May 7, 1974 AKIRA MIYATA ET AL 3,809,641

ELECTROPLATING APPARATUS WITH PLATING VESSEL HAVING PROTRUSIONS AND RECESSES

Filed Sept. 8, 1972 3 Sheets-Sheet 1

FIG. 1

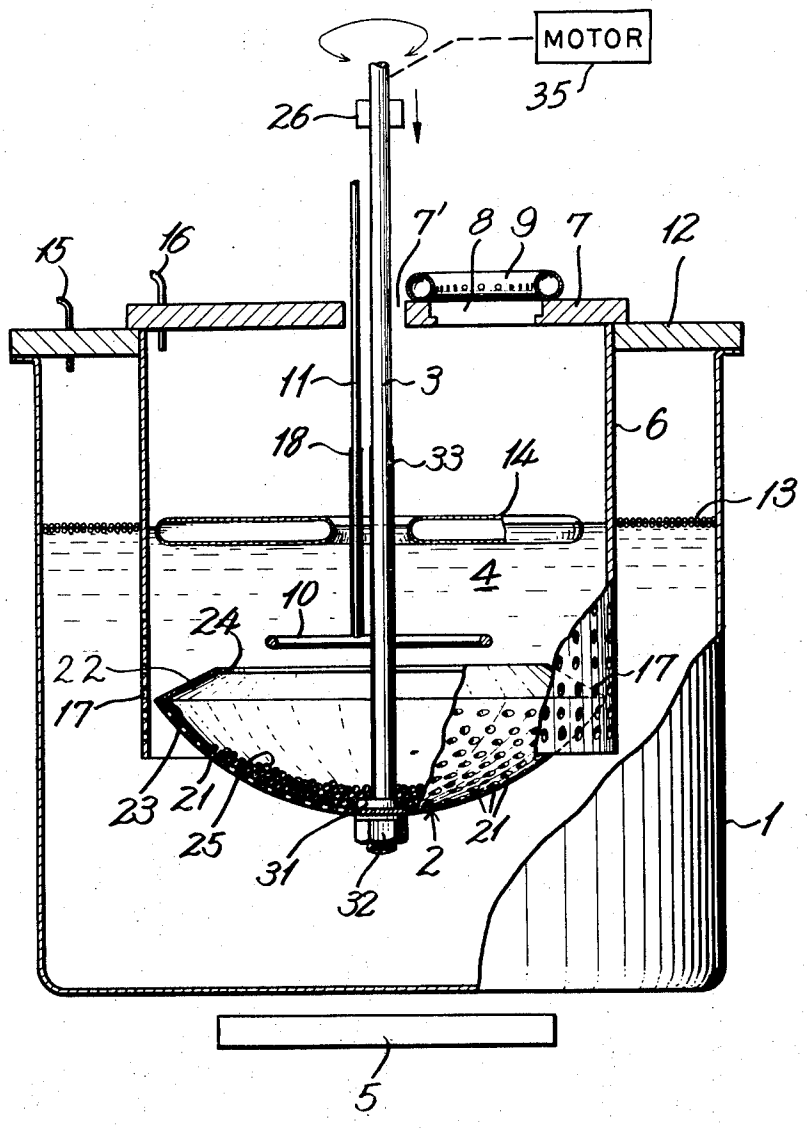


FIG. 2

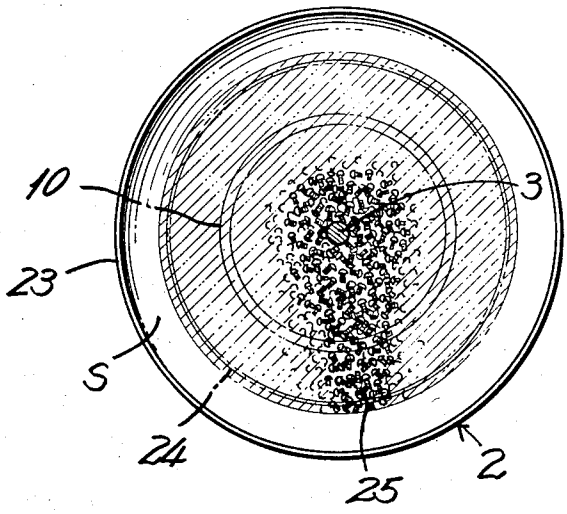


FIG. 3

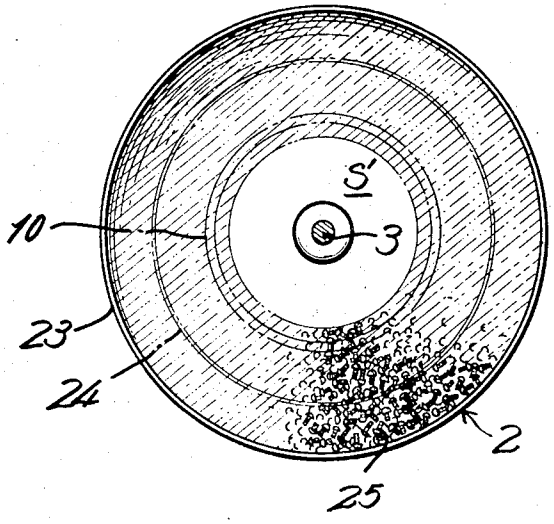


FIG. 4A

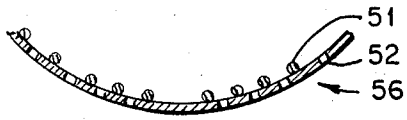


FIG. 4B

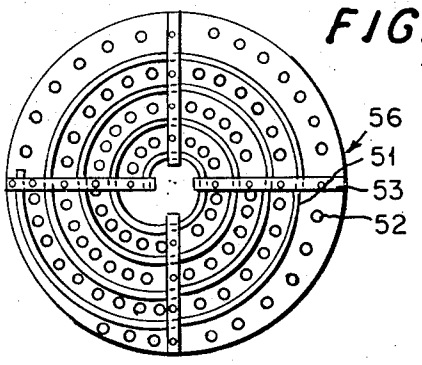


FIG. 5

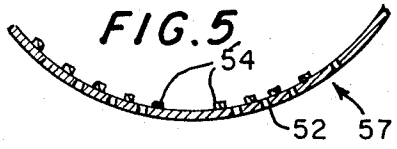


FIG. 6A

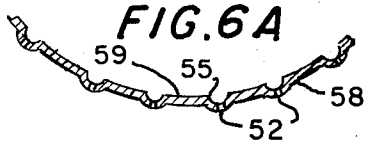


FIG. 6B

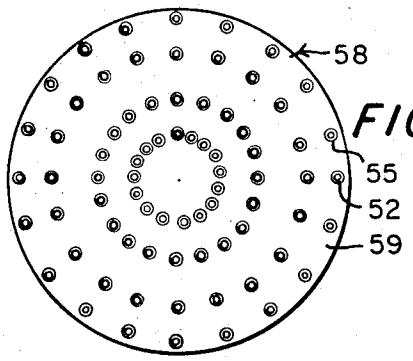


FIG. 6C

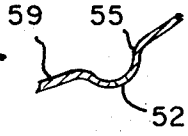
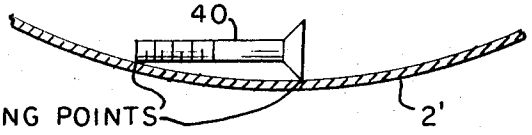


FIG. 7



PRIOR ART

FIG. 8A

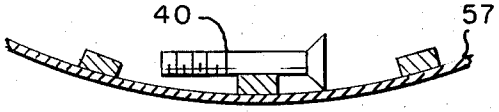
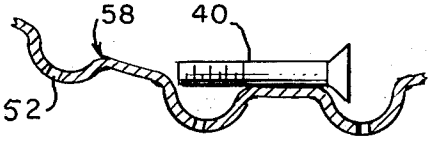


FIG. 8B



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ELECTROPLATING APPARATUS WITH PLATING VESSEL HAVING PROTRUSIONS AND RECESSES

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Continuation-in-part of application Ser. No. 57,865, June 12, 1970, which is a division of application Ser. No. 747,367, July 24, 1968, both now abandoned. This application Sept. 8, 1972, Ser. No. 287,271
Claims priority, application Japan, May 11, 1968, 43/31,518
Int. Cl. C23b 5/78
U.S. Cl. 204—213 18 Claims

ABSTRACT OF THE DISCLOSURE

An electroplating apparatus wherein articles to be plated are placed in a vessel and immersed in a fused salt plating bath. The vessel is the cathode and an annular anode is disposed over the articles. The vessel is intermittently rotated during the plating operation to drive the articles towards the periphery and then gather them in the center of the vessel. The vessel is pan-shaped and has protrusions and recesses in the surface thereof to provide better contact with articles to be plated, and has perforations therein to enable the fused salt bath to flow therethrough.

This is a continuation-in-part of U.S. patent application Ser. No. 57,865, filed June 12, 1970 and now abandoned, which is a division of U.S. patent application Ser. No. 747,367, filed July 24, 1968, now abandoned.

This invention relates to a plating apparatus, and more particularly to an apparatus for plating metals on a plurality of small articles simultaneously and uniformly in a fused salt plating bath.

In the electroplating of bolts, washers, nuts, fasteners or specially shaped small articles for architecture or other uses, it is often required to plate a plurality of such articles simultaneously and uniformly. A prior method, called barrel plating, comprises placing a large quantity of articles to be plated in a hexagonal or octagonal box-shaped cage and electroplating these articles with a water solution while rotating this cage. However, since a large quantity of articles confusingly placed in a cage-shaped barrel are being electroplated while said barrel is being rotated, such prior art apparatus does not permit satisfactory plating of articles in the middle of the stack of articles. Articles contact one another loosely during rotation and the higher electric resistance at least in a portion of the article, in contact with another article in a moving state does not permit the flow of enough cathodic current uniformly all over the accommodated articles. The articles plated are thus limited to these in the vicinity of the outside of the stack of articles. Articles in the middle or bottom portion of the stack are not properly plated, because they are apt to become an anode relative to those at the outside. Articles can be properly plated only when they are exposed alternately to the surface of the stack by being turned over. This hampers obtaining uniform plating.

Further, such prior art apparatus is limited to water solution electroplating. If such prior art barrel plating is applied to fused salt electroplating, the strong corrosive action of the fused salt will dissolve ground metal. Articles, for example, in the middle or bottom portion of the stack are put in the anodic state by the plating current, or previously plated metal. These phenomena degrade the quality of plating or make articles incapable of being plated.

On the other hand since it is practically impossible to treat many small articles one by one by ordinary electroplating, aluminum plating cannot be applied to small articles though this prior plating method has been known to have excellent properties such as high oxidation resistance.

Prior art devices utilizing the aqueous solution barrel plating method have been disclosed, for example, in U.S. Pat. No. 1,899,679; U.S. Pat. No. 843,321; and U.S. Pat. No. 951,662.

These prior systems have a common feature that the plating solution is agitated violently. In fused salt electroplating, however, if the fused salt bath is agitated violently, the surface thereof absorbs moisture in the air and causes decomposition of the bath, bringing about undesirable results.

Where an electrolytic cell having a circular configuration in the bottom and sides is used, as in the case of West German Pat. No. 857,880, frequent collisions occur among the articles to be plated during their movement. Such a cell cannot be used in fused salt electroplating.

The present invention is intended to improve the above prior art of electroplating, and the primary object of the present invention is to provide apparatus having a simple structure wherein a uniform distribution of cathodic current is applied to all the articles to be plated, when electroplating a considerable number of small articles, so as to make electroplating effective at all times.

A further object is to provide a plating apparatus particularly suitable for use in a fused salt plating bath, and wherein part of the electrolyte in the vicinity of the articles is periodically moved.

SUMMARY OF THE INVENTION

The present invention adopts a special pan-shaped cathodic vessel in which a predetermined quantity of small articles are accommodated. The vessel is adapted to be intermittently rotated at a circumferential speed which is sufficient to move the articles outwardly by centrifugal force. Thus, due to the revolution of the vessel, the articles are spread toward the circumferential edge of the vessel. When the vessel is at rest, the articles then roll down toward the middle portion of vessel, to form a thin layer, preferably only one layer, of articles to be plated. Thus, a constantly uniform current distribution is obtained for all small articles in the vessel, and the tendency that some portion will receive an insufficient flow of plating current because of stacks of articles, as occurs in the prior art, is substantially prevented.

Further, the present invention provides improved pan-shaped vessel structures which enable better contact between the vessel and the articles to be plated. The vessel has an irregular surface configuration, with protrusions, recesses, or the like, which provide improved contact and lower plating resistances.

As heretofore mentioned, due to strong corrosive action of fused salt electroplating, ground metal to be plated and previously plated metal are inevitably dissolved in case of the prior art barrel plating technique. This causes the degradation of the plating property, or even non-plating. According to the present invention, however, the substantially uniform distribution of current to all of the articles accommodated in the cathodic vessel effectively prevents the dissolution of the metal articles. The resulting products show good quality plating.

With the present invention, aluminum electroplating can be advantageously applied to small articles, thereby providing products having outstanding chemical and heat resistance. The prior art aluminum electroplating cannot be done effectively to small articles so that almost all aluminum plated products have not been commercialized.

The present invention can apply fused salt electroplating effectively in the above stated way without dissolution of ground metal and plated metal.

It is advantageous to provide aluminum electroplated fasteners or other small products for use in, for example, aircraft, high speed vehicles, etc. This is advantageous since such small articles would cause corrosion at the metal parts if they were not aluminized articles. The present invention can provide such products which were in fact unobtainable with the prior art plating apparatus.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a sectional view of a plating apparatus of the present invention;

FIGS. 2 and 3 partially show the states of arrangement of small articles in a vessel, FIG. 2 showing the state when the vessel is standing still and FIG. 3 showing the state when the vessel is rotating;

FIGS. 4A and 4B illustrate vessel configurations in accordance with the present invention;

FIGS. 5, 6A, 6B and 6C illustrate other vessel configurations in accordance with the present invention; and

FIGS. 7 and 8 illustrate the contact of a bolt to be plated with a prior art vessel and with a vessel of the present invention which is illustrated in FIG. 8, respectively.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. 1 generally shows an apparatus according to the present invention. A generally pan-shaped vessel **2** with a relatively shallow and gently arcuately concave bottom and open in the upper portion is mounted in a tank **1** containing plating bath **4**. Vessel **2** is only generally shown in FIG. 1. Detailed illustrations of improved vessels **2** in accordance with the present invention are shown, for example, in FIGS. 4–6. Connected to the center portion of vessel **2** is rotary shaft **3** which is secured to vessel **2** by a nut **32** and the flange seat **31** provided on the rotary shaft **3**. Cathodic current is supplied via shaft **3**. Pan-shaped vessel **2** is curved such that articles **25** contained in the interior of the vessel gather automatically at the center portion under the action of gravity and moreover are rolled or slid by centrifugal force toward circumferential edge of vessel **2** when vessel **2** is rotated at a given speed. On the opening edge **23** of vessel **2** is an annular cover **22** for checking the articles from spilling over the outer edge of vessel **2** when the vessel is rotated.

Vessel **2** is made of aluminum and is provided with perforations **21** over the surface thereof for in-flow and out-flow of a fused salt bath therethrough. Vessel **2** is coated on the backside with chemical and heat resistant synthetic resins such as polytetrafluoroethylene. The cover **22** is also formed of polytetrafluoroethylene or other material. An annular aluminum anode **10** is concentrically mounted about the rotary shaft **3** over the vessel opening **24**. The anode **10** is supported in place by support member **11** and supplied with anodic current. Tank **1** is provided at least on its inside surface with an anticorrosive layer such as a glass lining and on the top with a first cover **12** made of phenol-formaldehyde resin or polytetrafluoroethylene. From the opening portion of cover **12**, a cylinder **6** made of polytetrafluoroethylene or other anticorrosive material, having an inner diameter somewhat larger than the outer diameter of pan-shaped vessel **2** is suspended in the fused salt bath **4**. The portion of cylinder **6** which is immersed in the fused salt bath is provided with perforations **17** for passing said bath therethrough. The top opening portion of cylinder **6** is provided with a second lid **7** also made of phenol-formaldehyde resin or polytetrafluoroethylene. Through opening **7'** provided centrally in lid **7** are inserted the aforementioned rotary shaft **3** and support member **11**, as illustrated in FIG. 1.

On one side of the second lid **7** is provided another opening **8** for inserting articles which are to be plated. Around the opening **8**, it is preferable to form a gas flow curtain by jetting an inactive gas so as to stop air from intruding into the fused salt bath. Further, there is an annular floating piece **14** made of glass or other anticorrosive material which is floated on fused salt bath **4** in cylinder **6** and prevents evaporation of bath. Further evaporation preventive material **13** such as silicagel is also floated on the surface of bath **4** between cylinder **6** and tank **1** so as to cover the surface of the electroplating bath. At the bottom portion of tank **1** and also in other sections are arranged heaters **5** so as to keep the temperature of the bath as predetermined in the interior of tank.

Rotary shaft **3** is designed to be given a predetermined rotary movement by a rotary mechanism such as a motor **35** shown generally in FIG. 1. Inactive gas inlets **15** and **16** are provided respectively on lids **12** and **7**. A feeder collar or ring **26** is provided for furnishing electric current to rotary shaft **3**.

FIGS. 4–6 illustrate a number of pan-shaped electroplating vessels according to this invention which provide improved contact with the articles to be plated, thereby resulting in improved plating uniformity. FIG. 4A is a vertical sectional view of a vessel **56** according to this invention and FIG. 4B is a top plan of the same vessel. The vessel **56** has perforations **52** therethrough. Aluminum bars **51** arranged in a spiral-type configuration are fixed on the surface of vessel **56** by means of fixing members **53**. The aluminum bars **51** constitute protruding portions of the vessel structure and the spaces therebetween constitute receding portions of the vessel structure. Perforations **52** provide paths for the fused salt to pass through during operation. The bars **51** are shown in cross-section only by way of example, it being understood that they may take any other convenient shape. In a typical example, the vessel may have a diameter of 365 mm. and the round aluminum bars may have a diameter of 3 mm. Articles are plated more uniformly using the vessel of FIGS. 4A and 4B, as will become more apparent from the discussions hereinbelow with reference to FIGS. 8A and 8B.

FIG. 5 shows a modification of FIGS. 4A and 4B wherein square aluminum bars **54** are used. In this case the square bars may be of a size of 2 m. x 5 mm., for example.

FIGS. 6A and 6B show sectional and top views, respectively, of a vessel **58** provided with a plurality of generally hemispherical cavities **55** having small perforations **52** over the surface thereof. The perforations **52** are in the depressions or cavities **55**, but may be otherwise located. One typical example of the size of the cavity is 10 mm. in diameter and 5 mm. in depth, and that of the perforation is 3 mm. in diameter. In FIG. 6, reference numeral **59** denotes the protruding portions of the vessel and numeral **55** (cavity) denotes the receding portions of the vessel.

The above dimensions for FIGS. 4–6 are mere examples. They may vary depending on the types of articles to be plated and the conditions of treatment, as should now be apparent.

Various other vessel configurations may be used—the critical feature being the provision of protruding and receding portions in the surface of the vessel which contacts the articles to be plated.

In the present invention, a shallow, gently curved pan-shaped vessel having protrusions and recesses is used so that a wide contact area is provided between the vessel and articles to be plated, such as bolts, thereby permitting electric current to pass more evenly between the vessel and the articles. As shown in FIG. 7, when a pan-shaped vessel **2'** having a smooth surface is used for electroplating bolts **40** and the like, the vessel **2'** and the bolt **40** contact each other at substantially only two points. As

seen from FIG. 7, the contacting points are few in number and narrow in area. Therefore, application of an electric current causes high contact resistance between the vessel **2'** and the article **40**. As a result, (1) insufficient plating current flows from the vessel **2'** to the bolt **40**; (2) the bolt **40** has an electrical potential nearer to that of the anode than the vessel **2'** and the aluminum film earlier deposited on the surface of the bolt **40** tends to become dissolved in the fused salt again; and (3) excessively thick aluminum films tend to be deposited at contacting points between the vessel **2'** and the bolt **40**.

Thus, with the apparatus of FIG. 7, the outer diameter of the screw thread of bolt **40** tends to become too thick at the tip of the bolt where it makes contact with cathodic vessel, resulting in the production of defective bolts.

In order to obviate these defects, the present invention adopts a pan-shaped vessel as shown, for example, in FIGS. 4–6. FIGS. 8A and 8B illustrate the contact of a bolt **40** with vessels **57** and **58** of FIGS. 5 and 6, respectively. As seen from FIGS. 8A and 8B, the contact area of the bolt **40** with the vessel surface is large, thereby permitting electrical energy to flow more uniformly between the vessel and the bolt **40**.

In the present invention the articles to be placed have the portions thereof to be plated periodically changed, with the result that uniform plating all over the article is effected during the whole plating time. When the pan-shaped vessel is rotated via the rotary shaft **3** after turning off the current in the course of electrolytic operation, the articles to be plated move toward the peripheral portions of the vessel under the influence of centrifugal force. When all of the articles finish moving and are in the position shown in FIG. 3, the rotation of the rotary shaft **3** is stopped. The articles then roll down toward the center of the vessel and rest on the bottom with the projecting portions of the articles located in the receding portions of the vessel surface, and the receding portions of the articles lying on the projecting portions of the vessel (see FIG. 2), the articles being so positioned as to receive plating on new portions. Then, direct current is again applied between the anode and the vessel to continue electrolysis. Rotation of the rotary shaft **3** is repeated a plurality of times during the plating operation so as to have the entire surface of the article uniformly plated.

FIG. 2 shows the arrangement of articles to be plated when the vessel stands still during plating. FIG. 3 shows their state when they are spread by centrifugal force caused by the rotation of the vessel. The small articles **25** are shown in a collective state, but in a thin or single layer, in FIG. 2, and in a developed state in FIG. 3 just after rotation of the rotary shaft **3**. As shown in these figures, an area S or S' quite free of articles is developed at outer peripheral portion or the middle portion of vessel **2**. The repetition of these states not only rotates small articles **25** in groups but also changes their positions. While small articles such as screws or nuts transfer from the state of FIG. 2 to a developed state of FIG. 3, they roll in the vessel and are dispersed toward the periphery so as to be separated by a wider distance from each other. It is evident that the articles **25** are changed in position and coordination in the developing and gathering process, and consequently, uniform plating is obtained.

A feature of the present invention is that the pan-shaped vessels are provided with small perforations all over the surface thereof so as to shake off the fused salt in the vicinity of the articles (**21** in FIG. 1; **52** in FIGS. 4 and 5; and **52** in FIG. 6). In aluminum electro-plating by means of a fused salt bath, molecular aluminum salt ($AlCl_3$) in the bath is reduced on the surface of the article and is deposited in the form of aluminum ($Al^{+++}Al$). Therefore, there must exist in the vicinity of the article sufficient aluminum salt for aluminum depositing. According to the present invention wherein perforations are provided in the vessel, aluminum salt is newly supplied into the vessel through said perforation as the aluminum salt loses aluminum and is pushed toward the peripheral portions of the vessel by centrifugal force caued by the rotation of the vessel.

The present apparatus is also provided with a cylinder **6** in FIG. 1 having perforations **17**. This further facilitates circulation of the fused salt and also prevents the agitation action of the fused salt from reaching the surface of the bath where it touches the air. As described above, the fused salt where it is contacted with the article is moved by agitation but this movement does not reach the surface of the bath where it touches the air.

Still another feature of this invention is that the apparatus involved is of a simple structure. Since a fused salt (a mixture of $AlCl_3$, NaCl, and KCl) has strong corrosiveness against the apparatus, the plating apparatus must be of as simple construction as possible, so as to enable economical replacement of corroded parts thereof. The apparatus of the present invention clearly fulfills this object by utilizing a pan-shaped vessel which is inexpensive to fabricate and which is easily replaced.

The pan-shaped vessels **2, 56, 57, 58** serve as the container of articles **25** to be plated and at the same time as the cathode electrode. The vessels **2, 56, 57, 58** can be made of any metal of high electric conductivity. For example, for effective fused salt electroplating not only can a vessel made of aluminum as ground material be used, but also one made of a non-metal such as porcelain, glass lined with a copper net as a cathodic plate, or others can be used. The fact that the back side of such a vessel forms an insulating surface prevents useless flow of current from the bottom. To prevent a useless flow of current from rotary shaft **3** and support member **11**, the portions thereof in contact with the fused salt bath would preferably be protected with an anticorrosive coating such as polytetrafluoroethylene. Rotary shaft **3** and support member **11** can be made of glass or porcelain hollow material, the interior of which can be used as a passage of cathodic current. The annular anode is kept almost an equal distance from the surface of all articles to be plated and may be designed to stand still above the vessel.

An example of the operation of the apparatus of the present invention will now be given with reference to the basic structure of FIG. 1 using the vessel **58** of FIGS. 6A and 6B.

The fused salt contained 60 mol percent of $AlCl_3$, 25 mol percent of NaCl, and 15 mol percent of KCl. The temperature applied was 160° C. Electroplating was conducted by applying direct current between aluminum and the vessel, the aluminum former acting as the anode and the vessel acting as the cathode. Current was turned on to begin plating.

After a predetermined length of time, the current was turned off and the vessel **58** was rotated by turning the rotary shaft **3** by means of energizing the motor **35**. Rotation of the vessel **58** was stopped after all of the articles had moved and returned, and direct current was again applied between the anode and the cathode. These processes were repeated during the whole plating time. FIGS. 2 and 3 show the general positions of the articles before and just after rotating the vessel, respectively.

A movement cycle comprising a rest of 6.5 seconds and rotation of 0.5 second was used. Current for plating was 6.5 v., 100 a. Plating time was 40 minutes. The entire lot of finished products proved to be satisfactorily aluminum plated with a thickness of 15 microns.

Rotation of the rotary shaft **3** is conducted, for example, by continuously exciting the magnetic field of the DC shunt motor **35** and sending current intermittently to the armature circuit of the motor by a motor timer.

In carrying out plating, attention need be given to the following points in rotating the vessel: (1) acceleration in starting the rotation of the vessel; (2) deceleration in terminating the rotation of the vessel; (3) rotation speed of the vessel; (4) the number of revolutions of

the vessel in one rotating period and the length of time involved; and (5) the length of time during which the vessel lies stationary in each cycle of operation. These points will be determined for each case, depending upon the type of article being plated, the quantity, size of the plating apparatus, shape and configuration of plating vessel, etc.

When bolts were electroplated in accordance with the fused salt aluminum plating method by utilizing the apparatus shown in FIG. 1, with the smooth surface vessel **2**, inferior plated articles mounted to 10%. When the vessels **56**, **57**, **58** shown in FIGS. 4, 5 and 6, respectively, were utilized in the apparatus of FIG. 1 in accordance with the present invention, the result was about 2 to 3% inferior products on the average.

It should be clear that various modification can be made to the illustrated embodiments within the spirit of the present invention as defined in the accompanying claims.

What is claimed is:

1. Apparatus for electroplating articles comprising:

a tank for accommodating a plating bath;

a pan-shaped vessel having an upwardly curved, substantially horizontally extending, bottom and a wide upper opening and adapted to be immersed in said plating bath, the upward curvature of said vessel being upward from the center thereof toward the periphery thereof, the upwardly curved bottom of said vessel being adapted to retain articles to be plated thereon in a layer during the plating operation of said electroplating apparatus, and said vessel constituting the cathode of the electroplating apparatus, said curved bottom of said vessel being perforated and having an irregular surface configuration to provide more than point contact between the vessel and the articles to be plated;

a cover portion provided at the periphery of said vessel and extending inwardly and upwardly of said vessel at an acute angle with the horizontal for preventing said articles which are being plated from falling out of said vessel during operation of said electroplating apparatus;

a substantially cylindrical member surrounding at least a portion of said pan-haped vessel in said bath, said cylindrical member having a plurality of perforations therethrough for inflow and outflow of said plating bath;

means including a member extending substantially vertically into said tank and connected to said pan-shaped vessel for supporting said pan-shaped vessel completely immersed at a predetermined depth in said tank, and for imparting intermittent rotation to said pan-shaped vessel, said rotation time being short relative to the time said vessel is stationary, so as to move and spread out said articles toward the peripheral portions of said vessel to form said layer of articles;

an anode member disposed over said pan-shaped vessel; and

means for applying plating current to said anode and said cathode vessel when said vessel is stationary and for turning said plating current off when said vessel is rotating.

2. Apparatus according to claim **1** further comprising a heating means at the bottom of said tank.

3. Apparatus according to claim **1** wherein said bottom of said pan-shaped vessel is shaped and dimensioned such that articles to be plated are formed into a single layer on the bottom surface of said vessel by said intermittent rotation.

4. Apparatus according to claim **1** comprising a plurality of perforations all over the surface of said pan-shaped vessel.

5. Apparatus according to claim **1** including a plurality of protrusions on the upper surface of the bottom of said pan-shaped vessel.

6. Apparatus according to claim **1** comprising a floating member adapted to float on the surface of the bath contained in said tank and within the confines of the walls of said cylindrical member.

7. Apparatus according to claim **1** comprising a material adapted to float on the surface of the bath contained in said tank outside the confines of said cylindrical member.

8. Apparatus according to claim **1** wherein said vessel bottom is generally shaped as a portion of a sphere.

9. Apparatus according to claim **1** wherein the walls of said cylindrical member are adapted to extend above the surface of the plating bath accommodated in said tank.

10. Apparatus according to claim **1** wherein said tank is adapted to hold a fused salt plating bath.

11. Apparatus according to claim **3** wherein said anode member is an aluminum anode member.

12. Apparatus according to claim **1** wherein the curved bottom of said pan-shaped vessel has a plurality of spaced downwardly extending recesses formed therein.

13. Apparatus according to claim **12** wherein a hole is formed in the recessed portions of the bottom of said pan-shaped vessel.

14. Apparatus according to claim **1** including at least one member forming protrusions on the upper surface of the bottom of said pan-shaped vessel.

15. Apparatus according to claim **14** wherein said at least one member has a substantially circular cross-section.

16. Apparatus according to claim **14** wherein said at least one member has a substantially rectangular cross-section.

17. Apparatus according to claim **14** including a spirally formed member on the upper surface of the bottom of said pan-shaped vessel forming protrusions on said vessel.

18. Apparatus according to claim **17** comprising a plurality of perforations formed all over the surface of said pan-shaped vessel between protrusions.

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JOHN H. MACK, Primary Examiner

W. I. SOLOMON, Assistant Examiner

U.S. Cl. X.R.

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