The present invention relates to an apparatus and method for electroplating gravure cylinders that are used for gravure printing. The apparatus and method preferably utilize rectifiers that are able to pulse direct current several hundred times per second in order to repeatedly and intermittently establish an electric field between a supply of plating material and the gravure cylinder.
ELECTROPLATING OF GRAVURE CYLINDERS

FIELD OF THE INVENTION

[0001] The present invention relates to an apparatus and method for electroplating gravure cylinders, and more particularly to an apparatus and method for electroplating gravure cylinders using current pulses.

BACKGROUND OF THE INVENTION

[0002] Electroplating has been historically used to coat gravure cylinders with materials such as copper or chrome because of the efficiency associated with providing a thin uniform coating of an engravable material on the gravure cylinders by electroplating when compared with other methods. Gravure cylinders are plated with a thin layer of material of engravable material so that the desired print can be etched, engraved or embossed into/onto the deposited layer of plating material. The body of the gravure cylinders are typically steel or aluminum and are used to provide a sturdy and less expensive substrate for supporting the layer of plated material. Due to the cost associated with producing gravure cylinders, the cylinders are typically reconditioned after the completion of each print run. Reconditioning a cylinder allows a different print to be etched, engraved or embossed into/onto the cylinder for a subsequent print run.

[0003] The reconditioning process typically involves removing at least enough material from the outer surface of the cylinder to partially remove the existing etching or engraving and then electroplating a new layer of material onto the cylinder. Once the new layer of material is deposited onto the cylinder, new etching or engraving for a subsequent print run can be applied into the new plating material.

[0004] Gravure cylinders are plated by partially submerging a cylinder within an ionic fluid bath that includes ions of the material which are to be deposited onto the cylinder. The partially submerged cylinder is rotated so that the entire outer surface of the cylinder periodically enters and exits the ionic fluid bath. A supply of plating material is submerged within the ionic fluid and once an electrical field is established between the cylinder and the supply of plating material ions within the fluid bath are deposited onto the cylinder. These deposited ions are continuously repositioned within the ionic fluid bath because additional ions break free from the supply of plating material and enter the ionic fluid bath.

[0005] The apparatus includes a container for holding the ionic fluid bath and a reservoir for holding the plating material in fluid communication with the ionic fluid bath. An electrical power source is connected to the plating material and the cylinder to establish the electric field between the plating material and the cylinder. The electrical power source includes rectifiers that apply a constant direct current such that the plating material is continuously deposited from the ionic fluid onto the gravure cylinder.

[0006] In many applications the cylinder surface is bombarded with ultrasonic impulses in an attempt to improve the electroplating process. Additional rectifiers may also be added to the electrical power source to intermittently reverse the current for several seconds. A seldom used process facilitates removing the old engraving by reversing the current for long periods (e.g., 10-20 minutes). The engraving is more commonly removed by machining and then reversing the current for a few seconds prior to plating to facilitate better adhesion between the copper substrate and the new coating.

[0007] Electroplating gravure cylinders in order to recondition the cylinders for future print jobs is a cost effective way to provide a smooth, uniform surface on a gravure cylinder which is suitable for etching or engraving and then subsequent gravure printing. Therefore, any improvement in the devices or processes related to reconditioning gravure cylinders by electroplating would be desirable.

SUMMARY OF THE INVENTION

[0008] The present invention relates to an apparatus and method for electroplating gravure cylinders that are used for gravure printing. The apparatus and method preferably utilize rectifiers that are able to pulse direct current several hundred times per second in order to repeatedly and intermittently establish an electric field between a supply of plating material and the gravure cylinder. Pulsing current several hundred times per second in order to repeatedly establish a field between the supply of plating material and the gravure cylinder significantly reduces the plating duration and minimizes the surface pitting and nodules that are present using conventional electroplating processes and equipment.

[0009] The present invention is directed to an apparatus for electroplating a cylinder that is used in gravure printing. The apparatus includes a container and an ionic fluid bath stored within the container such that the gravure cylinder can be at least partially submerged within the ionic fluid bath. A supply of plating material is submerged within the ionic fluid bath and an electrical power source is operatively connected between the gravure cylinder and the supply of plating material. The power source cycles current at different levels, preferably several hundred times per second, to the ionic fluid bath in order to establish different electric fields between the supply of plating material and the gravure cylinder. The electric power source is preferably a periodic abrupt current change between a high level of current and a substantially lower level of current. However, other non-abrupt current variation over time at several times per second can also be applied without departing from the scope of the present invention.

[0010] In another form, the present invention is directed to a method of electroplating a gravure cylinder. The method includes partially submerging the gravure cylinder within an ionic fluid bath; submerging a supply of plating material within the ionic fluid bath; and pulsing different levels of current between the supply of plating material and the gravure cylinder.

[0011] In the preferred form of the method, the current is periodically reversed after cycling the current at several different levels in the forward direction. Periodically reversing the current between several cycles of current at different levels in the forward direction facilitates removing imperfections from the outer surface of the gravure cylinder. In addition, reversing current also helps to maintain a supply of copper in the immersion layer (i.e., the layer near the cylinder).

[0012] Pulsing direct current with or without periodically reversing current improves the ability to engrave the cylin-
der by reducing the grain size of the plating material that is deposited on the gravure cylinder and improves leveling across the cylinder surface. In addition, using pulsing rectifiers reduces the co-plate of hydrogen and minimizes the hardness differences between individual cylinders that are plated at different times and the hardness variation caused by the differences between cylinder suppliers.

[0013] Other features and advantages of the invention are set forth in the following drawings, detailed description and claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014] The invention will hereafter be described with reference to the accompanying drawings wherein like numerals denote like elements.

[0015] FIG. 1 is a section view showing a gravure cylinder partially submerged within an ionic fluid bath.

[0016] FIG. 2 is a top plan view illustrating the apparatus of the present invention with the gravure cylinder that is to be plated removed from the apparatus.

DETAILED DESCRIPTION

[0017] The apparatus and method of the present invention are shown in FIG. 1. A plating tank 10 includes a container 18 that is filled with an ionic fluid bath 14. A supply of plating material 12 is held submerged within the ionic fluid bath 14 by a reservoir 20 such that the plating material 12 is in continuous fluid communication with the ionic fluid bath 14. An electrical power source 22 is connected positively to the plating material 12 and negatively to a cylinder 16. The electrical power source 22 includes pulsing direct current rectifiers 23 (e.g., Power Pulse Model PEXXXX) that are preferably manufactured by Plating-Electronic GmbH, Marie-Curie-Strasse, Denzlingen, Germany, although other rectifiers could be used without departing from the scope of the present invention.

[0018] The supply of plating material 12 may be any type of material that is commonly used in electroplating processes. The material must be able to undergo ionization within the ionic fluid bath 14 in order to replenish the ions that are plated onto the outer surface of the cylinder 16. Copper is one of the materials that is commonly used in plating and will be used as the primary example throughout this description without implying any limitations as to the type of plating material which might be used in the apparatus and process of the present invention. Other examples of plating material include chromium (trivalent or hexavalent), nickel and nickel alloys.

[0019] Copper ions have a positive charge so that the power source 22 in forward current mode must supply a negative charge to the cylinder 16 and a positive charge to the copper plating material 12 in order to coat the cylinder 16 with copper. The negatively charged cylinder attracts the positively charged ions such that the copper ions are deposited on the surface of the cylinder 16. As the copper ions are deposited on the cylinder 16 they are removed from the ionic fluid bath 14. Additional copper ions are induced by the electrical potential present between the cylinder 16 and the copper plating material 12 to separate from the copper plating material 12 and enter the ionic fluid bath 14 thereby replacing the ions which have been deposited onto the cylinder 16.

[0020] The gravure cylinder 16 includes a longitudinal axis 37 and the cylinder 16 rotates about the longitudinal axis 37 during the electroplating process. The cylinder 16 rotates on a shaft 36 such that only a portion of this cylinder 16 is submerged within the ionic fluid 14 at any given time. Therefore, rotating the cylinder 16 through the ionic fluid bath 14 permits all parts of the cylinder 16 to be coated with copper ions from the ionic fluid bath 14.

[0021] The reservoir 20 which holds the plating material 12 within the ionic fluid bath 14 includes a titanium base tray 40 that is mounted on a support 42. A plastic liner 46 and a plurality of upper bars 48 are disposed between the base tray 40 and the plating material 12 such that the copper bars 48 are in contact with the plating material 12. The liner 46 is perforated in order to allow the ionic fluid to pass through to the base tray 40 where the ionic fluid can exit through the base tray 40 via a drainage conduit 50 into a fluid supply 28.

[0022] Referring now also to FIG. 2, the reservoir 20 includes a pair of exterior retaining walls 52 that extend upward from opposing bases of the base tray 40. A pair of end walls 54 are positioned at opposing ends of the exterior retaining walls 52 such that the reservoir 20 forms an enclosure that is large enough to receive the gravure cylinder 16.

[0023] A pair of interior retaining walls 56 are positioned substantially parallel to and inwardly from the exterior retaining walls 52. The pair of interior walls 56 extend upwardly from base tray 40 such that the section of the reservoir 20 between the interior retaining walls 56 is adapted to receive the entire supply of plating material 12.

[0024] A pump 32 returns the drained fluid from the fluid supply 28 back to the ionic fluid bath 14 via a conduit 30. The conduit 30 extends through the base tray 40 such that the fluid is pumped into the interior portions 71 of filter tubes 34. The filter tubes 34 extend longitudinally along the length of the reservoir 20 between the interior retaining walls 52 and exterior retaining walls 56. The filter tubes 34 are made up of a plurality of shorter filter tubes 34a, 34b, 34c, 34d. The plurality of filter tubes 34a, 34b, 34c, 34d are mounted on a plurality of brackets 58 that are intermittenly spaced along the length of the reservoir 20 (see FIG. 2).

[0025] The filter tubes 34 promote uniform ionic fluid distribution along the length of the reservoir 20. The filter tubes 34 are preferably constructed of a polypropylene material which restricts the flow of ionic fluid into the ionic fluid bath 14. The ionic fluid 14 enters the hollow interior portions 71 of the filter tubes 34 and then flows radially outward through the polypropylene material into the container 18. The restrictive polypropylene filter tube ensures that the filter tubes 34 are at least partially filled with ionic fluid 14 to promote the slow and even distribution of ionic fluid along the length of the reservoir 20.

[0026] A capping member 60 that includes a plurality of orifices 62 connects the tops of the interior retaining walls 52 with the tops of the exterior retaining walls 56 on the respective sides of the reservoir 20. Each of the filter tubes 34a, 34b, 34c, 34d is therefore enclosed by a capping member 60, an interior retaining wall 52, an exterior retaining wall 56 and a portion of the liner 46.

[0027] A barrier 24 is positioned between the plating material 12 and the cylinder 16. The barrier 24 extends
between the pair of interior walls 52 and covers the plating material 12 which would otherwise be exposed to the cylinder 16. Positioning the barrier 24 in this manner causes any ions that are given up by the plating material 12 to pass through the barrier 24 before they can contact the cylinder 16. The barrier 24 helps to prevent oxides and other undesirable contaminants from coming into contact with the cylinder 16. The barrier 24 is preferably made from a sheet of polypropylene that includes openings which are appropriately dimensioned to permit passage of ionic fluid yet prohibit passage of copper oxides and other contaminants. The fine mesh barrier allows positively charged ions to float evenly from the supply material thereby reducing valleys and peaks along the cylinder length and facilitating uniform ionic dispersion by diffusion.

[0028] The barrier 24 acts as a diffusion member and preferably includes a titanium grid 64 on which a polypropylene sheet 66 is located on the material supply side. The titanium grid 64 is mounted on a hinge 68 such that the barrier 24 can be pivoted away from the plating material 12 in order to facilitate easy insertion and removal of plating materials from the reservoir 20.

[0029] The titanium grid 64 includes apertures 70 such that the ions pass through the apertures 70 when they flow through the grid 64. The spacing between the apertures 70 promotes diffusion of the ions as they approach the cylinder 16. Diffusing the ions so that they are more uniformly dispersed within the ionic fluid bath 14 distributes the ions onto the cylinder 16 in a more uniform fashion. The apertures 70 are preferably circular and vary in size with all of the apertures 70 being less than two inches in diameter.

[0030] The ionic fluid bath 14 consists of a carrier fluid and ions that are generally disbursed throughout the carrier fluid. Once again referring to copper as an example, a copper sulfate is typically mixed with a fluid such as water. It should be noted that other additives which are commonly known in the art could also be added to the fluid. The sulfate breaks into ions of copper and sulfate with the copper ions having a positive charge and the sulfate ions having a negative charge. When the electrical field is established between the cylinder 16 and the plating material 12 the positively charged copper ions are attracted toward the negatively charged cylinder 16 while the sulfate ions move towards the reservoir 20. The copper ions are deposited on the outer surface of cylinder 16 while the sulfate ions move into proximity with the plating material 12 where the sulfate ions combine with naturally occurring oxides in the copper. As the sulfate ions combine with the oxides in the copper, a sludge is formed which drops into the reservoir 20.

[0031] The fluid level within the container 18 is maintained by an overflow wall 72 which is positioned inward from an outer wall 74 on the container 18. The ionic fluid bath 14 is maintained at a constant level since any excess ionic fluid 14 falls over the top of the overflow wall 72 into a passage 76 that returns the overflowing fluid to the fluid supply tank 28.

[0032] The power supply 22 preferably includes rectifiers 23 that pulse high levels of direct current several hundred times per second. Pulses of current in this type of application allows gravure cylinders to be reconditioned much more efficiently and with less waste of plating material. The power source 22 supplies a negative charge to the gravure cylinder 16 and a positive charge to the supply of plating material 12. The negative charge is applied to the cylinder 16 through a connector 78 that is in contact with the conductive shaft 36 attached to the cylinder 16. A positive charge is applied to the buss 80 that is in contact with the supply of plating material 12. The buss 80 preferably extends along the length of the reservoir 22 generally parallel with the longitudinal axis 37 of the cylinder 16.

[0033] An example of the operation of the plating tank is as follows. However, the example is for illustration purposes and is not intended on being limiting. A supply of copper plating material 12 in the form of oxygen-free copper nuggets that include approximately 0.04% phosphorus by weight is submerged within the ionic fluid bath 14. The ionic fluid bath 14 consists primarily of water mixed with copper ions and sulfate ions. Solution concentrations of the ionic fluid include 55-65 grams per liter of reagent grade sulfuric acid and 170-200 grams of copper sulfate per liter. The amount of total dissolved solids in the ionic fluid 14 is between 0-4 PPM and the amount of total chlorides in the ionic fluid is between 50-70 PPM. The ionic fluid 14 is preferably kept at a temperature between 28 and 32 degrees centigrade although other temperatures could be used, and the cylinder 16 is preferably rotated within the ionic fluid bath 14 by any conventional means at approximately 10 to 100 revolutions per minute. The container 18 holds approximately 3,000 liters of ionic fluid 14 which is recycled approximately 50 times per hour such that approximately 60,000 liters of ionic fluid 14 flows through the container 18 per hour.

[0034] Although other cycle times could be used without departing from the scope of the present invention, one known effective cycle time for plating 0.050 millimeters of copper onto the outer surface of the cylinder includes repeatedly pulsing the current on for 16 milliseconds and off for 8 milliseconds with one second of reverse current every 1,500 cycles. This duty cycle should be approximately 65% of the rated capacity of the pulsing direct current rectifier. The approximate current density generated with this type of duty cycle is anywhere from 20 to 80 amperes per square decimeter. The process is repeated until the desired plating thickness is reached.

[0035] Another set of cycle times for plating approximately 0.050 millimeters of copper onto a gravure cylinder includes pulsing the direct current rectifiers on for 50 milliseconds and off for 10 milliseconds repeatedly until the desired plating thickness is reached. The pulsing direct current rectifiers are operating with an 83% duty cycle using these cycle times and the current density should be anywhere from 20 to 40 amperes per square decimeter.

[0036] Pulsing current several hundred times per second in order to repeatedly establish a field between the supply of plating material and the gravure cylinder significantly reduces the plating duration and minimizes the surface pitting and nodules when they are present using conventional electroplating processes and equipment. Pulsing direct current also improves the ability to engrave the cylinder by reducing the grain size of the plating material that is deposited on the gravure cylinder and improves leveling across the cylinder surface. In addition, using pulsing rectifiers reduces the copulating of hydrogen and minimizes the hardness differences between individual cylinders that are plated at different times.
The foregoing description the present invention has been presented for purposes of illustration and description. The description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modi-
fications commensurate with the above teachings, and the skill and knowledge of the prior art, are within the scope of the present invention. The embodiments and forms described herein are intended to explain the best modes for practicing the invention and to enable others skilled in the art to utilize the invention in the disclosed or other embodiments and with various modifications required by the particular applications or uses of the present invention. It is intended that the appended claims be construed to include alternative embodiments and forms to the extent permitted by the prior art.

What is claimed is:

1. An apparatus for electroplating a cylinder used in gravure printing, the apparatus comprising:
   a container;
   an ionic fluid bath stored within said container such that the gravure cylinder is at least partially submerged within the ionic fluid bath;
   a supply of plating material within the ionic fluid bath; and
   an electrical power source operatively connected with the gravure cylinder and the supply of plating material, wherein said power source cycles current at different levels through the ionic fluid to establish different electric fields between the supply of plating material and the gravure cylinder.

2. The apparatus of claim 1 wherein said supply of plating material is stored on a reservoir that is submerged within the ionic fluid.

3. The apparatus of claim 1 wherein said electrical power source is a pulsing direct current rectifier.

4. The apparatus of claim 1 wherein said electrical power source cycles current at two levels.

5. The apparatus of claim 4 wherein one of said current levels is substantially near zero current.

6. The apparatus of claim 1 wherein said electrical power source cycles current at different levels at least several hundred times per second.

7. The apparatus of claim 1 further comprising a filter, wherein said ionic fluid bath is circulated through said filter to remove contaminants in said ionic fluid bath.

8. The apparatus of claim 1 wherein said container and said ionic fluid bath are sized such that the gravure cylinder is wholly submerged within said ionic fluid bath.

9. A method of electroplating a gravure cylinder comprising:
   partially submerging the gravure cylinder with an ionic fluid bath;
   submerging a supply of plating material within the ionic fluid bath; and
   pulsing different levels of current between the supply of plating material and the gravure cylinder.

10. The method as claimed in claim 9 wherein the gravure cylinder is submerged wholly within the ionic fluid bath.

11. The method as claimed in claim 9 wherein the ionic fluid bath is kept at temperature between 28 and 52 degrees Centigrade.

12. The method as claimed in claim 9 wherein the current is cycled between two different levels.

13. The method as claimed in claim 12 wherein one of the current levels is substantially near zero.

14. The method as claimed in claim 12 wherein one of the current levels is zero.

15. The method of claim 9 wherein the current flows in one direction.

16. The method of claim 9 wherein the current alternately flows in opposite directions.

17. The method of claim 9 wherein the current is periodically reversed in an opposite direction.

18. The method of claim 17 wherein the current is pulsed at different levels when the current is periodically reversed in the opposite direction.

19. The method of claim 9 wherein the current is cyclically pulsed in a forward direction for 16 milliseconds and then turned substantially off for 8 milliseconds.

20. The method of claim 19 wherein the current is reversed every 1500 cycles.

21. The method of claim 20 wherein the current is reversed for 1 second.

22. The method of claim 9 wherein the current is cyclically pulsed in a forward direction for 50 milliseconds and then turned substantially off for 10 milliseconds.

23. The method of claim 22 wherein the current is reversed every 1500 cycles.

24. The method of claim 23 wherein the current is reversed for 1 second.

25. The method as claimed in claim 9 further comprising rotating the cylinder within the ionic fluid bath.

26. The method as claimed in claim 25 wherein the cylinder is rotated at 70 revolutions per minute.

27. A method of electroplating a gravure cylinder comprising:
   partially submerging the gravure cylinder within an ionic fluid bath;
   submerging a supply of plating material within the ionic fluid bath;
   rotating the cylinder within the ionic fluid bath; and
   cycling current between the supply of plating material and the gravure cylinder where the current is cycled in one direction between substantially zero current and some higher level of current.

28. The method as claimed in claim 27 wherein the current is periodically reversed in an opposite direction.

29. The method as claimed in claim 28 wherein the current is reversed every 1500 cycles.

30. The method of claim 27 wherein the current is cycled several hundred times per second.