METHOD OF DEPOSITING ELEMENTAL MATERIAL FROM A LOW PRESSURE ELECTRICAL DISCHARGE

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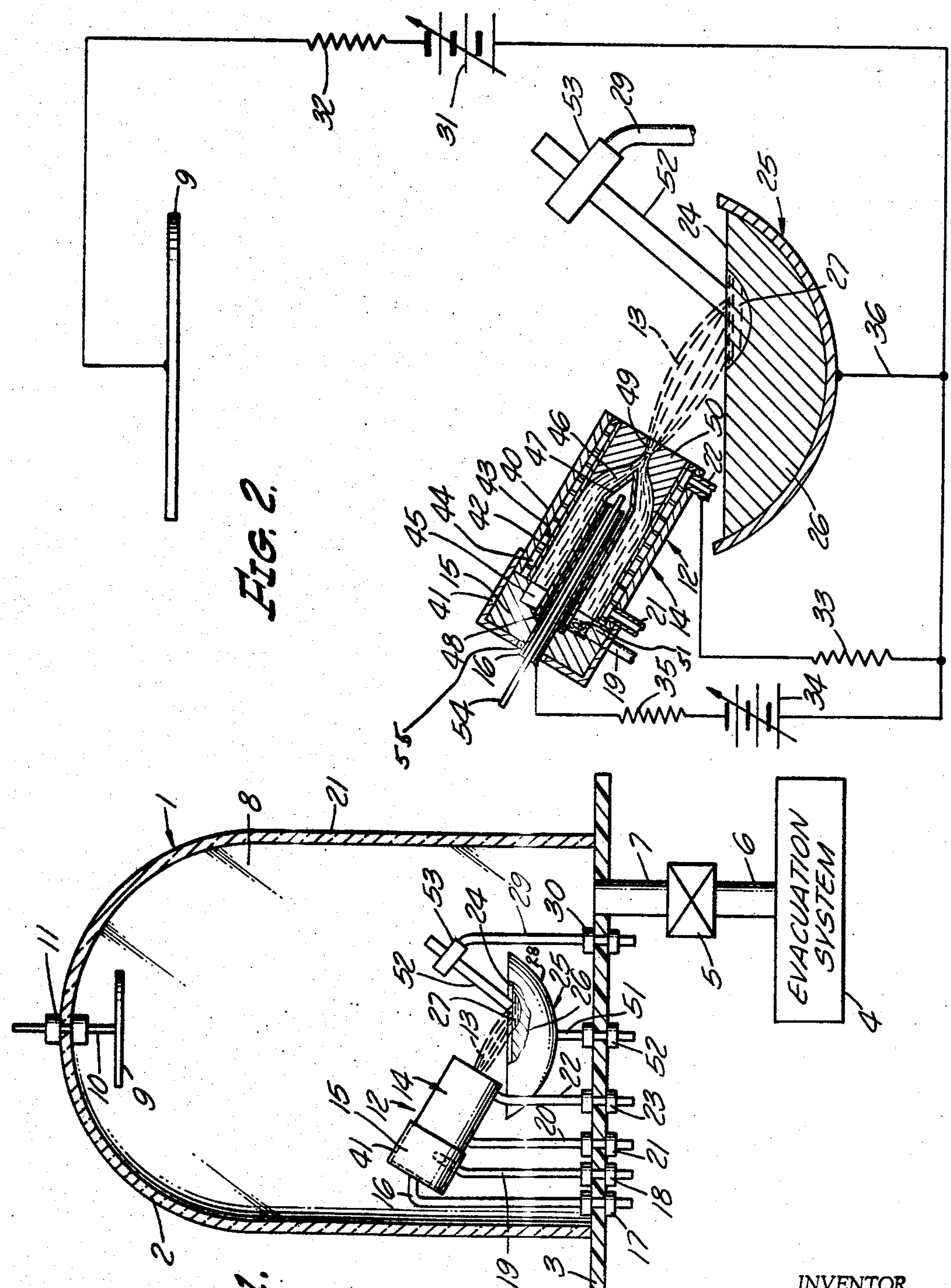


INVENTOR
JOHN TOM NAFF
BY [signature]
AGENT

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## METHOD OF DEPOSITING ELEMENTAL MATERIAL FROM A LOW PRESSURE ELECTRICAL DISCHARGE

John Tom Naff, Costa Mesa, Calif., assignor to Automatic Fire Control Inc., South El Monte, Calif., a corporation of California

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### ABSTRACT OF THE DISCLOSURE

A method of depositing elemental material from a glow discharge supported in an inert argon atmosphere between an anode source and a cathode for receiving the deposit of elemental material. The elemental material is vaporized from the anode source into the discharge by applying an arc plasma jet directly to the source.


This invention discloses and teaches improvements in a source of vaporized metallic and metalloid atoms and ions which are generated at high temperature in an arc device, said arc device being integrally included in a high voltage gaseous glow discharge circuit. This invention is useful in providing an atom and ion source which can be replenished with metallic or metalloid atom raw material on demand, providing an atom vapor source suitable for a long time duration metal vaporization and vapor plating process.

One of the serious limitations on low pressure gaseous glow discharge plating of metals on substrates is the short process operation time, imposed by using thin deposits, or small amount of coatings of the metals to be vaporized, on a thermally heated filament. This invention provides a solution to this problem.

Included in the objects of my invention are:

First, to provide an improved means of continuously generating over long process operating time periods the vaporized metal and metalloid atoms and ions suitable for application in a low pressure gaseous glow discharge metal plating process.

Second, to provide an improved ionized metal atom source for a low pressure, gaseous glow discharge, continuous metal ion plating device.

Third, to provide a high temperature arc source suitable for vaporizing and ionizing metal and metalloid atoms within the electrical field of a high voltage, low pressure, gaseous glow discharge plating machine, over long periods of time.

Fourth, to provide a replenishable electric arc means source for ionized metal and metalloid ions, integral with a low pressure gaseous glow discharge process for plating said metal and metalloid atoms on a substrate.

Other objects, together with a more complete understanding of my invention, are taught by reference to the following description and claims, which are to be read in conjunction with the following drawings, in which:

FIGURE 1 represents an elevational perspective and partial sectional view of the low pressure gaseous glow discharge device, incorporating the multiple arcs supplying metal and metalloid vapor.

FIGURE 2 is an enlarged detail elevational sectional and functional electrical schematic circuit view of the multiple arc sources of FIGURE 1, suitable for constructively practicing this invention.

Referring to FIGURE 1, in detail, there is shown an elevational perspective and partial sectional view of the high voltage, low pressure glow discharge apparatus **1**, having a gas tight, electrically non-conductive evacuable container **2** sealed by external atmospheric pressure to



the non-conductive base plate **3**. The low pressure evacuation system **4**, is connected to the valve **5** by the pipe **6**, and the pipe **7** connects the valve **5** to the base plate **3**. The components **2–7** represent prior art teaching.

A streaming argon gas atmosphere of 10–100 micron Hg. pressure is maintained in the gas phase **8** during the plating operating of apparatus **1**. The cathode plate **9** is adaptively secured in the apparatus **1** by the conductor **10**, which in turn is led through a gas-tight, non-conductive seal **11** to the exterior high voltage power source not shown.

The enclosed low voltage DC arc **12** is shown in elevational perspective view, with an exterior arc plasma jet **13** issuing from the arc **12**. The arc **12** has an exterior, liquid cooled, electrically conductive anode **14** and an interior, non-conductive cathode cap **15**. The electrical conductor **16** carries current through the cathode cap **15**, which is typically a porcelain electrical insulator, and the conductor **16** is in turn connected to the exterior atmosphere through the gas-tight, electrical lead-in seal **17**. The gas-tight seal **18** conducts the argon gas inlet tube **19** through the base plate **3** to the cathode cap **15**. The metal cap **41** secures cap **15** to the exterior anode **14**. The coolant fluid outlet **20** conducts the coolant, typically water, away from the exterior anode **14** through the gas-tight container seal **21**. The exterior anode fluid coolant inlet **22**, is led through the base plate **3** to the atmospheric exterior through the gas-tight seal **23**. The fluid coolant, typically water, is pumped through the anode fluid coolant jacket at a rate sufficient to maintain the arc **12** at the desired temperature, as it removes the excess thermal energy in the heated coolant fluid. The cathode **9** also may be water cooled.

The exterior arc plasma jet **13** forms a transferred jet impinging on the surface **24** of the low pressure glow discharge anode source structure **25**. Through the partial cross sectional view of anode structure **25** is shown the vaporizable coating metal **26** in the electrically conductive container **28**. The vaporizable coating metal **26** fuses to a molten pool **27** at and below the junction area of the impinging exterior arc plasma jet **13** and the metal **26**. The expendable rod **52** is shown supplying the reserve of the metal **26**, angularly located above the area of the molten metal pool **27**, in order to form a reserve source of the metal **26** which can be metered into the pool **27**, on signal. The support arm **29** locates the linear actuator **53** for the rod **52** in the required operating position and is also adapted to enclose and conduct a set of electrical power and signal wires to the exterior of the base plate **3**, through the gas-tight seal **30**.

FIGURE 2 illustrates the enlarged sectional view of FIGURE 1, detailing the anode vapor source invention. The enclosed low voltage DC arc **12** is shown in elevational operational position relative to the low pressure glow discharge anode source structure **25** and the replenishing expendable metal rod **52**. Other replenishing sources of the expendable metal **26** may also serve as a cooperative source of metal **26**. In further sectional detail the arc **12** has a cathode cap **15** made of electrically non-electrical conducting porcelain or the like high melting non-conductor. The cap **15** is tightly sealed to the outer water jacket shell **40** by the metal cap **41**. A circular opening **55** insulates cap **41** and tube **16**. The inner water jacket shell **42** is separated from the outer shell **40** by the helical wound or shaped water passage separator **43**, which insures continuously effective water cooling and highly efficient heat removal from the arc **12**. The water enters the anode at the inlet **22**, winds through the water passage **44** between the outer shell **40**, the inner shell **42** and the separator **43**.

The water fiinally exits at outlet **21**. The argon gas is metered into the gas inlet tube **19**, which is secured to the metal cap **41**. The tubular opening **51** pasess the argon gas in the tube **19**, venting the gas into the arc plasma opening **46**, through the annular ring openings **45**. The pointed cathode rod **47** is secured to the cap **15** and is also electrically conductively secured to and encloses the electrical conductor tube **16**. The electrical conductor tube **16** is the exterior tube in a pair of hollow coaxial fluid coolant heat transfer tubes, the inner coolant tube **54** is also disposed to conduct fluid coolant. Typically the water coolant is conducted through the exterior tube **16**, and exits through the inner water coolant tube **54**. The tube **16** also conducts power to the cathode **47**.

The metal cap **48** is also affixed to the cathode rod **47** and secures the tube **16**. The venturi shaped orifice **49** in the nozzle block **50** is sized and shaped to control the argon gas pressure, together with the gas inlet flow rate and the arc electrical performance, to maintain an argon gas pressure of 50–100 mm. Hg in the arc plasma opening **46**. The nozzle block **50** has a preferred venturi shaped nozzle approach to the upstream side of the nozzle orifice **49**. The nozzle block **50** is welded to the inner water jacket shell **42**. The components **40, 41, 42, 43** and **50** are typically copper metal, selected for use due to its high electrical and thermal conductivity.

The high temperature anode vapor source of this invention produces a high concentration of ionized atoms of the metal **26** in the anode column and arc attachment area and a large high temperature surface area from which the atoms can rapidly evaporate. The anode vapor source of this invention will thus provide the hot ionized atom source for high metal plating speed in the high voltage low pressure glow discharge.

A multiplicity of the anode vapor sources comprising the combination of the anode arc **12** and the anode structure **25** may be grouped in a single low pressure, high voltage plating device. For example, more than one anode arc of the type of arc **12** may be grouped to form transferred arcs to one anode structure **25** type. Or, a multiple number of single combinations of arc **12** and anode structure **25** may be grouped around a large complex shaped structure requiring plating, which is located in the cathodic plate region, thus ion metal plating onto the large complex shaped structure.

The high voltage, low pressure, gaseous glow discharge cathode plate **9** is typically operated in a streaming argon gas atmosphere **8** of 10–100 micron Hg pressure. The plate **9** is operated typically at 4000 DC volts with respect to the anode **25**, powered by the DC variable high voltage supply **31**, which is regulated through the resistance **32** connected by the wire conductor circuit **36**. The arc **12** is anodically connected by its anode **14**, at the coolant inlet **22** through a controlling resistance **33** to the anode **25**. The DC low voltage power supply **34** drives the arc **12**, regulating the current through resistance **35** to typically 50 amperes, and a DC voltage range of 10–30 volts.

In operation the arc **12** is supplied with up to 1500 watts at 30 volts DC, using a 50 mm. Hg pressure of argon gas, exiting through the orifice **49** having a diameter of about 0.010 inch. The arc **12** forms a transferred jet **13** with the junction area of the metal **26** melting to form the metal pool **27**. The molten metal pool **27**



acts cooperatively as the volatile metal anode for the high voltage, low pressure glow discharge between anode **25** and cathode **9**. Objects to be plated in the glow discharge are placed in the container **2**, located in the cathode **9** in the cathode dark space for metallic plating. Metals selected from the group tungsten, tantalum, aluminum, chromium, copper, graphite, gold and silver may be used as sources of vaporizable metal **26**.

Obviously many modifications and variations of the improvement in anode vapor sources are possible within the scope of this invention as disclosed and claimed, and the invention may be practiced otherwise than as specifically described.

I claim:

**1.** A method of depositing elemental material in a low pressure glow discharge in an argon atmosphere comprising: enclosing a low voltage DC arc plasma maintained in a streaming argon atmosphere, at a gas pressure of 50–100 mm. Hg and generated by a potential in the range of 10–30 volts and a total current not exceeding 50 amperes between an interior cathode and an exterior liquid cooled anode, exiting said enclosed arc plasma through a small orifice in said exterior anode to form an exterior arc plasma jet; forming a transferred arc plasma jet by impinging said exterior arc plasma jet on a low pressure glow discharge anode source structure containing vaporizable elemental coating material and causing said material to evaporate at the impingement junction area of said transferred arc plasma jet; supporting a high voltage, low pressure gaseous glow discharge in an argon atmosphere at a pressure between 10 and 100 microns of Hg between a cathode means, and said anode source structure containing said vaporizing elemental coating material, whereby said material moves through said discharge to said cathode and deposits thereon; and replenishing the source of said elemental coating material at said anode by advancing a consumable solid source into said anode as it is being used.

**2.** The method of claim **1** wherein said vaporizable elemental coating material is selected from the group consisting of aluminum, copper, chromium, tungsten, tantalum and graphite.

**3.** The method of claim **1** wherein elemental material is impinged by a plurality of arc plasma jets.


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ROBERT K. MIHALEK, Primary Examiner

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