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PROCESS OF ELECTRODEPOSITION OF METALS
BY PERIODIC REVERSE CURRENT
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Fig.1.

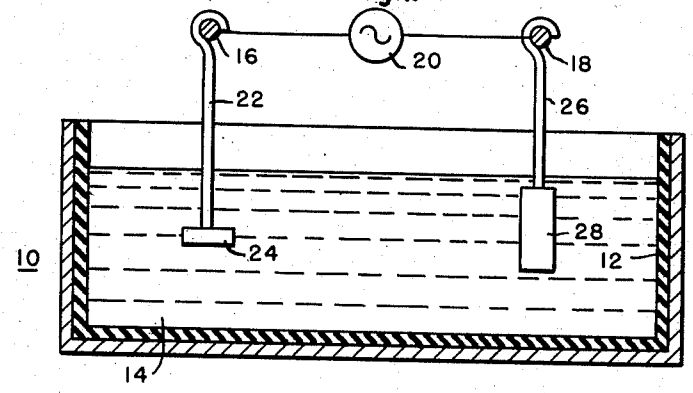



Fig.2.

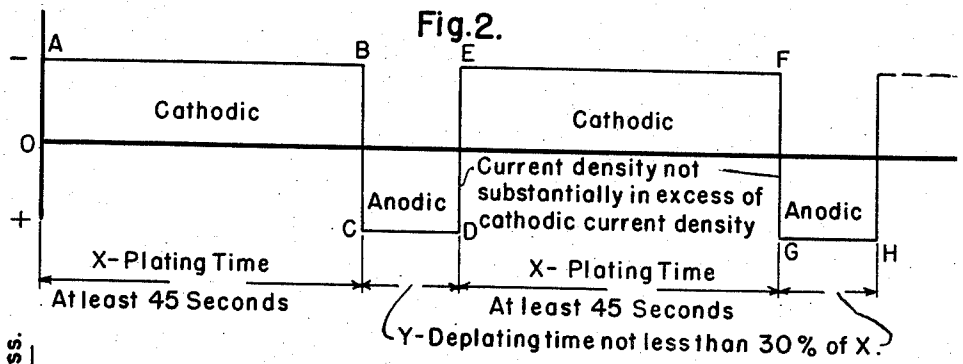
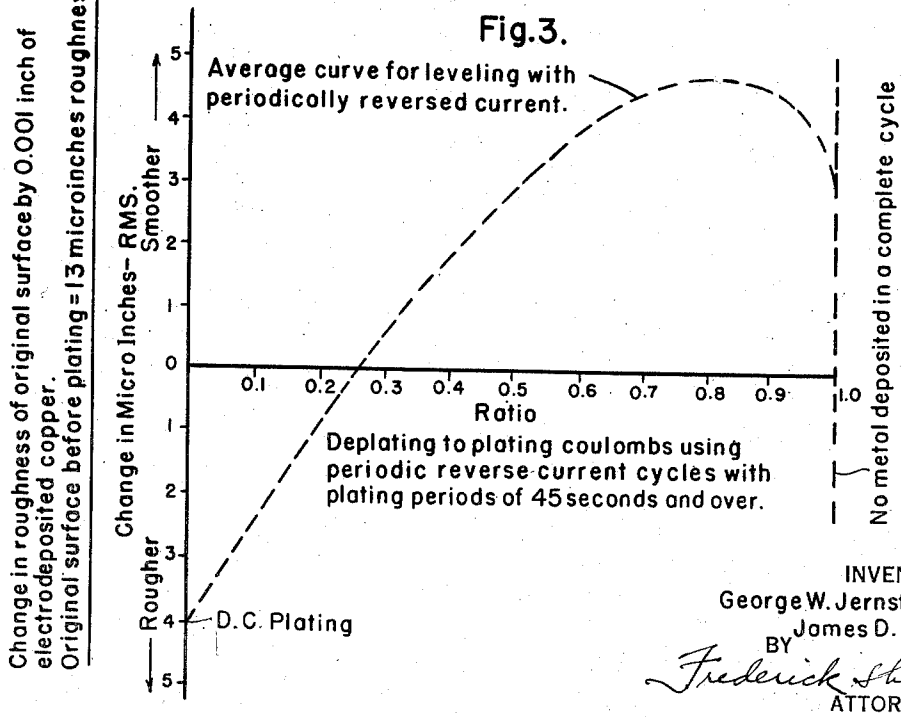



Fig.3.




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## PROCESS OF ELECTRODEPOSITION OF METALS BY PERIODIC REVERSE CURRENT

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8 Claims. (Cl. 204—41)

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This invention relates to the electrodeposition of metals by means of a periodically reversed electric current.

In electroplating metals upon base members, it is highly desirable to produce electrodeposits thereof that are as smooth as possible, and of maximum brightness. Furthermore, it is ordinarily desirable that the metal being deposited be applied upon a base member as a coating of substantially the same thickness throughout.

When electroplating with continuous direct current, it is recognized that due to current concentration phenomena dependent upon the shape of the base member in conjunction with other factors, such as concentration of ions containing the metal to be plated in the body of the solution adjacent the base member, the electrodeposits ordinarily vary greatly in thickness from point to point on a base member. This unequal building-up of the electrodeposits on various portions of the member is not only inefficient but is in many cases undesirable because it leads to an inferior product such, for example, as treeing, nodules, unacceptable roughness, as well as very thin electrodeposits, pores, and other defective plating. In order to remove excessive electrodeposits which build up on corners and sharp edges and similar places where excessive current concentrations occur, considerable manual work consisting of buffing, grinding, polishing and the like usually has been required as a necessary step in producing commercially acceptable plated work.

Many electrodeposits contain pores and other unplated flaws that extend to the base member. The protective value of electrodeposits, which otherwise would be satisfactory, may be greatly diminished because of the presence of pores and other defects. Corrosion is most readily initiated where pores occur. It is highly desirable to produce electrodeposits that completely cover the base member without pores or areas in which the electrodeposit is thinner than over the major portion of the plated member in order to secure optimum protective and decorative deposits.

It is also well known to those skilled in the art, that the electrodeposition of metals by continuous direct current must be carried out at current densities not exceeding certain limits if an acceptable quality of plate is to be secured. The plating current densities employed commercially are ordinarily maintained somewhat below these predetermined maximum permissible limits in order that the plater have a safe margin within

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which to operate. Continuous direct current plating, therefore, requires an extensive amount of equipment since the amount of work that can be plated per unit time in a given plating tank is limited by the allowable plating current density. Any increase in allowable current density that would still maintain the production of satisfactory plate proportionately reduces the number or size of plating tanks, the amount of solution in use, and related apparatus that is required.

In Patent No. 2,451,341, issued October 12, 1948, to one of the coinventors of the present invention, there is disclosed the electroplating of metals by means of a periodically reversed electrical current comprising cycles each of which is composed of a plating portion and a deplating portion. The plating portion of each cycle as disclosed in that patent does not exceed 40 seconds since under the conditions there disclosed no improvement in plating was possible if the plating period exceeded 40 seconds by any substantial amount. According to the conditions disclosed in the patent, a deplating current which would apply 10% of the coulombs applied by the plating current was adequate, and particularly good results were secured with a deplating current delivering 20% of the coulombs applied by the plating current.

It was found that deplating currents delivering more than 20% to 25% of the coulombs delivered by a plating current cycle of up to 40 seconds would not produce a benefit proportional to the excess of the metal deplated over the amount deplated by a deplating current of 25% of the coulombs of the plating current. On the other hand, deplating currents delivering in the amount of from 10% to 20% of the coulombs delivered during the plating portion of a cycle providing for plating current for 45 seconds or longer in a periodic reverse current cycle did not prove to be entirely satisfactory. At the time of discovering the unexpected advantages of reverse current plating, it was found, for example, that periodically reversed current cycles of the order of 70 seconds plating and 12 seconds deplating produced electrodeposits that were not appreciably better than continuous direct current plating, and the quality of such electrodeposits would not justify the extra equipment and plating time required to practice periodic reverse current processes to carry them out.

Following this observation of reverse current plating cycles that only produced an electrodeposit approaching that deposited by direct current plating, it is now unexpectedly discovered

that another range of cycles gives results in leveling that have never been attained in plating processes heretofore. This range of cycles which gives the unexpected results in leveling employs plating portions of 45 seconds and longer in conjunction with deplating currents of a magnitude that ordinarily one would not think of using and which will be described hereinafter. With these long time cycles, as compared to those set forth in Patent No. 2,451,341, we have produced electroplating for many purposes, superior in such properties, as levelness, to that produced previously.

The object of this invention is to provide a periodic reverse current cycle having a plating period of at least 45 seconds and a deplating period at least 30% of the time of the plating period and proportioned thereto to apply at least 30% of the coulombs delivered during the plating period.

A further object of the invention is to provide a periodically reversed current cycle having a plating period of at least 45 seconds and a deplating period during which a deplating current substantially less than the average plating current is applied to deliver at least 30% of the coulombs and up to 95% of the coulombs delivered during the plating period.

Other objects of the invention will in part be obvious and will in part appear hereinafter.

For a better understanding of the nature and objects of the invention, reference should be had to the following detailed description and drawing in which:

Figure 1 is a view in elevation, partly in section, through an electroplating setup operating in accordance with the invention;

Figure 2 is a graph plotting time against current as employed in the periodically reversed plating cycle of the present invention; and

Figure 3 is a graph plotting the change in roughness of metal surfaces against the ratio of plating to deplating coulombs provided by the periodically reversed current cycle of the present invention.

It has been discovered that many metals may be plated from aqueous electrolytes and particularly copper, silver, zinc, cadmium, tin, gold and alloys in which these metals predominate by a periodically reversed current in which the plating period is at least 45 seconds in length, and may exceed 300 seconds, and is correlated with a deplating period which is not less than 30% of the plating period and in which the average current density applied during the deplating period is not substantially in excess of the average plating current density and preferably less. The periodic reversed current cycle must be such that the deplating current delivers between 30% and 95% of the coulombs delivered by the plating current. Under these conditions, a long time cycle periodic reverse current will electrodeposit metal having a surface that is outstanding for its smoothness and levelness. In some cases, the electrodeposits made by these cycles are bright, but this is not always true. In all cases, we have obtained electrodeposits that were smoother than the metal to which they were applied. Furthermore, the uniformity of thickness of the electrodeposit is far greater than possible with either continuous direct current or with the process disclosed in Patent No. 2,451,341. Other advantages of the invention will be set forth hereinafter as it is described in detail.

The levelness and smoothness of electrodeposited metal is a critical factor. Many known plating processes cannot be carried out satisfactorily without the plated metal surfaces being buffed and polished to render the plated metal level and smooth and accordingly the cost of appling the plating is high. Due to this factor it has long been desired, but not realizable, to plate members uninterruptedly in a conveyorized process whereby the plated metal is not required to be buffed and polished. For example, according to present day practice automobile bumpers are buffed, then copper plated, the copper buffed, then nicked plated, sometimes the nickel is buffed, and finally chromium plated. Due to the interrupted processing and the manual buffing operations the plating of bumpers is relatively expensive. By comparison, by the practice of the present invention, formed steel bumpers may be periodically reversed current plated with a thickness of about 0.001 inch copper which is so level and smooth, far smoother than the steel base metal, that nickel and chromium may be immediately applied thereto, without any buffing, and the quality of the plated metal will be comparable to that of the best previous process involving buffing, but will cost far less. This entire process can be carried out in a single uninterrupted conveyorized operation.



Referring to Figure 1 of the drawing, there is shown an electroplating tank 10 provided with a chemically resistant liner 12 in which is located the electrolyte 14 of a suitable composition to electroplate the desired metal. The conductor bars 16 and 18 are each provided with current from the source 20 of periodically reversed current meeting the requirements herein set forth. The source 20 of periodic reversed current may be a direct current source, such as a battery. generator, or rectifier combined with suitable relays, reversing switches and resistances controlled by a timing mechanism to reverse the current at predetermined times and vary its value in accordance with the requirements of the invention. In other cases, other suitable mechanisms may be devised to produce the desired current cycle. The cycle may be secured by simply reversing the flow of current from a direct current source, or the flow of current from separate direct current sources may be alternated, one plating the member for 45 seconds or more and the other deplating the metal. The conductor bar 16 carries a hanger 22 on which there is supported a member 24 to be electroplated. The hanger 26 supported by the conductor bar 18 carries a suitable anode electrode 28, usually of the metal being plated.

Referring to Figure 2 of the drawing, there is illustrated the periodically reversed current cycle of the present invention. Assuming that the cycle starts at the point O, the plating period starts with the application of plating or cathodic current of the value A being applied to the member 24 to plate metal thereon. The plating current continues for a period of time X of at least 45 seconds to the point B. Then, the direction of flow of current is reversed so that the current passes through zero current value and reaches a value C thereby metal is deplated from the member 24. The average current density at C should not be substantially in excess of the average cathodic or plating current density during the interval X. Our experience is that good results occur if the average deplating current density does not exceed about 110% of the plating current density. The deplating period Y is not less

than 30% of the plating period X. When the deplating period terminates at D, the direction of flow of the current is again reversed to pass through zero current and then becomes a plating current with a value E. The cycle is repeated with a plating period of from E to F plating metal on the member, and then another reversal of direction of flow of the electrical current to a second deplating period from G to H, etc. During the cathodic or plating period, a metal is plated upon the member **24**, the amount of metal being plated being proportioned to the current and the time X as is well known. During the anodic or deplating period, the previously plated increment of metal on the member **24** is deplated in proportion to the anodic current and the time Y. This leaves a net increment of metal which is much smoother, more level, and freer from imperfections than the original increment plated during the cathodic period A to B. The plating of a second increment E to F upon this net increment is benefited by the previous deposit of the deplated increment of metal and in general the metal plated during the increment E to F will be somewhat superior to the increment plated during the period A to B. Upon deplating a part of the plated increment deposited in period E to F, we find that the net result is a still further improvement in the quality of the deposit. The application of additional cycles of periodic reverse current to the member will produce an increasingly improved total electrodeposit, though the improvement in a net plated increment produced by the last cycle over the preceding cycle may be somewhat less than that produced in the second cycle over the first cycle. This improved total metal deposit is secured with as little as three or four periodic reverse current cycles. Ordinarily, however, the periodic reverse current is applied for prolonged periods of time, whereby as many as 100 or more periodic reverse current cycles have been applied. Very heavy total deposits of more than 0.005 inch of metal have shown unusual smoothness and uniformity.

While the applied current during the cathodic or plating period is shown as a relatively constant current AB, in practice the current density does vary to some extent throughout the entire plating period. In some cases the current density decreases slowly throughout the entire time X so that the current at B is considerably less than the current at A. In other cases, the current may be rippled or irregular as is the case when alternating current is rectified. In any event the average current density during the cathodic or plating period X is considered in determining the average current density to be applied during the deplating period Y. Also, while the application of current from O to A and its reversal from B to C, etc., is illustrated as being effected substantially instantaneously, it is known that this is not the case, but that a finite period of time is required to effect changes in the direction and amount of flow of electrical current.

It has been found that the optimum results are obtained when the anodic or deplating current is of such a value that the current density on the member is from 50% to 90% of the current density applied by the cathodic or plating current A to B. In some cases the deplating current may even be less than 50% of the current density of the plating current. However, any reduction below 50% of the plating current density entails such a prolongation of the total plating time that it ordinarily is not economical and would not be employed commercially, although it is usable. Thus, for example, the deplating current density may be 35% of the plating current density.

For an illustration of the benefits secured by the practice of the present invention, reference should be had to Figure 3 of the drawing wherein there is plotted a curve of the change in roughness of a series of panels having an original roughness of 13 microinches root-mean-square (R. M. S.) by applying thereto an electrodeposit comprising 0.001 inch of copper. The copper was electrodeposited by periodic reverse cycles each having a plating period of over 45 seconds, and the ratio of coulombs of deplating current to the plating current coulombs were varied as indicated in the abscissa. The deplating current density did not exceed the plating current density. All of these panels were plated from a copper cyanide electrolyte of identical composition under comparable conditions of plating current densities. A panel plated with direct current, corresponding to the lowermost point at the left-hand end of the curve, was 4 microinches rougher than the original panel. As the periodic reverse current was applied with increasing ratio of deplating coulombs to plating coulombs, the roughness of the electrodeposited copper approached that of the base metal and, finally, at approximately a 0.25 ratio of deplating to plating coulombs, the electrodeposit was of the same roughness as the original metal surface. Thereafter, with ratios of deplating to plating coulombs of greater than 0.25 the copper that we electrodeposited became smoother and more level than the base metal upon which it was applied. A peak of improved smoothness and levelness was secured at a ratio of approximately 0.8. The curve illustrated is the result of a great many cycles, including cycles having plating periods of 45 seconds, 60 seconds, 90 seconds, 100 seconds, 142 seconds and 300 seconds. In all cases the points were relatively close to the curve shown. The best leveling appeared to be secured with cycles having a plating period of approximately 90 seconds for all ratios of deplating to plating coulombs. It is evident from the curve of Fig. 3 that an improvement in leveling of at least 25%, that is 3.25 microinches or better, is obtained over most of the effective range of ratios, that is from about 0.5 to 1.

Exceptionally good results have been secured by plating metals with periodically reversed current cycles in which the deplating current delivered from 50% to 80% of the coulombs delivered by the plating current.

While it may appear that it is inefficient and wasteful of previously plated metal to employ a deplating current of such a magnitude that it deplates 80% or more of the previously plated metal, it has been found that such cycles are practical and commercially usable inasmuch as the net metal so electrodeposited is of such extraordinary smoothness, levelness, and uniformity of thickness that no buffing, grinding or other manual after-treatment of the electrodeposit is required. It has been found that manual labor for such buffing operations usually constitutes the most expensive portion of providing members with electroplated coatings. Furthermore, the electroplating may be carried out at such a high current density as compared to permissible direct

current plating densities that the total plating time required in accordance with the practice of this invention to produce a deposit of a given thickness is, in many cases, less than that possible with previous optimum continuous direct current plating. In some cases, the total plating time with the present process to produce a given thickness of plated metal may exceed the total plating time required with continuous direct current process but the improved quality of the deposit by the former process justifies such increase in the plating time.

The following examples illustrate the practice of the invention:

*Example I*

An aqueous cyanide electrolyte of the following composition was prepared:

| | |
|---|---|
| Copper (as a metal) | 8 ounces per gallon. |
| Potassium hydroxide | 4 ounces per gallon. |
| Free potassium cyanide | 1 ounce per gallon. |
| Zinc oxide | Sufficient to provide 0.1 ounce per gallon of zinc. |
| Metal thiocyanate | To provide 0.5 ounce per gallon of thiocyanate ($CNS^-$). |

Copper was electroplated from this electrolyte using the following periodic reverse current cycles:

| Plating Period | | Deplating Period | | Total Plating Time, Minutes | Improvement in Roughness, Reduction in Microinches |
|---|---|---|---|---|---|
| Sec. | Amp./sq. ft. | Sec. | Amp./sq. ft. | | |
| 90 | 70 | 90 | 45 | 30 | + 5 |
| 90 | 70 | 120 | 33 | 30 | + 6.5 |
| 100 | 70 | 75 | 60 | 40 | +15 |

The best results in practicing the invention have been secured in plating copper with electrolytes containing both zinc and thiocyanate as addition agents. The zinc must be maintained in the amount of from 0.0038 to 0.57 ounce per gallon, and from 0.1 to 10 ounces of thiocyanate ($CNS^-$) should be present per gallon of electrolyte. The optimum proportions in cyanide-copper electrolytes have been zinc in the amount of from 0.005 to 0.2 ounce per gallon and thiocyanate from 0.5 to 2.0 ounces per gallon of the electrolyte. However, the periodic reverse current cycle of the present invention may be applied to conventional electrolytes containing no addition agent or electrolytes in which conventional addition agents are present. It has been our experience that for best results organic addition agents should be omitted from electrolytes to be plated by means of the present long time cycle periodic reverse current. In the presence of many organic addition agents blackening of the metal surfaces may occur, and we prefer to omit any organic addition agent whatever. The cyanide and thiocyanate are regarded as being inorganic in nature.

*Example II*

An acid copper electrolyte of the following composition was prepared:

| | Ounces per gallon |
|---|---|
| Copper sulphate | 27 |
| Sulphuric acid | 6.5 |

The electrolyte was maintained at room temperature, about 70° F. to 75° F. Copper was plated from the electrolyte by applying the following periodic reverse current cycle:

| Plating Period | | Deplating Period | |
|---|---|---|---|
| Seconds | Amp./sq. ft. | Seconds | Amp./sq. ft. |
| 95 | 60 | 60 | 50 |

Copper was electrodeposited on members for 30 minutes using the cycle. A substantially smooth and level deposit was produced in each case. The improvement in smoothness of the copper over the base metal was more than 5½ microinches. For comparison, copper was electroplated from the same electrolyte using continuous direct current at a density of 23 amperes per square foot for one sample and 42 amperes per square foot for a second sample, each being plated for 30 minutes. On the first sample, the roughness of the copper deposit was 25 microinches on a base member that had an original roughness of 15 microinches, that is, there was a net increase in roughness of 10 microinches. In the second sample, the increase in surface roughness of the plated copper was approximately 13 microinches to a value of 30 microinches on a base member that had an original surface roughness of 17 microinches.

*Example III*

A zinc electrolyte was prepared as follows:

| | Ounces per gallon |
|---|---|
| Zinc | 8.9 |
| Sodium hydroxide | 8.8 |
| Sodium cyanide (total) | 24 |

Zinc was plated from the electrolyte using various periodic reverse current cycles in accordance with the invention, and smooth plating of less roughness than the original base was deposited.

By comparison zinc was plated by continuous direct current from the same electrolyte at a current density of 5 amperes per square foot for 30 minutes, and on a base member having an original surface roughness of 13 microinches, the zinc deposited had a surface roughness of 29½ microinches or an increase in roughness of 16½ microinches.

*Example IV*

A periodic reverse current having a plating period of 90 seconds and a deplating period of 60 seconds is applied to the following electrolyte for plating brass:

| | Grams per liter |
|---|---|
| Copper cyanide | 30 |
| Zinc cyanide | 9.5 |
| Sodium cyanide | 56 |

Extremely smooth and level brass electrodeposits were secured. The deposits were approximately 4 microinches smoother than the original base metal.

*Example V*

Cadmium is plated from the following electrolyte:

| | Ounces per gallon |
|---|---|
| Cadmium oxide | 3.5 |
| Sodium cyanide | 14.5 |

Cadmium is plated from the electrolyte using a periodically reversed current of 60 seconds plating period and at a current density of 50 amperes per square foot and a deplating period of 30 sec-

onds at a current density of 40 amperes per square foot. Smooth, bright coatings of cadmium are produced.

*Example VI*

A silver electrolyte is prepared as follows:

| | Grams per liter |
|---|---|
| Silver cyanide | 40 |
| Potassium cyanide | 62 |
| Free potassium cyanide | 40 |
| Potassium carbonate | 50 |
| Potassium hydroxide | 10 |

A periodic reverse current having a plating period of 90 seconds at an average current density of 15 amperes per square foot and a deplating period of 60 seconds at an average current density of 12 amperes per square foot is employed to electrodeposit smooth, level deposits of silver.

*Example VII*

An aqueous gold plating solution is prepared containing:

| | Ounces per gallon |
|---|---|
| Gold | 0.5 |
| Free potassium cyanide | 0.4 |

Gold is electroplated therefrom using a periodic reverse current of 72 seconds plating at a current density of 10 amperes per square foot and a deplating period of 40 seconds at a current density of 5 amperes per square foot. Smooth, level deposits of uniform thickness are obtained.

It has been found that the electrodeposition of metals using the longer current cycles as disclosed herein requires a relative movement of the electrolyte to the surface of the member. The reason for this is that due to the relatively long deplating time in each periodically reversed current cycle of the present invention there may occur a local depletion of ions that should be present adjacent the member to react with the metal being deplated to cause effective deplating thereof. Under conditions of local ion depletion, oxides tend to be produced on the surface of the member while it is being deplated. Such oxides have an inhibiting and detrimental effect upon the entire plating process. To prevent such effects it is desirable to cause a relative motion between the electrolyte and the member being plated of an amount of at least 1 foot a minute to provide a continuous supply of ions to the surface of the member. Such relative motion may be secured by pumping the electrolyte around the member being plated or by vigorously stirring or agitating the electrolyte so that it circulates to the required extent. With moving conveyor systems, the movement of the member being plated will be adequate if of the value of one foot a minute or more.

Sheet metal and wire may be plated satisfactorily by the periodically reversed current cycle of the invention while being moved through the electrolyte at a speed of above 1 foot per minute. It will be understood that commercially the electrolytes will be agitated at a much greater velocity in order to secure optimum results. We have obtained excellent electroplating on automobile bumpers and hardware by blowing air through the electrolyte at such a rate that the velocity of the electrolyte is above 10 feet per minute over the surface of the member being plated. Extremely smooth and uniform electrodeposits have been secured under these conditions. We have checked the thickness of electrodeposited copper on large automobile bumpers and have found the copper to vary less than 10% over the entire portion of the bumper. With direct current plating, similar copper electrodeposits have varied at least 2:1 in thickness.



It will be appreciated that the electrolytes in the above examples are exemplary and not exhaustive. In general, it may be stated that any electrolyte from which the given metal may be plated by continuous direct current may have applied to it periodic reverse current in accordance with this invention and improved plating obtained. Various electrolytes from which brasses, bronzes, gold-copper, and other alloys may be plated are known and may be employed.

The preparation of the base members to be plated with periodic reverse current should be such as to produce a chemically clean surface as is conventional in order to secure the desired adherence of the metal to the base member. The preparation of the base member, therefore, may include brushing, grinding, sandblasting, shot blasting, degreasing, electrolytic cleaning and the like. Various types of base members may be plated. Metallic bodies on which metal may be plated from conventional electrolytes may be electroplated by periodic reverse current. Carbon and graphite forms may be electroplated. Electrotypes and electroforming base members consisting of wax or resinous patterns plated or coated with powdered graphite or precipitated silver may be electroplated as disclosed herein and the electrodeposited metal stripped therefrom. It will be found that electrotypes, molds and other electroformed members produced in accordance with the present invention will give a superior reproduction of the surface.

The electrodeposits produced by the use of periodic reverse current in accordance with the present invention may be plated subsequently with one or more other metals applied with similar periodic reverse current or by any other desirable process such as by continuous direct current. It is not necessary to use the same reverse current cycle in plating, but plating may be initiated with one cycle, then another employed, or the cycle may be changed a number of times to secure the same desired effect. In many cases it has been found that the outstanding smoothness of the electrodeposits of the present invention enables the plating of subsequent metals even by continuous direct current or other conventional process to great advantage since the smoothness of the surface beneficially affects the subsequent plating which is equally smooth. Thus, we have been able to plate one layer of metal in accordance with the periodic reverse current process set forth and thereafter plate thereon nickel and chromium by direct current, and the nickel and chromium were so bright that no buffing was required. The periodic reverse current produces metal deposits that are so homogeneous and free from pores and other flaws that they possess an improved corrosion resistance for a given thickness over the same metal applied by continuous direct current.

It is intended that all the matter contained in the above description shall be deemed to be illustrative and not limited.

We claim as our invention:

1. In the process of electroplating copper on a relatively rough surface of an electrically conducting member, the steps comprising placing the member and an anode in contact with an alkaline copper electroplating electrolyte, passing through the member, the electrolyte and the

anode a plurality of cycles of periodically reversed current, each cycle consisting of essentially, first, a plating electrical current applied for a period of time of from 45 to 300 seconds to plate copper from the electrolyte on the member and, second, a deplating current applied for a period of time of at least 30% of the plating current period, the average deplating current density on the surface of the member being from 50% to 90% of the average plating current density, and the coulombs delivered during the deplating portion of the cycle being from 30% to 95% of the coulombs delivered during the plating portion of the cycle whereby a substantial portion of the metal plated during the previous plating portion of the cycle is deplated, and causing a relative movement of the member to the electrolyte of at least one foot a minute, the applied plurality of cycles of periodically reversed current producing a smooth level deposit of plated copper that has a progressive decrease in roughness of at least 25% of the surface roughness per 0.001 inch of copper plated, with areas near the edges having closely the same thickness of copper as areas removed from the edges of the member.

2. The process of claim 1 wherein the electrolyte is an alkaline copper cyanide electrolyte containing from 0.0038 to 0.57 ounce per gallon of zinc.

3. The process of claim 1 wherein the electrolyte is an alkaline copper cyanide electrolyte containing from 0.0038 to 0.57 ounce per gallon of zinc, and from 0.1 to 10 ounces per gallon of thiocyanate.

4. In the process of electroplating successive deposits of copper and nickel on an electrically conducting member having a surface of a roughness of about from 13 to 17 microinches R. M. S., the applied deposits being commercially acceptable as to smoothness and levelness, without any polishing or buffing being applied to either of the plated deposits, the steps comprising, first, plating copper on the member from a copper cyanide electrolyte by placing the member and an anode in contact with the electrolyte, passing through the member, the electrolyte and the anode a plurality of cycles of periodically reversed current, each cycle consisting of essentially, first, a plating electrical current applied for a period of time of from 45 to 300 seconds to plate copper from the electrolyte on the member and, second, a deplating current applied for a period of time of at least 30% of the plating current period, the average deplating current density on the surface of the member being from 50% to 90% of the average plating current density, and the coulombs delivered during the deplating portion of the cycle being from 30% to 95% of the coulombs delivered during the plating portion of the cycle whereby a substantial portion of the metal plated during the previous plating portion of the cycle is deplated, and passing air through the electrolyte to cause a relative movement of the electrolyte to the member of at least one foot a minute, the cycles of periodically reversed current being continued until a deposit of copper of the order of 0.001 inch has been plated, the thickness of the plated copper being substantially the same over the entire surface plated, and, second, plating a predetermined thickness of nickel over the copper, the plated copper having a surface roughness of at least 25% less than the original roughness whereby the subsequently applied nickel is smooth.

5. In the process of electroplating on an electrically conducting member a metal from the group consisting of copper, silver zinc, cadmium, tin, gold and brass, from an electroplating electrolyte thereof, the surface of the member being plated having a roughness of about from 13 to 17 microinches R. M. S., the steps comprising placing the member and an anode in contact with the electrolyte and passing in series through the member, the electrolyte and the anode a plurality of cycles of periodically reversed current, each cycle consisting of essentialy, first, a plating electrical current for a period of time of from 45 seconds to 300 seconds to plate metal from the electrolyte on the member and, second, a deplating electrical current for a period of time of at least 30% of the plating period, the average deplating current density on the member not exceeding 90% of the average plating current density, and the coulombs delivered by the deplating current being between 30% and 95% of the coulombs delivered during the plating portion of the cycle whereby a substantial portion of the previously plated metal is deplated, and passing air through the electrolyte to cause a movement of the electrolyte and the member relative to one another at a rate of at least one foot a minute, the applied plurality of cycles of periodically reversed current producing a deposit of plated metal at least 25% less rough than the surface of the member for a 0.001 inch of metal plated, the plated metal being of a closely uniform thickness over the entire surface plated.

6. In the process of electroplating on an electrically conducting member a metal from the group consisting of copper, silver, zinc, cadmium, tin, gold and brass, from an electroplating electrolyte thereof, the surface of the member being plated having a roughness of about from 13 to 17 microinches R. M. S., the steps comprising placing the member and an anode in contact with the electrolyte and passing in series through the member, the electrolyte and the anode a plurality of cycles of periodically reversed current, each cycle consisting of essentially, first, a plating electrical current for a period of time of at least 45 seconds to plate metal from the electrolyte on the member and, second, a deplating electrical current for a period of time of at least 30% of the plating period, the average deplating current density on the member being from 50% to 90% of the average plating current density, and the coulombs delivered by the deplating current being between 30% and 95% of the coulombs delivered during the plating portion of the cycle whereby a substantial portion of the previously plated metal is deplated, and causing a relative movement of the electrolyte and the member relative to one another at a rate of at least one foot a minute, the applied plurality of cycles of periodically reversed current producing a deposit of plated metal of a roughness of at least 25% less rough than the surface of the member for a 0.001 inch of metal plated, the plated metal being of a closely uniform thickness over the entire surface plated.

7. In the process of electroplating on an electrically conducting surface of a member a metal from the group consisting of copper, silver, zinc, cadmium, tin, gold and brass, from an alkaline electroplating electrolyte thereof, the surface being of a roughness of about from 13 to 17 microinches R. M. S., the steps comprising placing the member and an anode in contact with the electrolyte and passing in series through the mem-

ber, the electrolyte and the anode a plurality of cycles of periodically reversed current, each cycle consisting of essentially, first, a plating electrical current for a period of time from 45 to 300 seconds to plate metal from the electrolyte on the member and, second, a deplating electrical current for a period of time of at least 30% of the plating period, the average deplating current density on the member not exceeding 90% of the average plating current density, and the coulombs delivered by the deplating current being between 30% and 95% of the coulombs delivered during the plating portion of the cycle whereby a substantial portion of the previously plated metal is deplated, and passing air through the electrolyte to cause a movement of the electrolyte and the member relative to one another at a rate of at least one foot a minute, the applied plurality of cycles of periodically reversed current producing on the member a deposit of plated metal substantially of a roughness of at least 25% less than the surface of the member on which it is plated for a 0.001 inch of metal plated, the plated metal having a desired thickness over the entire surface plated.

8. In the process of electroplating on a relatively rough surface of an electrically conducting member a metal from the group consisting of copper, silver, zinc, cadmium, tin, gold and brass, from an alkaline electroplating electrolyte thereof, the steps comprising placing the member and an anode in contact with the electrolyte and passing in series through the member, the electrolyte



and the anode a plurality of cycles of periodically reversed current, each cycle consisting of essentially, first, a plating electrical current for a period of time from 45 seconds to 300 seconds to plate metal from the electrolyte on the member and, second, a deplating electrical current for a period of time of at least 30% of the plating period, the average deplating current density on the member being between 50% and 90% of the average plating current density, and the coulombs delivered by the deplating current being between 30% and 95% of the coulombs delivered during the plating portion of the cycle whereby a substantial portion of the previously plated metal is deplated, and causing a movement of the electrolyte and the member relative to one another at a rate of at least one foot a minute, the applied plurality of cycles of periodically reversed current producing on the member a deposit of plated metal at least 25% less rough than the surface of the member to which it is applied for a 0.001 inch of metal plated, the plated metal being of a closely uniform thickness over the entire surface plated.

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