The present invention includes a method of electroplating an object, where the objects are stacked in at least one sleeve and the objects have an interior surface, that upon stacking, form a stack conduit. The sleeves are then racked to provide fluid communication between a plating solution reservoir and the stack conduit. Plating of the inner surfaces of the objects occurs by flowing an electroplating solution from the reservoir through the stack conduit in the presence of a current. The present invention also includes systems for carrying out the above method.
ELECTROPLATING SYSTEM AND METHOD

CLAIM OF PRIORITY
[0001] This application claims the benefit of U.S. provisional application 60/551,087, filed on Mar. 8, 2004.

FIELD OF THE INVENTION
[0002] The present invention relates to a system for plating a metallic composition onto a substrate and more particularly relates to a system for bulk electroplating a composition onto the interior surface of a cylindrical or semi-cylindrical object.

BACKGROUND OF THE INVENTION
[0003] Plating of metallic compositions onto objects has been used to achieve both functional and decorative enhancements for the plated object. In addition, plating has been used to improve the wear resistance of the object.

[0004] One particularly useful technique for plating is electroplating. Electroplating is well known in the art and involves the deposition of a metallic layer onto a conductive object by placing the object into an electrolytic bath. The bath contains a salt solution of the metal to be plated i.e. an electroplating solution. A DC current is passed through the solution to cause the metal ions to deposit on the conductive object. The process may also be run in reverse to cause deplating or removal of a metallic layer. Both deposition and removal are encompassed in electroplating.

[0005] Electroplating has several advantages including being relatively inexpensive and relatively fast compared to other techniques. Two disadvantages, however, complicate the use of electroplating in applying wear resistance metallic compositions.

[0006] First, electroplating tends to be indiscriminate, meaning that any conductive surface that is exposed to the plating solution and electrical current will be coated. Sometimes called bleed over, this indiscriminate coating may lead to imperfections in the size or shape of the coated object. Normally such imperfections are small, but in the area of precision parts (e.g. gears, cogs, etc.) where tolerances are tight, even small imperfections may lead to significant problems.

[0007] Second, electroplating tends to deposit the metallic composition in an uneven manner, particularly near the edge of the object being plated. So called edge effects typically result in the metallic composition being applied to a thickness that is 50% or more than desired. Again because of tight tolerances, even small edge effects may have a significant impact on the overall quality of the coated object.

[0008] In addition to these disadvantages, commercial pressure continually require that production costs be minimized, production quantities be increased, all while manufacturing high quality coated objects.

[0009] The present invention overcomes one or more of these problems.

SUMMARY OF THE INVENTION
[0010] The present invention includes a method of electroplating an object, where the objects are stacked in at least one sleeve and the objects have an interior surface, that upon stacking, form a stack conduit. The sleeves are then racked to provide fluid communication between a plating solution reservoir and the stack conduit. Plating of the inner surfaces of the objects occurs by flowing an electroplating solution from the reservoir through the stack conduit in the presence of a current. The present invention also includes systems for carrying out the above method.

BRIEF DESCRIPTION OF THE DRAWINGS
[0011] In the drawings:
[0012] FIG. 1 illustrates, in perspective, an object that may be plated using the systems and methods of the present invention.
[0013] FIG. 2 illustrates, in horizontal cross-section, a sleeve that holds objects during the electroplating process as shown at section line 2--2 on FIG. 4.
[0014] FIG. 3 illustrates, in cross-section, a sleeve cut through a spacer as shown at section line 3--3 on FIG. 4 in the context of an electroplating solution tank.
[0015] FIG. 4 illustrates, in perspective, a rack system that holds up to four tubes of objects during the electroplating process.
[0016] FIG. 5 illustrates, in top view the rack of FIG. 4.

DETAILED DESCRIPTION
[0017] The present invention includes methods and systems for bulk electroplating objects comprising at least one sleeve for a stack of objects and a rack to hold the objects during the plating process. Bulk electroplating includes the plating of at least about 20 objects simultaneously or in a single lot. In other embodiments, the number of objects simultaneously plated is at least about 100, at least about 250, at least about 500, at least about 750, at least about 1000, at least about 1500, at least about 2000 or more. Bulk electroplating may be accomplished by subdividing the objects into sub-lots of any convenient size, preferably between about 20 and about 50 objects per sub-lot, such that the objects in sub-lots total the overall number of object simultaneously plated. A sub-lot may be conveniently be held within the sleeve.

[0018] Bulk electroplating also refers to plating a given number of objects in a given time period. For example, bulk electroplating may refer to plating at least about 5000 objects in a day or in a shift. In other embodiments, the number of objects plated in a day or a shift is at least about 10,000, at least about 15,000, at least about 20,000, at least about 25,000, at least about 30,000, at least about 35,000, at least about 40,000, at least about 45,000, at least about 50,000 or more.

[0019] Any electrically conductive object may be plated with the systems and methods discussed herein. Preferably, the object comprises an interior surface that is suitable for plating. The interior surface is preferably cylindrical to create a through hole in the object, although the may include flat surfaces or arcuate surfaces other than cylindrical. The area of the interior surface is not critical but in one preferred embodiment, its area is about 1 in².

[0020] The size and shape of the object is not critical, but should be relatively consistent, such that when the objects
are stacked one on top of the other in the sleeve, the through holes align. Of course, the size of sleeve also cooperates with the objects to help insure alignment. The aligned through holes create a conduit through the stacked objects.

[0021] Preferably, the objects comprise mating surfaces on their top and bottom, such that the junction of two objects does not substantially interrupt the conduit through the stacked objects. Preferably, the mating surfaces are substantially flat, although notches, grooves or other devices may be used to insure that the alignment of the stacked objects. Also, the top surface of one object and the bottom surface of another object may nest together to help maintain a substantially uninterrupted conduit. In addition, although not preferred, sealing rings may be interspersed between stacked objects to help maintain the continuity of the conduit created by the stacked objects.

[0022] One preferred class of suitable objects to be plated is gears that comprise a cylindrical interior surface, as seen in FIG. 1. More preferably, the interior surface is a bearing surface. The gears also comprise a top mating surface and a bottom mating surface, where the gears would touch when stacked. The mating surface surfaces help insure that, when stacked, the objects form a relatively smooth interior surface over the entire length of the sleeve, thus helping to eliminate bleed through and edge effects. Alternatively, one or more objects may be combined to form an interior surface (e.g., half bearings).

[0023] As suggested above, the sleeve holds the objects to be plated in alignment when the objects are stacked in the sleeve such that the interior surfaces of the objects form a conduit through the stacked objects. The sleeve may be made of any material; preferably that exhibits stability during long term exposure to plating solution. The sleeve material should also be electrically inert.

[0024] As seen in FIGS. 2-4, each sleeve comprises a relative top and bottom. At or near the bottom is a sleeve inlet. At or near the top is a sleeve outlet. Objects may be stacked within the sleeve. Electroplating solution is introduced to the conduit of the stacked objects at the inlet and exits the conduit at the outlet. Flow of electroplating solution is shown in FIG. 4 by arrows.

[0025] A cathode and an anode are associated with each sleeve. Both the cathode and the anode are located in the interior of the sleeve. Preferably the cathode is located parallel to the major axis of the sleeve and adjacent to the sleeve. The cathode may touch the sleeve and may be permanently affixed to the sleeve or may be unattached to the sleeve. The anode is preferably co-linear with the major axis of the sleeve. Preferably the cathode and the anode are parallel to one another.

[0026] Preferably, the cathode touches each of the objects in the stack, while the anode resides within the conduit created by the stacked objects. Preferably, the anode does not touch the objects.

[0027] The anode and cathode may be made of any suitable material but preferably are non-corroding. Non-corroding (e.g., steel) anodes have several advantages over corroding anodes. In particular, with a non-corroding anode, anode corroding compositions may be eliminated, which in turn eliminates deposits of carbonate salts and the associated uneven plated surface. Also, a non-corroding anode provides a more consistent plated surface because the thickness of plating can be controlled more precisely. In particular, as the anode corrodes, the amount of metal ions in solution fluctuates because of uneven corrosion. Also, anode replacement is an expensive that can be eliminated.

[0028] The orientation and spacing of the cathode and anode may be insured through the use of an inlet spacer and an outlet spacer. The inlet spacer may be permanently affixed to the sleeve or merely held within the sleeve, with the later being preferred. The outlet spacer is typically not permanently attached to the sleeve. The spacers may include one or more locating holes adapted to receive the cathode and/or anode therein. A cathode locating hole may be positioned near or on the periphery of the spacer so that the cathode is near or adjacent to the sleeve. The cathode locating hole may or may not be a through hole, but preferably is. An anode locating hole is preferably positioned at the center of the spacer so that its axis is co-linear with the major axis of the sleeve. Preferably, the anode locating hole is a through hole in the inlet spacer that aligns with the sleeve inlet. The spacers help to maintain a set distance between the cathode and the anode and help prevent arcing.

[0029] The anode may also comprise one or more centering devices. In one embodiment, the anode comprises an arrow head or other device that is adapted to center the received anode in the anode locating hole of the inlet or outlet spacer. In another embodiment, the anode comprises a cross or other device that positions the anode along the major axis of the sleeve. Such a cross is typically located at or near the sleeve outlet and cooperates with the sleeve or spacer to align the anode, while only partially or minimally interfering with the plating solution as it exits the sleeve. The arrow heads and crosses may be used in combination.

[0030] The anode may also comprise an insulating sheath located near the top (and/or bottom) of the sleeve. The insulating sheath helps to prevent bleed through by preventing the top of the last object in the stack from being exposed to plating solution and current.

[0031] The sleeve may also contain one or more guide rods attached to the interior of the sleeve. The guide rods may be positioned within the sleeve such that the objects are temporarily held in place when stacked in sleeve. For example, when the object is a gear, the guide rod may be sized to substantially fill the space between two teeth on the gear. By using two or more guide rods, the object may be accurately held in position in the sleeve during the plating process. In one preferred embodiment, the cathode acts as a guide rod. The inlet and outlet spacers may also include holes for the guide rods. The guide rods are preferably electrically inert, either because of their composition or because they are not connected to an electrical source.

[0032] With regard to FIG. 3, the rack holds at least one sleeve of objects. Preferably, the rack is adapted to hold at least 2, at least 4, at least 8, at least 12, at least 16 or more sleeves of objects.

[0033] As seen in FIG. 4, the rack includes at least one inlet to receive electroplating solution provided by a pump from a reservoir. For each sleeve, the rack also comprises an outlet where the inlet and outlet are connected by a passage. The outlet is designed to be
fluidly connected to the sleeve at the sleeve inlet. In one embodiment, the reservoir is an open topped tank; in another embodiment, the reservoir is a closed top vessel. In a preferred embodiment, the rack with sleeves is placed in the open topped tank during the electrolyzing process.

[0034] In addition, the rack comprises an anode bar 52 and a cathode bar 54. Each of the anode and cathode bar comprises a connection point 56 for an anode and a cathode associated with each sleeve. Preferably, the connection points are adapted for the quick connection of the anode or cathode to the respective bar. For example, clips or clamps may be used. As seen in FIG. 2a, wing-nut clamps are preferred to connect the anodes and cathodes to their respective bars. Each of the anode and cathode bars comprises a master connection point 58, where the bars may be connected to an electrical source (e.g. one or more rectifiers).

[0035] In one embodiment, the combination of the rack outlet and the anode/cathode connection points help hold the sleeves to the rack. This combination is particularly useful where the cathode is affixed to the sleeve. Alternately, an additional attachment device may be used to secure each sleeve or a group of sleeves to the rack. In one suitable embodiment, the rack outlets and anode/cathode connection points are located such that during electroplating, the sleeves are held in an upright position and the anode/cathode bars are in a horizontal position, although this is not necessarily the case.

[0036] Any metallic composition (e.g. metal, alloy or metal containing composition) may be plated on to an object according to the present invention. For example, bronze and nickel boride are the preferred metallic compositions that may be plated with the present invention.

[0037] The plated objects that result from the use of the present system and method may advantageously have a highly consistent thickness of plated material. For example, the thickness preferably varies by less than about ±20% over the plated surface. More preferably, the thickness varies by less than about ±10% over the plated surface, while most preferably the thickness varies by less than about ±5% over the plated surface. In one embodiment, the thickness of the plated material is less than about 0.01000 inches, less than about 0.00500 inches, less than about 0.00250 inches, less than about 0.00150 inches, less than about 0.001 inches, and less than about 0.00050 inches. In a preferred embodiment, the thickness is about 0.0008 inches, where the thickness may range by ±0.00005 inches.

[0038] The high consistency in the thickness of the plated material results in the elimination of post-processing finishing steps. Known plating methods require a post-processing step such as a grinding or polishing step to achieve thickness uniformity. Such a post-processing step also requires that the surface be inspected after processing to insure that the processing did not otherwise spoil the surface. Thus, both the post-processing and inspection steps can be eliminated by using the method and system of the present invention, although these steps may be used if desired.

[0039] Because of the alignment of the stacked objects in the sleeve to create a substantially uninterrupted conduit, the interior surface of the object is the only portion of the object that is plated. That is, the object is substantially free of plating except on its interior surface.

[0040] The plating process according the present invention is described below. Although specifically described with respect to the preferred embodiment of plating of bearing surfaces of gears, it should be understood that the method is more generally applicable.

[0041] The method has several steps including stacking the gears in the sleeves, racking the sleeves and plating the bearing surfaces of the gears. Stacking the gears involves placing the gears in the sleeve in such a manner as to provide the best possible alignment with the least amount of effort. An inlet spacer is placed in the sleeve and aligned because of the cathode and preferably at least one guide rod. Next, the gears are placed in the sleeve. Again the cathode and the guide rod help ensure that the proper alignment is achieved, such that the interior surfaces (e.g. the bearing surfaces) of the stacked gears form a substantially uninterrupted conduit. An outlet spacer is used to top off the stack of gears. Attachment of the cathode and guide rod to the sleeve eases the placement of spacers and gears, but is not required. After the sleeve is filled with spacers and gears, the anode is inserted into the conduit formed by the stack of gears. The anode is inserted into the conduit formed by the stack of gears. The anode is located in the inlet spacer, insuring that the end of the anode in centrally located in the conduit. The cross helps insure that the other end of the anode is centrally located within the conduit. Together, the centering devices help to properly align the anode with respect to the gear stack and cathode. Although described in a particular sequence, these steps may be performed in other sequences without departing from the invention.

[0042] Next, racking of the stacked gears involves fluidly connecting the inlet of each sleeve to a rack outlet. The sleeve is set in place on the rack outlet and may be held in place by gravity or otherwise clamped to the rack outlet or the rack. Next, the cathode and anode are connected to their respective bars at the connection points, further securing the sleeve to the rack.

[0043] Plating the bearing surfaces involves placing the rack into a tank of plating solution. The level of plating solution in the tank should not be too high as to flow into the sleeve outlets. The rack inlet is fluidly connected to a pump that will circulate plating solution from the tank through the rack passages to the sleeve inlet. The plating solution travels through the stack conduit and out of the sleeve outlet and back into the tank, where the circulation begins again. The cathode and anode are electrically connected to a rectifier that provides the electricity needed to plate the gears. An anode insulating sheath is used to minimize plating of the top or bottom gear.

[0044] Several aspects of the plating step may be manipulated to influence the resultant plate on the bearing surface of the gears. Initially, the use of flowing plating solution helps create a consistent plate thickness because the relative concentration of electrolytes in solution is stable because the solution is continually being refreshed.

[0045] In addition, the flow rate of the solution through the stacked conduit may help determine the consistency of the thickness of the plate by preventing defects. The pumping of electroplating solution also prevents/removes bubbles from the bearing surface of the gears. Bubbles, if allowed to remain, cause defects in the plated layer.

[0046] While any flow rate may be used, preferred flow rates from the pump to the sleeve intake range from about
What is claimed is:

1. A method of electroplating an object, comprising:
   stacking at least two objects in at least one sleeve, wherein the objects comprise an interior surface such that upon stacking, the interior surfaces form a stack conduit;
   centrally locating an in the stack conduit;
   racking the at least one sleeve to provide fluid communication between a plating solution reservoir and the stack conduit;
   plating the inner surfaces of the objects by flowing an electroplating solution from the reservoir through the stack conduit in the presence of a current.

2. The method of claim 1, further comprising placing a cathode into the sleeve prior to stacking.

3. The method of claim 2, wherein the anode is a non-corroding anode.

4. The method of claim 3, wherein stacking further comprises placing at least one spacer into the sleeve before stacking of the objects is started or after stacking of the objects is finished.

5. The method of claim 4, wherein centrally locating the anode further comprises placing a centering device within at least one of the spacers.

6. The method of claim 1, wherein the stacking step further comprises stacking objects in at least 2 sleeves.

7. The method of claim 6, wherein the stacking step further comprises stacking objects in at least 16 sleeves.

8. The method of claim 1, wherein the stacking step further comprises stacking at least 750 objects.

9. The method of claim 1, wherein the stacking step further comprises pumping the plating solution through the stack conduit against the force of gravity.

10. The method of claim 9, wherein the plating solution exits the stack conduit and returns to the reservoir.

11. The method of claim 1, wherein a substantially uniform thickness metallic layer results in the absence of post-plating processing.

12. The method of claim 1, wherein plating of the objects other than the interior surfaces is substantially avoided.

13. A system for electroplating an object, comprising:
   at least one sleeve, each adapted to receive a stack of objects, wherein each stack of objects provides a stack conduit, each sleeve comprising:
   a sleeve inlet and a sleeve outlet,
   a cathode located on the interior of the sleeve and outside the stack conduit, and
   an anode centrally located in the stack conduit; and
   a rack comprising:
   at least one inlet for fluidly receiving an electroplating solution from a reservoir,
   an outlet fluidly communicating with the sleeve inlet to provide the electroplating solution from the rack to the stack conduit,
   a passage fluidly connecting the at least one inlet and each outlet,
   a cathode bar comprising a master connection point and a connection point for the cathode associated with each sleeve, and
   an anode bar comprising a master connection point and a connection point for the anode associated with each sleeve.
14. The system of claim 13, further comprising at least one spacer provided above or below the stacked objects, wherein the at least spacer comprises a center hole adapted to receive a centering device attached to the anode.

15. The system of claim 13, wherein the anode comprises a centering device adapted to cooperate with the sleeve to center the anode within the interior of the sleeve.

16. The system of claim 13, further comprising at least one guide rod in addition to the cathode.

17. The system of claim 13, further comprising at least two sleeves.

18. The system of claim 17, further comprising at least 16 sleeves.

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