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METHOD FOR PLATING BY CONDENSER DISCHARGE

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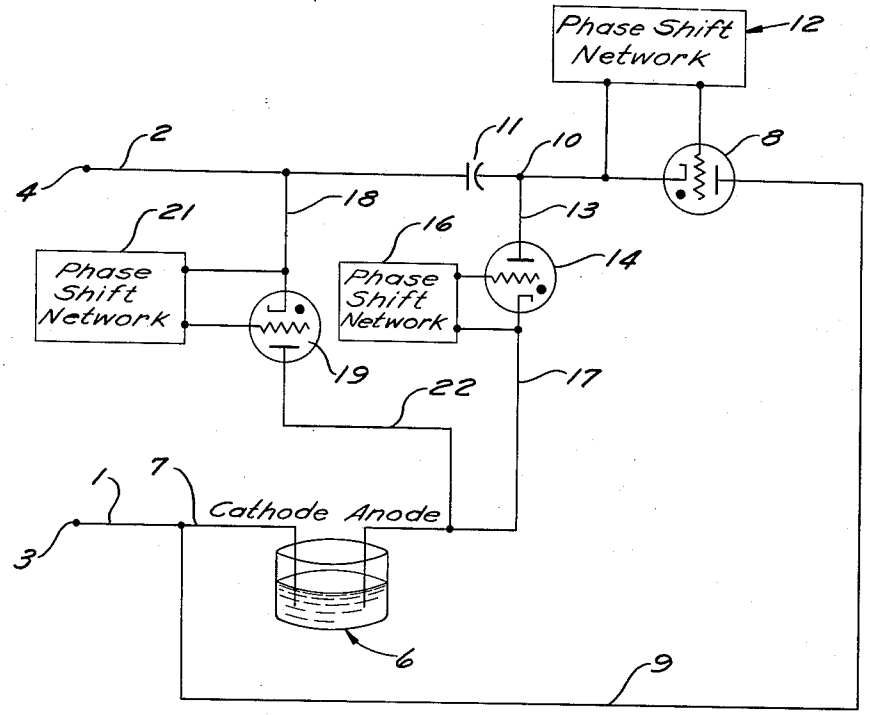


fig. 1

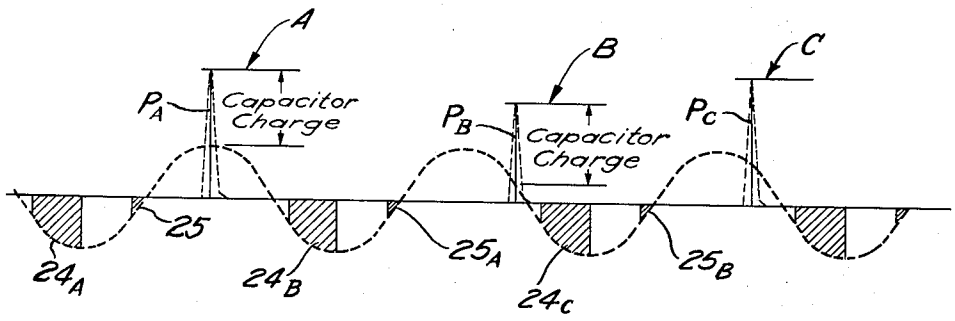


fig. 2

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METHOD FOR PLATING BY CONDENSER DISCHARGE

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6 Claims. (Cl. 204—50)

This invention relates to a method for supplying electrical energy to plating electrodes and relates particularly to a method involving repeatedly and alternately charging a capacitor and discharging same between said plating electrodes.

This application is a continuation-in-part of my application Serial No. 319,759, filed November 10, 1952 and entitled: Plating by Condenser Discharge.

As shown in my application entitled "High Voltage Electro-plating Means," Serial No. 302,669, now abandoned, I have found that many advantages can be obtained in electro-plating by using high voltage pulses which are spaced apart by a predetermined interval of time. The high voltage involved in said pulses effects high peak densities and thus effects a more tightly adhering and generally better grade of plating and the spacing apart of said pulses results in the average voltage and average currents remaining about the same as presently used in conventional practice.

Further, the use of high voltage and high current density pulses gives a better "throwing power" in the plating equipment and thus effects a more even plating regardless of the uneven spacing between the anode and cathode which may occur due to an irregular shape in the item being plated.

With low voltage plating, the resistance of the plating bath has a material effect on the quantity of current flowing therethrough. Inasmuch as the resistance of the plating bath is proportional to the distance between the electrodes, irregularities in the shape of the item being plated, will effect differences between anode and cathode for different parts of the item being plated and it will thereby often in conventional practice result in an uneven plating on such irregular items. However, as the voltage source for the plating bath increases, this resistance becomes less of a controlling factor. Where the voltage pulses rise as high as from about 200 volts to about 300 volts at their peaks, this resistance variance between the anode and various parts of the item being plated becomes a minor factor and the current density to all portions of the work remains substantially the same.

Thus, a major object of the invention is to provide a method adaptable to electro-plating practice for attaining maximum voltage peaks while holding the average voltage and currents within magnitudes known to conventional practice, and doing so by creating pulses of relatively high current density but of short duration.

A further object of the invention is to provide a method for effecting spaced uni-directional pulses through a plating bath wherein the magnitude of said pulses, the duration of said pulses and the intervals between said pulses are all subject to precise and accurate control.

A further object of the invention is to provide a method for charging a capacitor on one half cycle of an alternating supply and discharging said capacitor through the plating bath.

A further object of the invention is to provide a method for charging a capacitor one half cycle of an alternating supply and discharging said capacitor through the plating bath during an opposite half cycle of said alternating supply.

Other objects and purposes of the invention will be apparent to persons acquainted with methods of this general sort upon a reading of the specification and inspection of the accompanying drawings.

In the drawings:

Figure 1 shows a circuit diagram of one embodiment of apparatus capable of practicing the invention.

Figure 2 illustrates the sequence of events during operation of the apparatus.

GENERAL DESCRIPTION

In general, my method comprises charging a capacitor on one half cycle emanating from an alternating current supply and then permitting said capacitor to discharge through the plating bath on the other half cycle from said alternating supply. Various control means may be supplied in a specific circuit for controlling both the magnitude and spacing of the pulses supplied by the successive capacitor discharges.

While the specific embodiments of the method which have actually been practiced have all been based on a 60 cycle alternating source, no reason is apparent why this method would not function equally well on other sources of other frequencies, such as 25 cycles or at such higher frequencies as 400 to 600 cycles, and such use should be recognized as within the scope of the invention.

DETAILED DESCRIPTION

While the subject matter of the present invention is a method, and a method which may be practiced by a variety of different kinds of apparatus, it is believed that the method will be best understood with reference to a specific item of apparatus adaptable for carrying out said method and accordingly reference will not be directed toward such apparatus and the method will be described in terms thereof.

Turning now to Figure 1 of the drawing, supply conductors 1 and 2 are connected to terminals 3 and 4 of any convenient alternating source, such as 230 volts at 60 cycles. The supply conductor 1 is connected by the conductor 7 to the cathode of the plating assembly 6 and by the conductor 9 to the anode of a condenser charging tube 8. The cathode of said condenser charging tube 8 is connected to one side of the capacitor 11 the other side of which is connected to the supply conductor 2. The grid of the condenser charging tube 8 is connected to the cathode thereof through any convenient phase shift network 12, such as that shown in my application Serial No. 302,669. A conductor 13 connects a point 10 between the capacitor 11 and the cathode of the condenser charging tube 8 to the anode of the discharge pulse tube 14. The grid of said discharge pulse tube 14 is connected to the cathode thereof through another phase shift network 16 which may also be of the form shown in my application Serial No. 302,669. The cathode of said discharge pulse tube 14 is connected by the conductor 17 to the anode of the plating assembly 6.

A further conductor 18 connects the other side of the capacitor 11, that is, the side opposite that connected to the conductor 13, to the cathode of a negative stripping pulse tube 19. The grid of said last-named tube is connected to the cathode thereof through a phase shift network 21 which may be of the form shown in my application Serial No. 302,669. The anode of said negative

stripping pulse tube **19** is connected by the conductor **22** also to the anode of the plating assembly **6**. It will be apparent hereinafter that the circuit including the negative stripping pulse tube **19** is alternative and, while advantageous, is not essential to the operation of the basic circuit.

All of the tubes herein utilized are gas filled tubes, such as thyratrons or ignitrons. For reasons which will be apparent as the description proceeds, vacuum tubes cannot be used in the particular circuits shown.

OPERATION

With the condenser charging tube conductive, it will be seen that a negative pulse, that is, the lower half-cycle as shown in Figure 2, will charge the capacitor **11** to a positive value at the side adjacent the cathode of said tube. Actuation of the phase shift network **12** will delay the conductivity of tube **8** and thereby limit the total charge on the capacitor. Inasmuch as said capacitor **11** will only charge up to the peak voltage of the pulse, the charge thereon with a small amount of delay in the phase shift circuit **12** will be as indicated by the shaded areas **24** in Figure 2. The resistances in the circuit, particularly within the tube **8** and in the conductor **9**, will limit the time constant for charging capacitor **11** and the phase shift provided by the phase shift network **12** will control the energy allowed for charging within the time limit.

With the capacitor **11** charged, the discharge thereof will be permitted to take place in the half-cycle indicated by the upper portions of the curve shown in Figure 2 in response to the firing of the discharge pulse tube **14**. Anode voltage for the firing of said tube **14** is provided both by said capacitor and by the reverse pulse between the terminals **3** and **4**, and the tube **14** becomes conductive as soon as it is so permitted by the phase shift network **16**. Since the circuit between the terminals **3** and **4** is in series with the capacitor **11**, the voltage passing through the discharge pulse tube **14**, and thereby through the plating bath, will be the sum of the charge on said capacitor and the voltage between said terminals. This condition is illustrated in Figure 2 wherein the line "A" indicates the voltage passed through the plating bath when the discharge pulse tube is caused to fire substantially coincidentally with the peak of the positive pulse and the line "B" illustrates the voltage passed through the plating bath when the said tube **14** is caused to fire at a point near the end of the positive pulse. In this way, the voltage applied to the plating bath may be varied merely by varying the phase shift network **16** and without the necessity of altering the capacitor **11** or other parts of the circuit. Thus, in Figure 2, the negative pulse **24***a* stores energy for discharge through the bath in a pulse P_A, said pulse occurring substantially at the peak of the sine wave and, being added to the voltage of the peak of the sine wave, makes a total voltage of the pulse indicated by the line A. Similarly, the portion of the negative pulse indicated by the shaded portion **24***b* stores energy which appears in pulse P_B, but here, since the stored energy is added to a lower portion of the sine wave, the total value of the pulse is indicated by the line B and is somewhat less than that of pulse P_A. The shaded portion **24***c* of the next negative pulse stores energy which appears in pulse P_C, whose total value is intermediate that of the pulses P_A and P_B.

As the discharge pulse tube **14** becomes conductive, the capacitor **11**, which had been previously positive on the side adjacent the anode of said tube **14**, now becomes negative. As soon as the anode of said tube **14** is rendered negative, it is extinguished and the pulse through the plating bath is terminated.

The phase shift network **16** is so adjusted that the discharge pulse tube **14** will not fire earlier than a point at or near the peak of the positive wave form in order that the anode voltage supplied to the tube **14** will be steadily decreasing, or at least not materially increasing, after the initial firing of said tube in order that the tube will remain extinguished after the said pulse as above described has passed therethrough.

The negative stripping pulse tube is provided with a third phase shift network **21** for permitting a brief pulse to pass through the plating bath at a selected portion in negative half-cycle. The phase shift network **21** is preferably so adjusted that it will permit the tube **19** to pass a pulse through the plating bath at the extreme end of the negative pulse as indicated by the shaded portions **25** in Figure 2 and it will thereby provide a brief negative stripping pulse to pass through the plating bath immediately following each of the positive plating pulses. It will be noted that the position of the circuit including the negative stripping pulse tube **19** bears such relation to the capacitor **11** that it will not affect the charging of said capacitor even though the said tube **19** is conductive during the same half-cycle as that during which tube **8** is conductive. This current reversing function is described in more detail in application Serial No. 302,669 but, briefly, its purpose is to remove the gases tending to form on the cathode after each plating pulse and thereby keep the work clean and at all times of maximum receptiveness to the plating material. A negative pulse **25***a* as shown in Figure 2 strips the electrodes from the effects of the pulse P_A and the negative pulse **25***b* strips the electrodes from the effects of the pulse P_B.

Specific examples follow:

Reference Example 1

As a reference example a plating operation was carried out in the following manner. A "standard copper solution" was prepared consisting of copper cyanide 3.5 ounces per gallon of water, sodium cyanide 4.5 ounces per gallon of water, Rochelle salt 4 ounces per gallon of water, and caustic soda ½ ounce per gallon of water. A copper bar was immersed in the solution and comprised the plating anode. A steel plate 3 inches by 4 inches by ¼ inch was placed in the standard copper solution and comprised the cathode. A D. C. current was applied thereto at a voltage of 5 volts and with a current density of 30 amperes per square foot. The plating operation was continued for 90 seconds. Following the plating operation the thickness of the copper plating was noted, the plated plate was exposed to a standard 30 day salt spray test and the grain structure was observed.

Reference Example 2

A further reference experiment was carried out by first preparing a "standard cadmium solution" comprising cadmium oxide 3 ounces per gallon of water and sodium cyanide 18 ounces per gallon of water. A cadmium bar was immersed in the solution and comprised the plating anode. A 3 inch by 4 inch by ¼ inch steel plate was immersed therein and comprised the cathode. A constant D. C. current was applied thereto at a voltage of 8 volts and a current density of 20 amperes per square foot for a period of 11 minutes. The coating deposited was measured at 0.0003 inch and the density of cadmium deposited was observed.

Reference Example 3

The procedure of reference Example 2 was followed using a hollow steel cylinder in place of the steel plate used in reference Example 2, said cylinder being a standard one half inch steel pipe. The cylinder was held stationary with respect to the anode and upon removal from the plating operation the thickness of cadmium deposited was measured at the central point of the side of the cylinder facing the anode and in each direction around the surface of the cylinder away from said central point.

With the above reference examples for comparison purposes, the method of the invention was then subjected

to a series of experimental tests. Typical examples follow:

EXAMPLE 1

Using the standard copper solution as above described, a copper anode and a steel plate of the same character and size as above described, said plate was immersed in said solution as a cathode and subjected to a current applied according to the invention wherein the voltage was at 160 volts peak and the current density was about 130 amperes per square foot at the peak, the average voltage being about 6 volts and the average current density being about 19 amperes per square foot. The plating time was about 19 seconds. Upon the removal of the plate from the plating solution it was found that the plating thickness was the same as in reference Example 1, the adherence following the same 30 day salt spray test as above mentioned was better than in reference Example 1 and the grain structure indicated was more densely packed than in reference Example 1. When conditions of reference Example 1 were modified to secure the same plating thickness in 19 seconds, the density and adherence were much inferior to that obtained here.

EXAMPLE 2

Using a cadmium bar as an anode and a steel plate of the same size as used in the above reference examples as a cathode, the electrodes were placed in a standard cadmium solution as above described and plating current according to the method of the invention was applied at 160 volts peak, density of 300 amperes per square foot at the peak with an average voltage of about 6 volts and an average current of about 8 amperes per square foot. The plating was continued for 7½ minutes. On removal of the plate from the solution it was found that the thickness of cadmium deposited was 0.0003 inch and that the cadmium density was about the same as with the plate referred to in reference Example 2. When the conditions of reference Example 2 were modified to secure the same plating thickness in 7½ minutes, the density and adherence was much inferior to that obtained here.

EXAMPLE 3

The procedure of Example 2 was repeated with a one-half inch steel pipe of exactly the same size and character as that used in reference Example 3 as a cathode. As in reference Example 3, the steel cylinder was held motionless with respect to the anode. Upon examination of the plated cylinder, it was found that the cadmium was not as thick on the side which had faced the anode as it was in the case of reference Example 3 but that it extended further around the pipe and was of more uniform thickness throughout its extent around the pipe than in the case of reference Example 3.

EXAMPLE 4

The procedure of Example 1 was repeated with peak voltages of 75 volts. It required approximately twice the time that was required in Example 1 to procure the same results but the results were comparable and, particularly, the grain structure was good.

EXAMPLE 5

The procedures of Example 1 were repeated with voltages of 300 volts. The plating was here accomplished extremely rapidly but the grain structure was not sufficiently dense nor adherent and the results were considered unsatisfactory.

EXAMPLE 6

The procedures of Example 1 were repeated with a peak voltage of 600 volts. Here the plating was extremely fast but the grain structure was even less dense than with 300 volts and this was entirely unsatisfactory.

EXAMPLE 7

The procedures of Example 2 were repeated with 75 volts, 300 volts and 600 volts respectively. The results with 75 volts were acceptable, particularly in that the grain structure was good but approximately twice the time that was required to secure comparable thickness and plating as that required in Example 2. The results with 300 and 600 volts peak occurrence were unsatisfactory due to insufficiently dense and insufficiently adherent grain structure. The plating was, however, accomplished very quickly.

EXAMPLE 8

The procedures of Example 3 were repeated with peak volts of 75 volts, 300 volts and 600 volts. The results with 75 volts were acceptable, particularly in that the grain structure was good but approximately twice the time was required to secure comparable thickness and plating as that required in Example 3. The results with 300 and 600 volts peak occurrence were unsatisfactory due to insufficiently dense and insufficiently adherent grain structure. The plating was, however, accomplished very quickly.

EXAMPLE 9

Each of the foregoing examples was repeated and at the end of each half-cycle of plating current there was interposed a momentary reverse pulse. This appeared to keep the electrolyte clean and effective longer than was true when it was not used and a slightly better plating density was obtained than when it was not used. The plating time was not changed by the use of this reverse pulse. The peak voltage was approximately 25 volts.

Accordingly a method of carrying out the above outlined objectives and purposes has been set forth. It will be recognized that while a specific embodiment has been selected for illustrative purposes, both the steps of the method herein shown may be varied in a variety of ways according to the choice of the designer or to meet individual operating conditions and such variations will be within the scope of the hereinafter appended claims excepting as said claims by their own terms expressly require otherwise.

I claim:

1. In a method of utilizing an alternating potential for electro-plating a metal chosen from the group consisting of copper and cadmium onto a base member from an electro-plating electrolyte in which the metal to be plated is dissolved and in which the base member is immersed, said base member being one of a pair of spaced electrodes and the other of said electrodes also being immersed in said electrolyte, the steps comprising: supplying electrical energy to the plating electrodes in a series of unidirectional pulses obtained by storing electrical energy from repeated negative half-cycles of said alternating potential; adding the potential of said stored energy from each negative half-cycle to the potential of the immediately subsequent positive half-cycle of said alternating source; and conducting the resulting potentials through said plating bath until a selected quantity of electrical energy has been conducted therethrough; controlling the magnitude of said stored energy by controlling the portion of said negative half-cycle which is stored; and further controlling the magnitude of current through said plating bath by controlling the portion of said positive half-cycle which is added to said stored energy.

2. In a method of utilizing an alternating potential for electro-plating copper onto a ferrous base member from an electro-plating electrolyte in which the copper to be plated is dissolved and in which the ferrous base member is immersed, said base member being one of a pair of spaced electrodes and the other of said electrodes being composed of the copper and also being immersed in said electrolyte, the steps comprising: supplying electrical energy to the plating electrodes in a series of unidirectional pulses obtained by storing electrical energy from repeated negative half-cycles of said alternating potential; adding the potential of said stored energy from each negative half-cycle to the potential of the immedi-

ately subsequent positive half-cycle of said alternating source; and conducting the resulting potentials through said plating bath until a selected quantity of electrical energy has been conducted therethrough; controlling the magnitude of said stored energy by controlling the portion of said negative half-cycle which is stored; and further controlling the magnitude of current conducted through said plating path by controlling the portion of said positive half-cycle which is added to said stored energy.

3. A method of utilizing an alternating potential for electro-plating a metal chosen from the group consisting of copper and cadmium onto a ferrous base member from an electro-plating electrolyte in which the metal to be plated is dissolved and in which the base member is immersed, said base member being one of a pair of spaced electrodes being composed of the material to be plated and the other of said electrodes also being immersed in said electrolyte, the steps comprising: supplying electrical energy to the plating electrodes in a series of uni-directional pulses obtained by storing electrical energy from repeated negative half-cycles of said alternating potential; adding the potential of said stored energy from each negative half-cycle to the potential of the immediately subsequent positive half-cycle of said alternating source; and conducting the resulting potentials through said plating bath until a selected quantity of electrical energy has been conducted therethrough; controlling the magnitude of said stored energy by controlling the portion of said negative half-cycle which is stored; and further controlling the magnitude of current conducted through said plating bath by controlling the portion of said positive half-cycle which is added to said stored energy.

4. A method defined in claim 3 including the further step of conducting a portion of selected ones of said negative half-cycles through said electrolyte.

5. The method defined in claim 3 including the step of conducting a final portion of each of said negative half-cycles through said electrolyte.

6. In a method of utilizing an alternating potential for electro-plating a metal chosen from the group consisting of copper and cadmium onto a base member from an electro-plating electrolyte in which the metal to be plated is dissolved and in which the base member is immersed, said base member being one of a pair of spaced electrodes and the other of said electrodes being composed of the material to be plated and also being immersed in said electrolyte, the steps comprising: supplying electrical energy to the plating electrodes in a series of uni-directional pulses obtained by storing electrical energy from at least one negative half-cycle of said alternating potential; adding the potential of said stored energy from said negative half-cycle to the potential of the immediately subsequent positive half-cycle of said alternating source; and conducting the resulting potentials through said plating bath until a selected quantity of electrical energy has been conducted therethrough; controlling the magnitude of said stored energy by controlling the portion of said negative half-cycle which is stored; and further controlling the magnitude of current through said plating bath by controlling the portion of said positive half-cycle which is added to said stored energy.

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