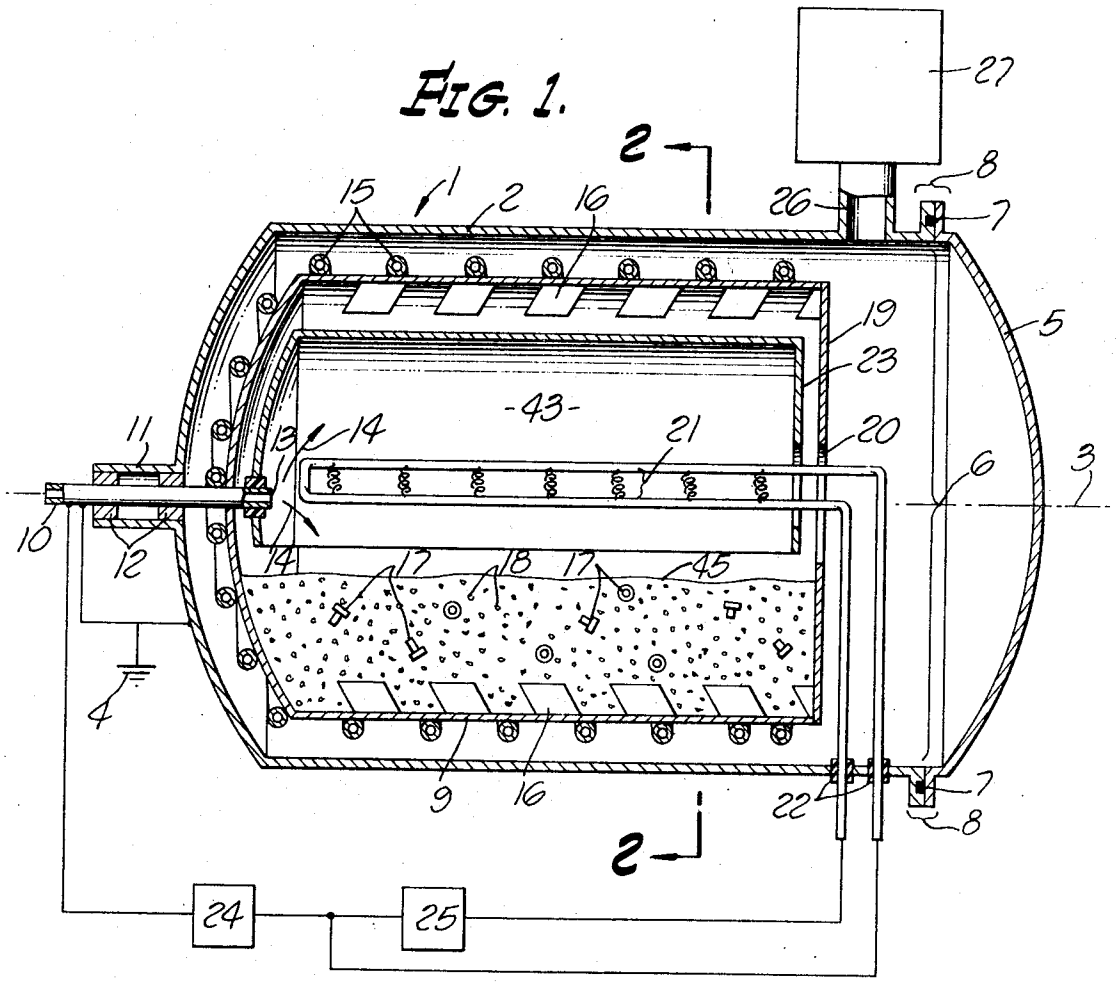
May 26, 1970 R. C. BRUMFIELD ET AL 3,514,388

ION METAL PLATING OF MULTIPLE PARTS

Filed March 18, 1968 2 Sheets-Sheet 1

FIG. 1.



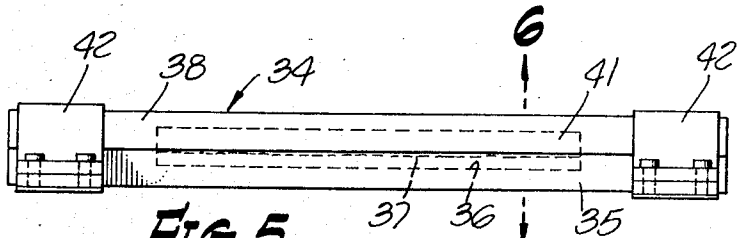
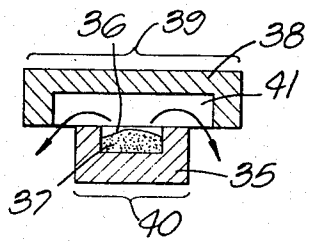


FIG. 5.

FIG. 6.



INVENTORS.
ROBERT C. BRUMFIELD
JOHN T. NAFF
BY ALONZO T. W. ROBINSON
AGENT

May 26, 1970 R. C. BRUMFIELD ET AL 3,514,388

ION METAL PLATING OF MULTIPLE PARTS

Filed March 18, 1968 2 Sheets-Sheet 2

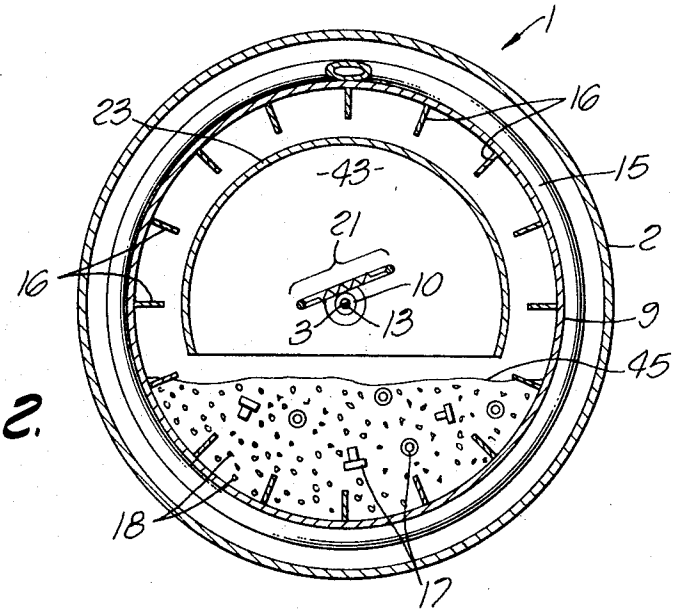


FIG. 2.

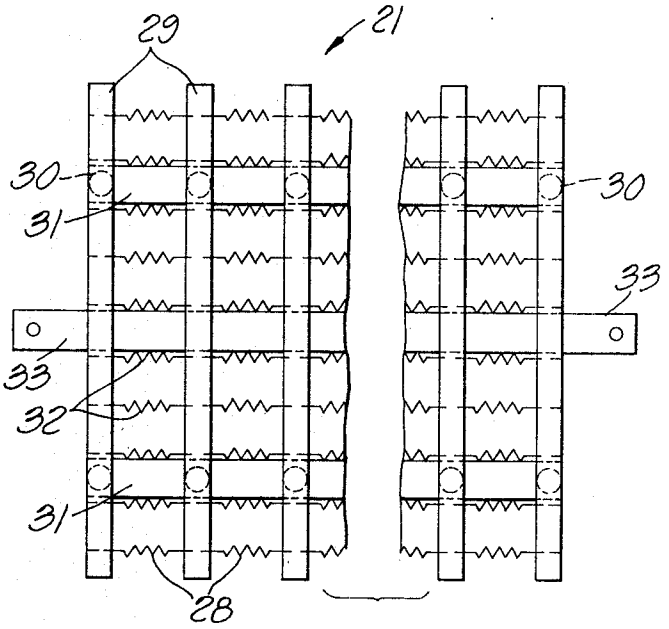


FIG. 3.

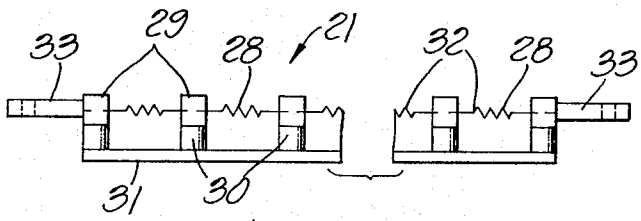


FIG. 4.

INVENTORS.
ROBERT C. BRUMFIELD
JOHN T. NAFF
BY ALONZO T. W. ROBINSON

J. F. Bowen, Sr.
AGENT

United States Patent Office 3,514,388 Patented May 26, 1970

3,514,388

ION METAL PLATING OF MULTIPLE PARTS

Robert C. Brumfield, Emerald Bay, John T. Naff, Costa Mesa, and Alonzo T. W. Robinson, Huntington Beach, Calif., assignors to Automatic Fire Control Inc., South El Monte, Calif., a corporation of California

Filed Mar. 18, 1968, Ser. No. 713,709
Int. Cl. C23c 15/00
U.S. Cl. 204—192 8 Claims

ABSTRACT OF THE DISCLOSURE

This invention teaches a process and apparatus useful in simultaneously metal plating a large number of metal and non-metal parts with a metal coating by ion metal plating, typically in a low pressure argon atmosphere with a high voltage, abnormal glow discharge, rotating the parts while they are physicaly intermixed with void filling conductive particulates.

BACKGROUND OF THE INVENTION

This invention related to an improved process for ion metal plating a multiplicity of metal and non-metal parts in a single plating operation, utilizing improved apparatus for the plating process. Conventionally, metal parts have been previously ion metal plated by separately and individually placing each part in an evacuable apparatus, wherein the low pressure, high voltage argon gas abnormal glow discharge is generated between the fixed position heated plating metal anode structure and the fixed position cathode structure having one or more parts to be plated electrically conductively secured thereto. This process is disclosed in Mattox, U.S. 3,329,601.

The above conventional process is characterized by high labor costs, in terms of individually placing each part to be plated in electrical contact with the cathode, and removing the part after each plating operation. The process also leaves undesirable rack or cathode structure marks on the plated part, due to non-uniform electrical field strength shadow zones present during the metal deposition step.

SUMMARY OF THE INVENTION

This invention teaches a process and apparatus suitable for simultaneous metal plating of a large number of metal and non-metal parts of varying sizes in a single ion plating operation, utilizing a typical low pressure argon gas, high voltage abnormal glow discharge. In this improved ion metal plating apparatus, a fixed position, electrically grounded, vacuum tight, exterior drum container is located with the cylindrical axis of symmetry horizontal, and there is a vacuum tight removable closure on an end of the drum. An electrically insulated, mixing, interior drum shell slowly rotates axially concentrically inside the fixed exterior drum and is open to the gas pressure inside the exterior drum.

The interior rotating drum shell has mixing baffles located therein, to promote tumbling and mixing of objects placed in the interior drum. The metal and non-metal parts to be plated are located in the bottom half of the interior drum shell together with an amount of discretely sized particulates of the same metal as the plating metal, the particulate balls or other small sized irregularly shaped pieces are sized to fit in the interstices between the metal and non-metal parts to be plated and to fill the parts interstices to a high volume percentage. A fixed position anode structure is located concentric with the rotating interior shell drum axis of rotation and the interior shell metal rotating drum is the cathode of the low argon gas pressure, high DC voltage abnormal glow discharge system.

The discretely sized, metal balls or other small sized, irregularly shaped particulates of the plating metal serve to fluidize or buoy up the parts to be plated, supply multiple electrical contacts between these parts and the rotating drum shell cathode, and minimize the electrical field strength shadows which can produce uneven metal plating on the rotating metal parts.

Included in the objects of this invention are:

First, to provide an improved ion metal plating process for simultaneously ion metal plating a large number of metal and non-metal parts in a single plating operation, without individually attaching each part to a fixed position cathode.

Second, to provide an improved ion metal plating process for simultaneously metal plating a large number of metal and non-metal parts, eliminating plating imperfections due to electrical field strength inequalities in the ion plating step.

Third, to provide good low temperature control of the parts plated in an ion metal plating, low gas pressure, high voltage abnormal glow discharge.

Fourth, to provide a rotating drum plating apparatus for simultaneously metal plating multiple parts in a low gas pressure, high voltage abnormal glow discharge.

Fifth, to provide a process for simultaneously ion metal plating multiple metal and non-metal parts, concurrently burnishing the metal parts and minimizing the number of nicks or scratches formed on the metal parts.

Sixth, to provide means for greatly reducing the labor required to ion metal plate a large number of relatively small metal and non-metal parts.

Other objects and advantages of this invention are taught in the following description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

The description of this invention is to be read in conjunction with the following drawings:

FIG. 1 is an elevational partial sectional, partial perspective drawing of the rotating drum ion plating apparatus useful in simultaneously metal plating multiple metal parts in a low gas pressure, high voltage, abnormal glow discharge.

FIG. 2 is a view through 2—2 of FIG. 1.

FIG. 3 is a detailed partial plan view of a commercial anode filament source of plating metal, in series-parallel electrical connections.

FIG. 4 is a side elevational view of the anode filament source of FIG. 3.

FIG. 5 is a perspective elevational view of another anode plating metal source.

FIG. 6 is an elevational view through 6—6 of FIG. 5.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to FIG. 1 in detail, the ion plating evacuable apparatus 1 of this invention is shown in an elevational view. A fixed position, vacuum tight, cylindrical, exterior metal drum 2 is disposed with the drum cylindrical axis of symmetry 3 located horizontally, and the drum 2 grounded at 4. A vacuum-tight, removable, swinging hinged door closure 5 seals the drum 2 at the drum opening 6, with suitable gasket seals 7 or the like in the flange pair 8. An electrically conductive and grounded, interior mixing drum 9 also has the horizontally disposed cylindrical axis of symmetry 3. The axes of cylindrical symmetry of exterior drum 2 and interior mixing drum 9 are not required to coincide, but it is convenient to do so. The interior mixing drum 9 is supported by the hollow shaft 10, which is located in the vacuum-tight bearing shaft gland 11 secured to the exterior drum 2. The bearing and seal combination 12 provide a vacuum-tight rotational

seal, upon which the shaft **10** can be supported and the shaft **10** is supplied with rotative power. The hollow shaft **10** has an opening **13** into the drum **2**, which can be used as an argon gas inlet. The bearing and seal combination **12** is bathed in a stream of argon gas **14** at 1.1 atmosphere pressure, providing a pressure gradient preventing air leaks into the exterior drum **2**. The interior mixing drum **9** is also electrically grounded through shaft **10** to ground **4**.

The water cooling means **15** is thermally conductively secured to the interior mixing drum **9**, providing a means to absorb and conduct heat away from the interior mixing drum **9**. Although a spirally wound metal tubing **15** is shown welded to the exterior of the interior mixing drum **9** and is the water cooling means **15** in this modification, a conventional jacketed shell around the drum **9** can be an equivalent water cooling means **15**, as well as conventional spiral continuous openings cast in the wall of the interior mixing drum **9**. The water cooling stream exits from the apparatus through a standard rotative sealing device.

The baffle mixing blades **16** are interiorly located on the walls of the interior mixing drum **9**, and are radially aligned toward the axis of symmetry **3**, so as to provide a mixing and tumbling action for the metal or non-metal parts **17** and the electrically conductive void filling means **18** which are co-mingled in the lower half of the interior mixing drum **9**.

The co-mingled metal and non-metal parts **17** and electrically conductive void filling means **18** are held in the interior mixing drum by the removable closure **19**, having the coaxial opening **20** therein, the opening **20** being coaxial with the axis of symmetry **3**.

An anode plating metal source **21** is coaxially disposed along the axis of symmetry **3**, and the source **21** is electrically insulated from the exterior metal drum **2** by the pair of insulators **22**. Further details of the metal source **21** are illustrated in FIGS. 4–6. A sheet metal electrostatic shield **23** is disposed in a non-rotating, fixed position within interior mixing drum **9**, spaced within one cathode dark space of drum **9**, forming a semi-cylindrical metal shield around the axis of symmetry **3** and is mechanically secured to and electrically insulated from shaft **10**. The electrostatic shield **23** is electrically isolated in the apparatus, being substantially at the anode potential.

The interior mixing drum **9** functions as the cathode in the low pressure, abnormal glow discharge ion metal plating apparatus. The potential drop between the high voltage anode source **21** and the interior mixing drum cathode **9** can vary from 1500 to 5000 v. DC, and the potential is supplied by the power source **24**. The anode plating metal source is supplied low voltage power by the power source **25**.

A pipe opening **26** extends from the exterior metal drum **2**, and opening **26** vents into evacuation pump means **27**, having gas regulation means adapted to maintain the interior of drum **2** at an argon gas pressure range of 5 to 100 microns.

FIG. 2 illustrates the concentric circular construction of the apparatus **1**. The exterior metal drum **2** concentrically encloses the interior mixing drum **9**. The internally projecting radial baffle mixing blades **16** are secured to the interior of the drum **9**, and the water cooling tubing **15** is circumferentially welded to the exterior of drum **9**. The anode plating metal source **21** is shown located coaxially on the axis of symmetry **3**, and the opening **13** of the hollow shaft **10** provides an argon gas inlet.

FIGS. 3 and 4 together illustrate one modification of an anode plating metal source **21**, utilizing tungsten, tantalum or molybdenum coiled wire filaments **28**. The multiple wire filaments **28** are disposed and secured in parallel array between the electrically conducting bus bars **29**, by clamping or the like. The bus bars **29** are mechanically disposed on and secured to mounting electrical insulators **30**, and the insulators **30** are secured to and disposed in spaced position along the thermal and electrical insulator support plates **31**.

As illustrated in FIGS. 3 and 4, multiple parallel wire filaments can be connected in an array across a pair of bus bars **29**, and then the array connected in series with other multiple arrays to form a parallel-series array of anode wire filaments. The filaments **28** can be heated to vaporization temperature of the plating metal coating **32** on the filaments **28**, by an AC power source of up to 120 volts or the like, applied at the bus tabs **33**. In this anode plating metal source **21**, the plating metal coating **32** or plating metal clips are applied to the wire filaments **28** by known technique.

FIGS. 5 and 6 together illustrate another modification of anode plating metal source **34** which can be disposed coaxially along the axis of symmetry **3** of FIGS. 1 and 2. The anode plating metal source **34** is equivalent to the anode plating metal source **21**. The rectangular boat **35** may be an inter-metallic composite of boron, titanium, silicon nitrides, and has a rectangular cavity **36** shaped therein. The cavity **36** is filled with substantial amounts of the plating metal **37** in bulk form. A vapor deflector shield **38** is coplanarly disposed adjacently above the boat **35** as shown in FIGS. 5 and 6, the width **39** of the shield **38** being wider than the width **40** of the boat **35**. The rectangular cavity **41** of the deflector shield **38** is adjacently opposed to the boat cavity **36**. The vapor deflector shield **38** serves to deflect downward the hot metal vapors of the plating metal **37**. The rectangular boat **35** and the vapor deflection shield **38** are clamped together, electrically resistively heated and physically supported along the axis of symmetry **3**, by the pair of metal clamps **42** which serve as the electrical power conductors to the anode source **34**.

The electrically conductive void filling means **18** provides the base of the important inventive advance in the ion plating art. The void filling means **18** can be electrically conductive parts to be metal plated or an electrically conductive, bulk volume filler structure. In operation, the metal or non-metal parts **17** to be plated are randomly disposed in the lower half of the interior mixing drum **9**, and the void volume in between the parts **17** are filled with electrically conductive void filling means **18** which are carefully sized in a multiple series of graded volume sizes and shapes to provide as nearly maximum filling of the void volume between the parts **17**. Thus, the parts **17** statistically always remain in electrically conductive contact with the cathode interior drum **9** and the potential electrical field strength shadow zones are reduced to a minimum. The slow speed rotation of the interior mixing drum **9** insures the parts **17** are statistically uniformly exposed to the metal ions vaporized from the anode plating metal sources **21** and **34**, in the electrical field potential between the anode and cathode with a statistical minimum of field strength shadow.

Economically it is an advantage to co-mingle large and small volume parts **17** in a series of graded sizes in the mixing drum **9**, a parts diameter ratio of 10:1, or the like, being suitable. In this manner, the maximum number of parts are plated in a single plating operation, and a minimum volume of low economic value void filling means **18** is required. It is possible to schedule and comingle parts **17** for the plating operation in a size distribution pattern, requiring almost no low economic value void filling means **18**. The low economic value void filling means may be either metal balls, rods or pebbles of the physical shapes used in typical industrial grinding mill operations, but physically sized to fill the voids between the parts **17**. Ceramic type balls, rods or pebbles, including quartz sand, may be substituted for metal, as void filling means, for they may be first plated with the plating metal in a preliminary operation, prior to ion plating the parts **17**.

The rotational speed of the interior mixing drum **9** must be carefully controlled to avoid nicking and peening the metal parts during the plating operation. Typically a range of 1–10 r.p.m. is suitable.

By controlling the low speed rotation of the mixing drum **9**, the size of the metal parts **9** and void filling means **18**, the parts **9** are buoyed up and cushioned during the plating operation, as well as burnished.

Typically the size of the interior mixing drum **9**, or the like, can range from one having a 15 inch diameter x 24 inch long, to one having a 5 feet diameter x 6 feet long.

In operation, a typical load of bolts and nuts in a range of sizes to provide a minimum of void space in between the parts **17** is placed in the interior mixing drum **9**, or the like. The removable closure **19** is shut on drum **9**, and the required volume of appropriately sized void filling means **18** is added through the opening **20**. The anode plating metal source **21** or the anode source **34** is positioned along the axis of symmetry **3** and wired to the power source **25**. The swinging door closure **5** is sealed vacuum-tight to the exterior drum **2**. The vacuum evacuation means **27** removes all air from the interior of drum **2**, and an argon gas atmosphere **43** is introduced and maintained in range of 5 to 100 micron pressure.

Typically, during a parts cleaning initial stage the argon atmosphere **43** is held at 10 micron pressure. During a four hour period of degassing and cleaning of parts, the potential range between the anode source **21** and the metal parts **17**—interior mixing drum **9**—void filling means **18** forming combination cathode **44** can be from 1500 to 3000 volts DC, and 2000 volts is a typical potential, and is supplied by power source **24**. A current density at the frontal area **45** of the tumbling metal parts **17** and void fill means **18** is regulated over a range of 0.05 to 0.5 ma./cm.^{2}, and is typically 0.15 ma./cm.^{2}.

During the cleaning step as well as the following ion plating step, cooling water is circulated through the water cooling tubes **15**, or the like, providing heat transfer out of the ion plating apparatus **1**, thus maximizing the allowable cathode current density and shortening the cleaning or degassing time 3 to 5 fold over the standard rack type plating procedure of Mattox.

Immediately following the cleaning step, the unopened apparatus **1** is switched to the ion metal plating step. The argon gas atmosphere **43** is now held at 15 micron pressure, the potential gradient between anode source **21** and the cathode combination **44** ranges from 2500 to 5000 volts DC, with 3500 volts typical. The frontal area **45** of the metal parts **17** and void filling means **18** has a cathode current density range of 0.1 to 1.0 ma./cm.^{2} with 0.4 ma./cm.^{2} being typical. The anode plating metal sources **21** and **34**, and the like, are operated at the required power input from the low voltage power source **25**, providing a resistively heated metal plating source **21** or **34** which has a metal vapor pressure approximately equal to the argon gas pressure, typically 10 microns. The plating metal temperatures for the sources **21** and **34** correspond to the temperatures illustrated in Table I.

TABLE I

Material:	Temperature (° C.) (at 10 micron) vapor pressure
Al	996
Cr	1205
Cu	1273
Au	1465
Fe	1447
Pb	718
Ni	1510
Pt	2070

Continuing the rotation of the interior mixing drum **9** and its contents while also water cooling drum **9**, the metal atoms vaporized from the sources **21** or **34**, are largely directed toward the frontal area **45** of the parts **17** and the void filling means **18**, and the metal vapor atoms are deposited on the parts **17** and the means **18**, the electrostatic shield **23** tending to repel the metal atoms. As generally explained by Mattox, a large portion of the metal atom vapor is ionized in the argon gas discharge and these ionized atoms are accelerated to the pre-cleaned parts surfaces, along with other metal atoms in the vapor having only thermal energy. The pre-cleaned parts surfaces which have been subjected to prior argon ion bombardment have surfaces which provide very adherent metal plating layers in the final plating step.

A typical cleaning step requires about four hours for a load of ½ inch diameter bolts in a 30 inch diameter inner mixing drum **9**. The cleaning time is a function of parts **17** size, as the parts **17** are tumbled in the drum **9** and intermittently exposed at the frontal area **45**. The larger the parts **17**, the shorter the cleaning time. The time required to ion plate the parts **17** with metal plate **32**, or the like, is about 1½ hours for a 0.0005 inch thick coating of aluminum.

The process and apparatus of this invention provide superior means of ion metal plating non-metal parts. The non-metal parts **17** in the comingled parts **17**—void filling means **18** are continuously drained of their electron charges by the electrically conductive void filling means **18** which are in contact with the grounded interior drum **9**. Thus electrically insulated parts **17** can be ion plated in this process and apparatus.

A wide range of plating metal **32** and **37** may be applied to parts **17**. Preliminary to the ion plating process, the parts **17**, or the like, are first cleaned if necessary in the conventional steps required prior to high quality metal plating by any standard plating process, e.g., removing metal scale, washing, pickling and drying. Important plating metals which may be applied by this ion metal plating process and in the ion metal plating apparatus taught in this invention, are listed in Table II. Typically plating metals of Group A, such as aluminum, chromium, cadmium and copper may be coated on substrate parts of Group B made of steel, titanium, nickel-copper alloy, magnesium, gold, silver or the like in Table II. Non-metal parts of Group B may typically be coated with all the plating metals of Group A as listed in Table III, and the plating process and apparatus is not limited to the non-metals listed in Table III.

Ceramic based electrically conductive void filling means may be prepared for use in this process and this apparatus, by first placing the required sizes of ceramic balls, rods, pebbles or quatrz sand alone in the interior mixing drum **9**. Then the heated anode metal plating source means **21** or **34** is operated as in the standard metal evaporation process, at low argon gas pressure, to provide a thin electrically conductive coating of the metal coating **32** or **37** on the ceramic shapes.

The plating process and apparatus taught herein provide a means for simultaneously ion metal plating a large number of metal and non-metal parts with a very low unit of labor time per metal part plated. Therefore, this invention is a very important advance over the prior art in contributing to the commercial utilization of ion metal plating. The slow speed rotation of the metal parts contributes to a polishing action on the parts and to electrical field strength uniformity which eliminates parts rack marks and the like.

Obviously many modifications and variations of this improvement in ion metal plating process and apparatus are possible in the light of the above teachings. It is therefore understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically described.

TABLE II

Plating Metal (Group A)	Metal Parts (Group B)
Aluminum	Steel
Chromium	Titanium
Cadmium	Nickel-copper alloy
Copper	Magnesium
	Gold
	Silver
Platinum	Nickel-copper alloy
Gold	Nickel-copper alloy
Titanium	Steel
Iron	Aluminum
Lead	Titanium
Chromium	Zinc die cast alloy

TABLE III

Plating Metal (Group A)	Part Substrate (Group B)
Aluminum	Glass
Gold	Pyroceram
Copper	Carbon
	Methyl methacrylate polymer
	Polyvinyl chloride
	Chloropolyvinyl chloride
	Aluminum oxide
	Anodized aluminum
	Epoxy resin castings

We claim:

1. An ion metal plating apparatus comprising in combination:

(a) a fixed position, vacuum-tight cylindrical, exterior drum, having a horizontally disposed cylindrical axis of symmetry and a vacuum tight, removable closure secured to one drum end,

(b) a slowly rotatable, electrically conductive, interior drum having a horizontally disposed cylindrical axis of symmetry, said interior drum being located completely within said exterior drum, said interior drum end adjacent said exterior drum removable closure having a removable closure with a coaxial opening therein,

(c) an anode plating metal source disposed coaxially along the axis of rotation of said interior drum, electrically insulated from said interior drum and from said exterior drum, being mechanically secured to and supported by said exterior drum,

(d) a cathode source electrically secured to said interior drum,

(e) water cooling means thermally conductively secured to said interior drum,

(f) a gas injector inlet disposed coaxially along the axis of rotation of said interior drum, having gas flow regulating means attached to said inlet,

(g) electrically conductive void filling means, located in the lower half of said rotatable interior drum, said void filling means being multiple sized to provide volume filing of the interstices formed between the metal parts to be plated in said interior drum,

(h) a source of argon gas conductively secured to said gas injector inlet,

(i) evacuation means conductively secured to the interior of said exterior drum, having gas pressure regulating means adapted to regulate the gas pressure inside said exterior drum,

(j) a direct current, high voltage power means, having a voltage range of 2000 to 5000 volts, electrically connected to said anode and said cathode for supplying a cathode current density up to 2 milliamperes/cm.^{2}, as measured on the cathode surface confronting the anode, and

(k) a low voltage power supply for heating said anode metal plating source to the required metal volatilization temperature.

2. The ion metal plating apparatus of claim 1 in which said electrically conductive void filling means is a multiple sized, spheroid type shaped particulate, having a metal composition equivalent to the plating metal, and having a multiple particle size distribution substantially reducing the free volume between the metal parts being plated.

3. The ion metal plating apparatus of claim 1 in which said electrically conductive void filling means is a multiple sized, spheroid type shaped, particulate ceramic type composition, having a complete exterior coating of the plating metal, and having a multiple particle size distribution substantially reducing the free volume between the metal parts being plated.

4. The ion metal plating apparatus of claim 1 in which said interior drum is concentrically located within said exterior drum, both said interior drum and said exterior drum being disposed along a common horizontal cylindrical axis of symmetry, said interior drum having a rotatable shaft coaxially secured to one end of said interior drum, and said rotatable shaft extending through a gas tight bearing support coaxially secured between adjacent ends of said exterior drum and said interior drum.

5. The ion metal plating apparatus of claim 1 in which said interior drum has a multiplicity of baffle mixing blades located inside said interior drum, so aligned and secured as to promote mixing and stirring of said metal parts and said electrically conductive void filling means.

6. The process of ion plating in the apparatus of claim 1, comprising:

(a) placing the cleaned, degreased metal parts to be plated in said interior drum, in a volume amount regulated to provide a minimum anode-cathode distance greater than the cathode dark space distance,

(b) filling the interstices between said metal parts with said electrically conductive void filling means,

(c) rotating said interior drum at a rotative speed below which said metal parts and said electrically conductive void filling means are injected into the interior drum volume above the mixing said metal parts and said void filling means,

(d) maintaining an argon gas atmosphere in the exterior drum in the range of 10 to 100 microns Hg pressure,

(e) applying a DC electrical field potential range of 2000 to 5000 volts between said anode and said cathode and applying a cathode current density of 0.1 ma./cm.^{2} to 1.0 ma./cm.^{2} of confronting rotating cathode frontal area, for a period of time required to clean the metal parts by glow discharge,

(f) then immediately thereafter applying low voltage, not to exceed 120 volts, to the metal plating anode vapor source, to deposit metal plating atoms on said metal parts and said void filling means.

7. The process of claim 6 wherein said plating metal is selected from the group consisting of copper, silver, gold, zinc, cadmium, aluminum, tin, lead, chromium, iron, nickel and platinum.

8. The process of claim 6, in which said bearing support is bathed in a stream of argon gas injected at a higher ambient pressure than the argon gas pressure in the operating argon gas pressure in the interior of the exterior drum.

References Cited

UNITED STATES PATENTS

3,329,601	7/1967	Mattox	204—192
3,282,814	11/1966	Berghaus	204—192

HOWARD S. WILLIAMS, Primary Examiner

S. S. KANTER, Assistant Examiner

U.S. Cl. X.R.

117—106; 204—298