about 10 grams per liter of free boric acid. Preferably, the amount of stannous ion will exceed the lead ion and will be in the range of about 45 to 65 grams per liter, with the amount of lead ranging from about 35 to 15 grams per liter. A most desirable feature of the invention is that it enables the formation of electrodeposits of solder having a composition at or near the eutectic point for tin/lead alloys, and the most desirable range of the ions in the bath therefore is about 53 to 57 grams of stannous ion per liter and about 27 to 23 grams of lead ion per liter. The fluoborate baths are preferred and, to be satisfactory, must contain at least about 100 grams per liter of the fluoborate radical; preferably the amount of the radical will not be less than about 150 grams per liter. Such a bath should contain at least about 50 grams per liter of fluoboric acid and at least about 10 grams per liter of boric acid. The bath preferably has a pH of less than about 3 and desirably below about 1. It is common practice in tin-lead plating to use refined peptone as an additive.

[0040] The baths are operable over a fairly wide range of cathode current density, depending upon other factors such as temperature, agitation, etc. More specifically, the operable range is about 10 to 200 amperes per square foot and preferably about 20 to 120 amperes per square foot, with a narrower range of 25 to 35 amperes per square foot being most desirable for the production of deposits having a substantially eutectic composition. The plating efficiency is generally quite high and will range up to about 95 percent under optimum conditions, based upon the theoretical rate of deposition, and bright deposits of excellent quality can best be produced at a bath efficiency in excess of 70 percent. The applied voltage should be about 0.2 to 5 volts and preferably 0.5 to 4 volts.

[0041] The baths should be operated at a temperature of at least about 50° F., and preferably from about 60 to 90° F. Operation below about 50° F. tends to be inefficient and to produce undesirable deposits, whereas temperatures higher than about 90° F. tend to cause oxidation of the tin ion to the stannic state and to produce dull, rough and generally unacceptable deposits; furthermore, the bath is consumed at an excessive rate at temperatures that are unduly high.

[0042] Some agitation is desirable to obtain high quality, uniform deposits and to avoid development of sludge or film, and plating at high current densities and temperatures may be improved by more intense agitation. However, excessively high rates of agitation are undesirable because they can cause excessive consumption of the bath and impose limitations upon the current densities at which brightness is achieved. Not only is agitation of the bath itself desirable but agitation of the cathode may be beneficial in obtaining a uniform plate and enabling extension of the range of satisfactory current density.

[0043] The process is adapted to still plating and barrel plating apparatus with equal efficacy, and may be used for strip, wire and connector strip. Use of the bath and process is particularly significant with respect to connector strip, printed circuit boards, and the like because of the excellent solderability of the plate produced. Filtration of the bath is not essential but will normally be beneficial when contamination of the bath is encountered due to air-borne impurities and carryover from other finishing operations; preferably, it will be effected on a continuous basis. Various filtering media may be utilized including fabrics, such as a polypropylene, and other conventional filtering materials.

[0044] The depletion of the various components of the bath is best corrected by analysis for the several components on a periodic basis which can be established for a given facility. To determine the amounts of stannous salt required, an iodine titration technique may be used; the lead content may be checked by precipitation with dilute sulfuric acid. Tin-lead alloys are electrolytically deposited in thicknesses typically ranging from about 0.2 to about 2 mils when used in printed and other circuitry to provide a solderable finish, a contact material, or an etchant resistant.

[0045] Although the present invention has general applicability in the field of manufacturing and assembly of integrated circuits, and specifically in the electroplating of the solder bumps or under bump metallurgy for flip chip electrical interconnect, it is to be understood that the present invention is also applicable for use with any electroplating apparatus and process in which achieving a uniform plating thickness is desired. Although the anode as been herein described has a anode, it also find use as any electrode such as a cathode.

[0046] While the present invention has been particularly shown and described with reference to preferred embodiments, it will be readily appreciated by those of ordinary skill in the art that various changes and modifications may be made without departing from the spirit and scope of the invention. It is intended that the claims be to interpreted to cover the disclosed embodiment, those alternatives which have been discussed above and all equivalents thereto.

What is claimed is:

1. An anode comprising a shaped, substantially solid, metal body; a metal electrode shaft having one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft; the one or more barbs being fixed within the body.

2. The anode of claim 1 wherein the shaft comprises a plurality of barbs which are fixed within the body.

3. The anode of claim 1 wherein the one or more barbs are fixed within the body by casting the body around the one or more barbs.

4. The anode of claim 1 wherein the portion of the shaft outside of the body is absent of barbs.

5. The anode of claim 1 wherein the body comprises tin, lead, copper, aluminum, silver, bismuth, indium, antimony, tin-lead alloy, tin-silver-copper alloy, silver-bismuth alloy, or combinations thereof.

6. The anode of claim 1 wherein the body comprises from about 0% to about 100% tin and from about 0% to about 100% lead.

7. The anode of claim 1 wherein the body comprises from about 5% to about 63% tin and from about 37% to about 95% lead.

8. The anode of claim 1 wherein the shaft and one or more barbs comprise titanium, copper, silver, platinum, tantalum, stainless steel, gold or combinations thereof.

9. The anode of claim 1 wherein the shaft and one or more barbs comprise nickel plated titanium.

10. The anode of claim 1 comprising a plurality of barbs projecting outwardly from a periphery of the shaft at one end of the shaft, said barbs being fixed within the body and wherein the body comprises from about 5% to about 63% tin and from about 37% to about 95% lead; and wherein the shaft and one or more barbs comprise nickel plated titanium.

11. The anode of claim 1 wherein the body has a solid rectangular, square, circular, oval, trapezoidal, triangular, ring or irregular shape, and either with or without apertures therein.

12. An anode comprising a metal electrode shaft and a shaped, substantially solid metal body cast around one end of the shaft.

13. The anode of claim 12 comprising a metal electrode shaft having one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft, a substantially solid, metal body cast around the barbs.

14. A method for producing an anode which comprises:

a) providing a metal electrode shaft having one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft;

b) providing a shaped, substantially solid, metal body;

c) fixing the one or more barbs through the metal body.

15. The method of claim 14 comprising a plurality of barbs projecting outwardly from a periphery of the shaft at one end of the shaft, said barbs being fixed within the body and wherein the body comprises from about 5% to about 63% tin and from about 37% to about 95% lead; and wherein the shaft and one or more barbs comprise nickel plated titanium.

16. A method for producing an anode which comprises:

a) providing a metal electrode shaft;

b) casting a molten metal around one end of the shaft and cooling the molten metal to thus form an anode comprising a solid metal body enveloping said end of the shaft; and

c) subsequently removing the anode from the mold.

17. The method of claim 16 which comprises:

a) providing a metal electrode shaft;

b) placing one end of the electrode into a fixture;

c) placing the fixture and the end of the electrode within the fixture into a casting mold;

d) casting a molten metal into the casting mold and cooling the molten metal to thus form an anode comprising a solid metal body enveloping said end of the shaft; and

f) subsequently removing the anode from the mold.

18. The method of claim 16 which comprises:

a) providing a metal electrode shaft;

b) applying a flux composition to one end of the shaft;

c) placing the flux applied end of the electrode into a fixture;

d) placing the fixture and the flux applied end of the electrode into a casting mold;

e) casting a molten metal into the casting mold and cooling the molten metal to thus form an anode comprising a solid metal body enveloping the flux applied end of the shaft; and

f) subsequently removing the anode from the mold.

19. The method of claim 16 wherein the flux applied end of the shaft has one or more barbs projecting outwardly from a periphery of the shaft at one end of the shaft, which one or more barbs are fixed within the body.

20. The method of claim 16 comprising a plurality of barbs projecting outwardly from a periphery of the shaft at one end of the shaft, said barbs being fixed within the body and wherein the body comprises from about 5% to about 63% tin and from about 37% to about 95% lead; and wherein the shaft and one or more barbs comprise nickel plated titanium.

21. The anode produced by the method of claim 16.

22. The anode produced by the method of claim 17.

23. The anode produced by the method of claim 18.

24. The anode produced by the method of claim 19.

25. The anode produced by the method of claim 20.

26. An electrolytic arrangement which comprises:

a) a vessel containing an electrically conductive fluid; and

b) the anode of claim 1 in the electrically conductive fluid, which anode is connected to an electric circuit; and

c) a cathode in the electrically conductive fluid, which cathode is connected to an electric circuit.

27. The electrolytic arrangement of claim 26 wherein the electrically conductive fluid comprises water and at least one ionic species.

28. The electrolytic arrangement of claim 26 wherein the electrically conductive fluid comprises an ionic species derived from the anode material.

29. The electrolytic arrangement of claim 26 wherein the cathode comprises a material selected from the group consisting of semiconductors, ceramics, silicon and combinations thereof.

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