US 20030168344A1

(19) United States
(12) Patent Application Publication (10) Pub. No.: US 2003/0168344 A1
Mavliev (43) Pub. Date: Sep. 11, 2003

(54) SELECTIVE METAL DEPOSITION FOR ELECTROCHEMICAL PLATING

(75) Inventor: Rashid Mavliev, San Jose, CA (US)

Correspondence Address:
APPLIED MATERIALS, INC.
2881 SCOTT BLVD. M/S 2061
SANTA CLARA, CA 95050 (US)

(73) Assignee: Applied Materials, Inc.

(21) Appl. No.: 10/095,785

(22) Filed: Mar. 8, 2002

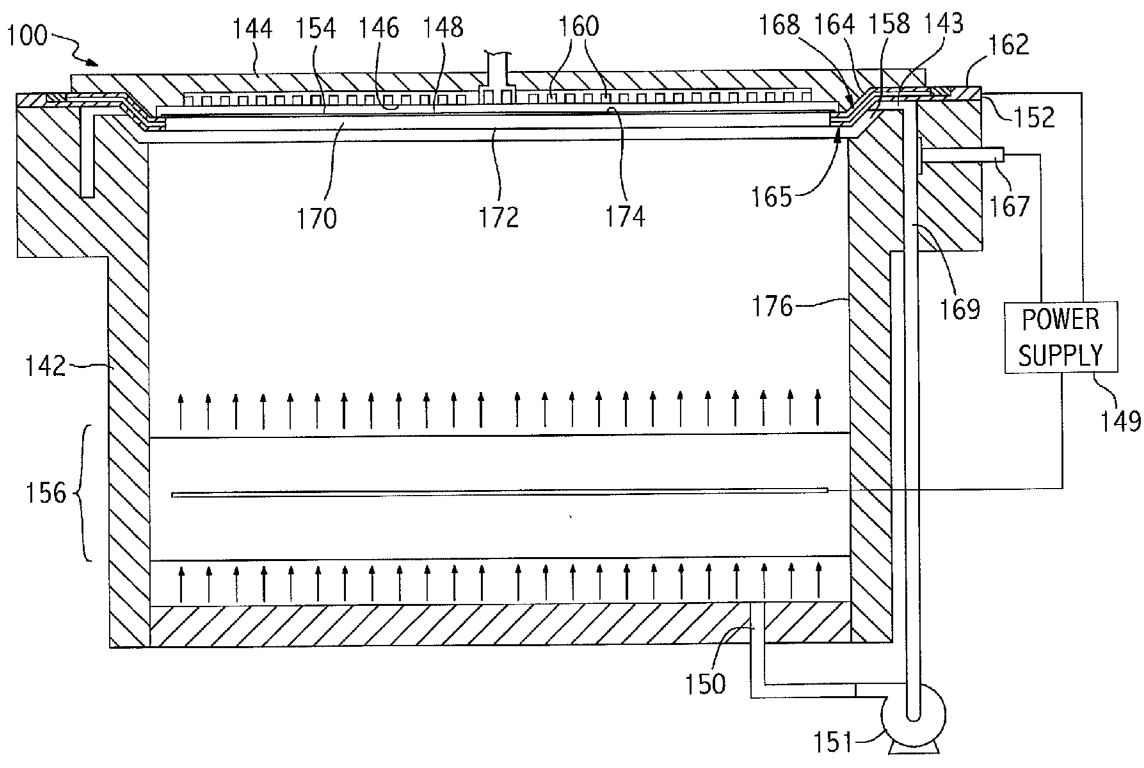
Publication Classification

(51) Int. Cl.[7] ............................ C25D 5/02; C25D 17/00; C25C 7/00

(52) U.S. Cl. ......................... 205/133; 205/291; 205/136; 204/227; 204/242

(57) ABSTRACT

A method and apparatus for plating metal onto a substrate including positioning an anode spacer including a anode surface and a substrate contact surface with the substrate contact surface immediate a deposition surface of a substrate. The apparatus generally includes a plating cell configured to contain a plating solution therein, an anode disposed in the plating solution, and an anode spacer positioned in the plating cell, the anode spacer having an anode surface, and a substrate contact surface positioned immediate a deposition surface of the substrate, the anode spacer configured to communicated the plating solution therethrough. The method generally includes positioning a substrate in a plating cell, positioning an anode spacer immediate a deposition surface of the substrate, and flowing a plating solution through the anode spacer to plate a metal onto the deposition surface.



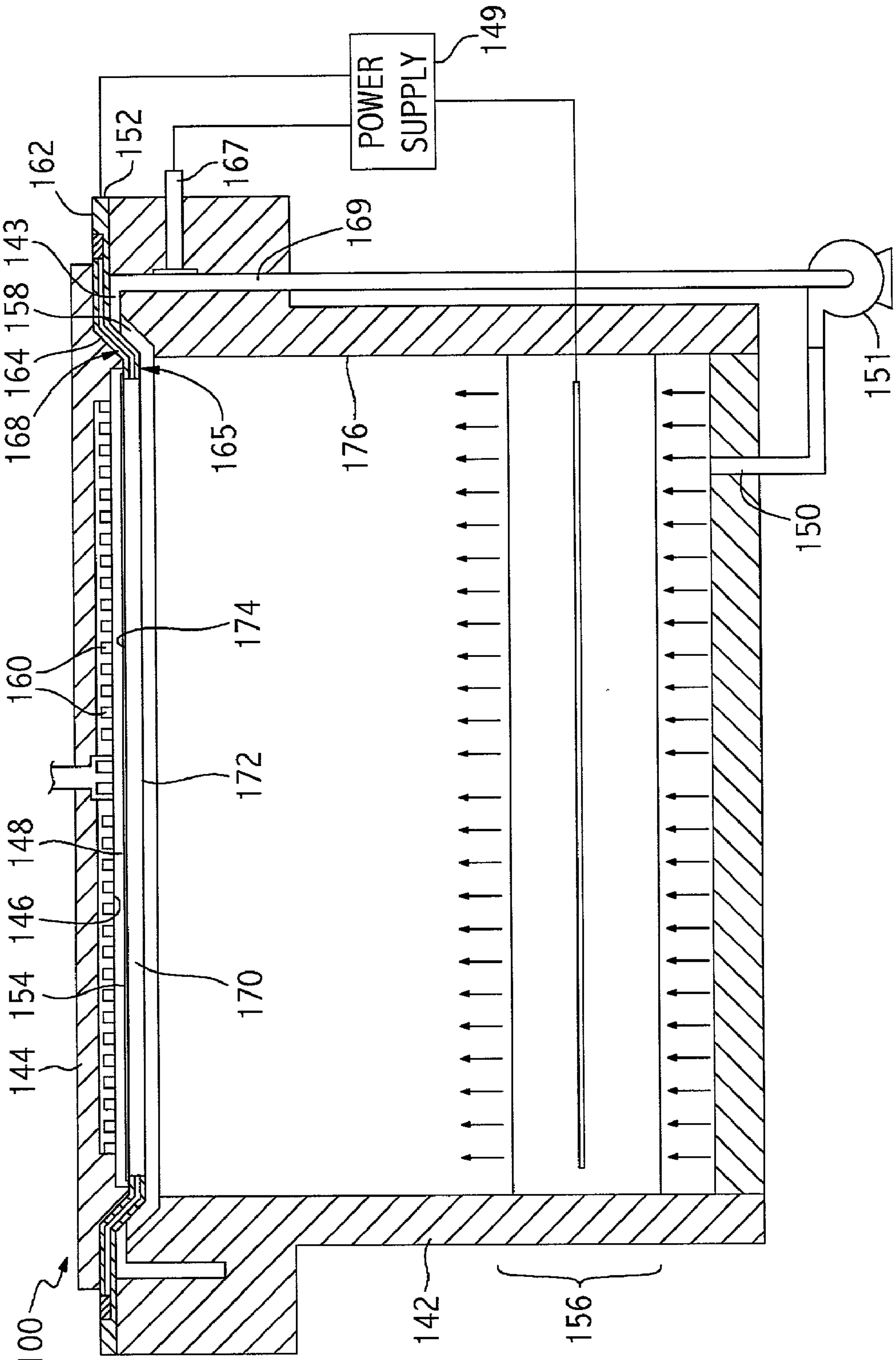

POWER SUPPLY
149
152
162
167
169
143
158
164
168
165
176
151
150
174
160
172
148
146
154
170
144
100
142
156

FIG. 1

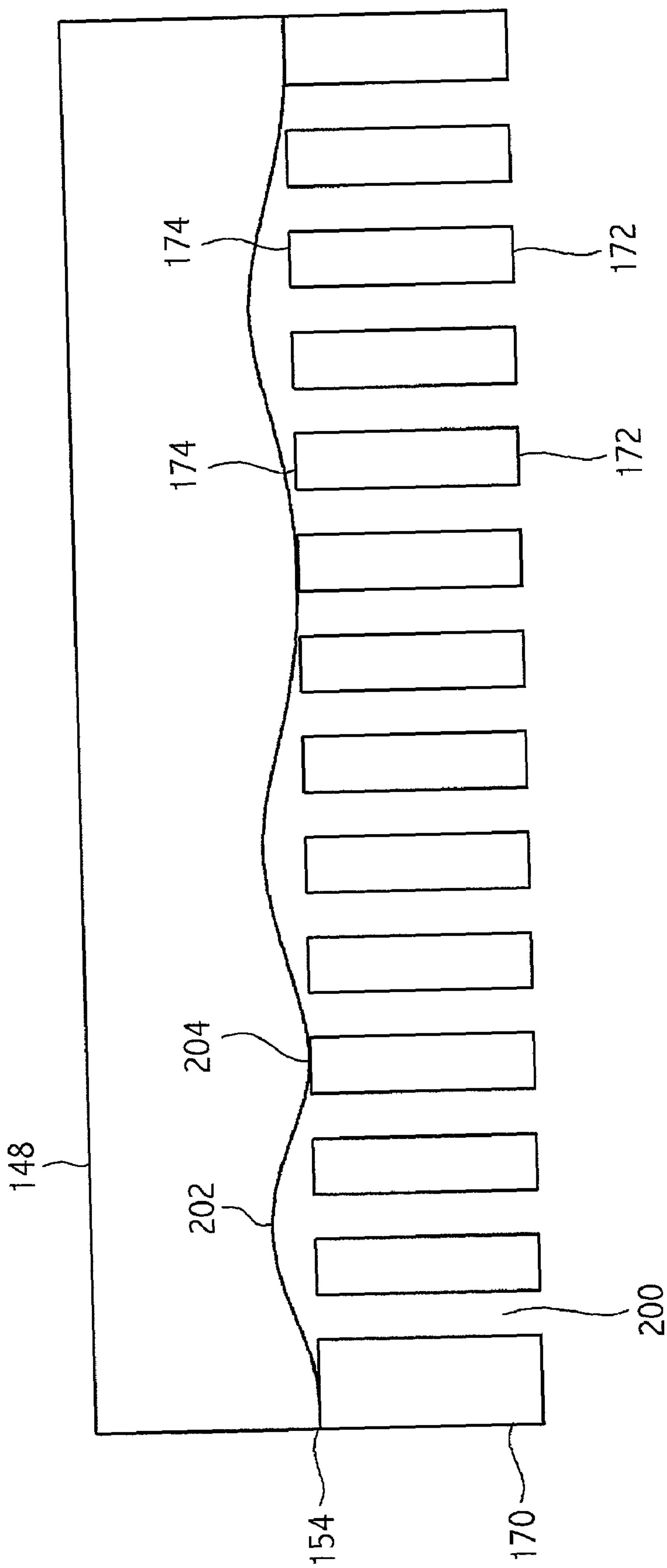



FIG. 2

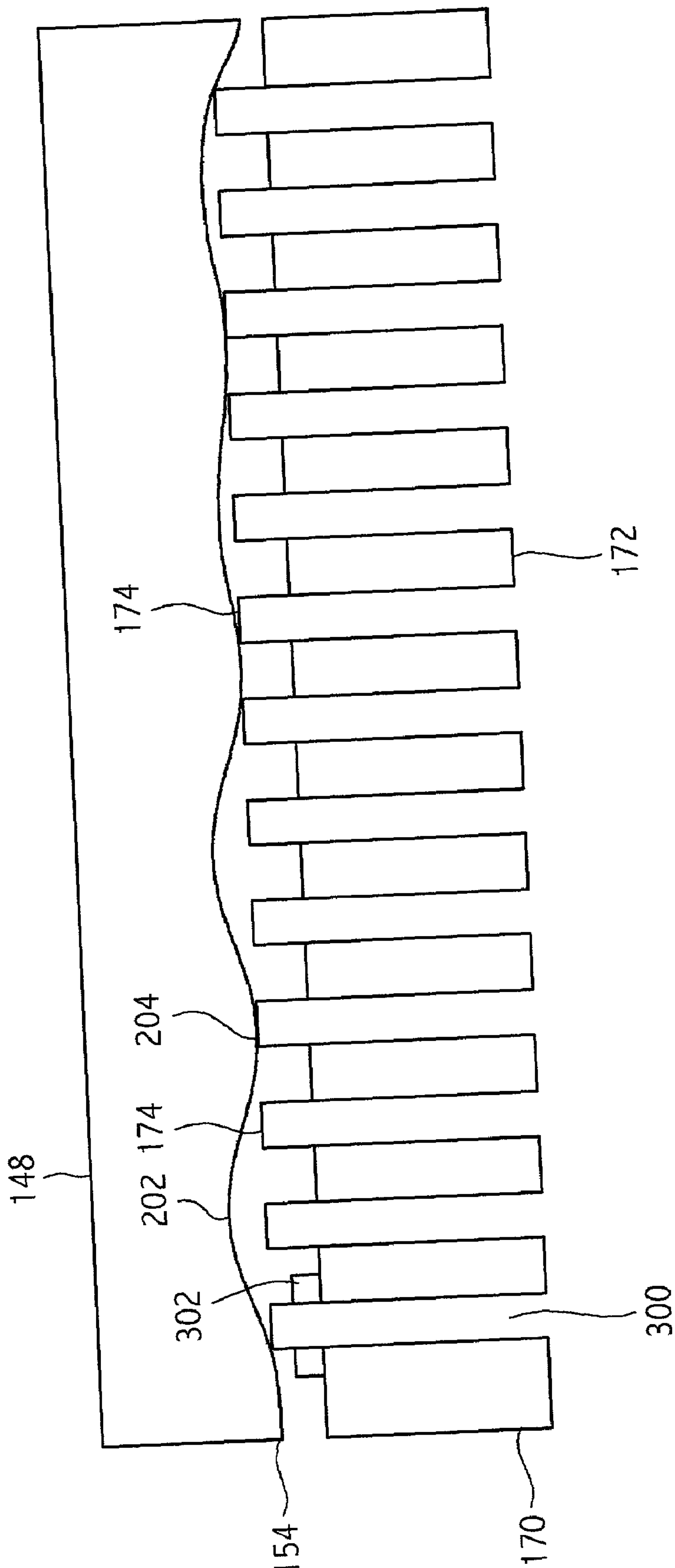



FIG. 3

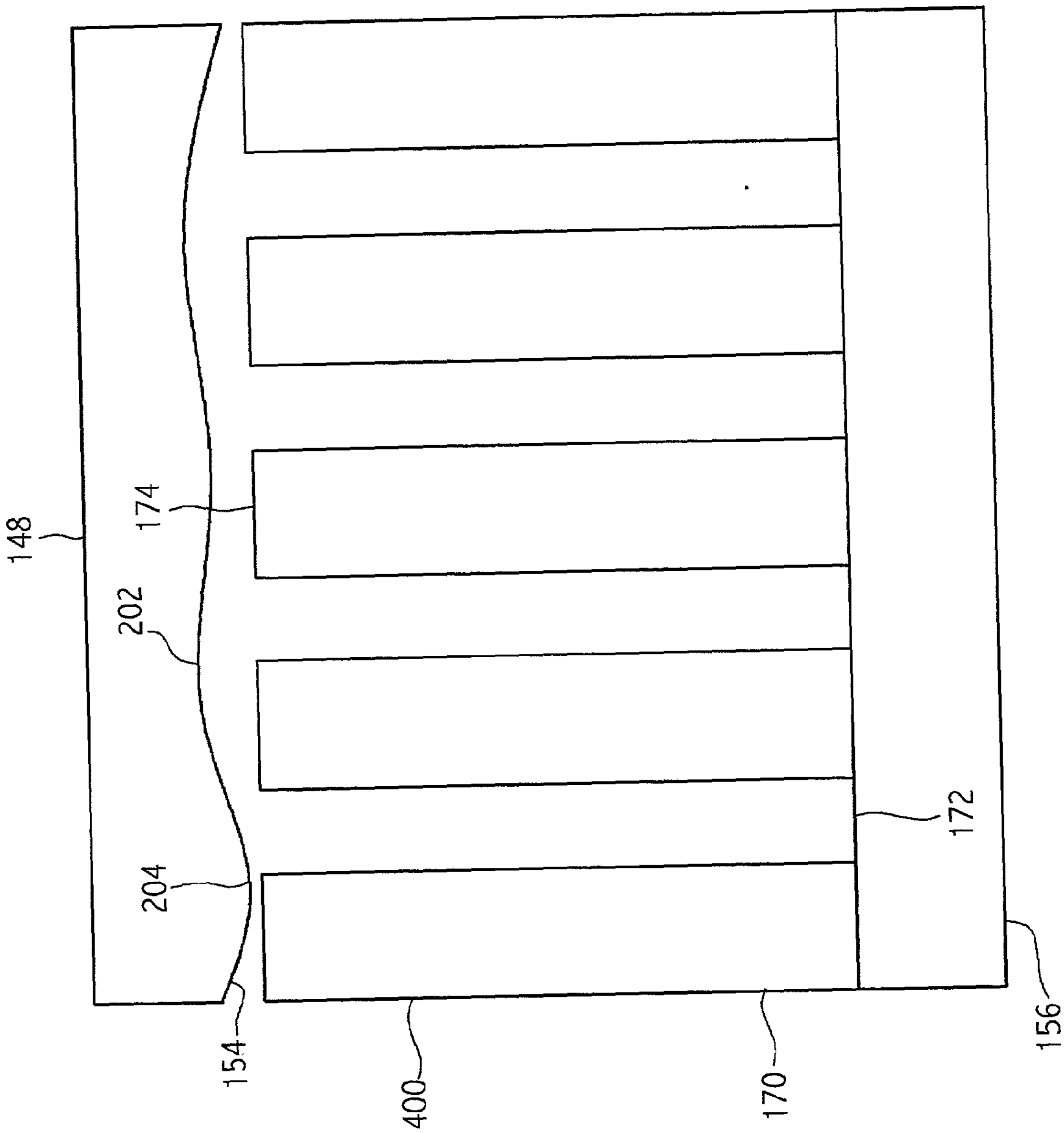



FIG. 4

# SELECTIVE METAL DEPOSITION FOR ELECTROCHEMICAL PLATING

## BACKGROUND OF THE INVENTION

**[0001]** 1. Field of the Invention

**[0002]** The present invention generally relates to a method and apparatus for selectively depositing metals onto a substrate.

**[0003]** 2. Description of the Related Art

**[0004]** The production of sub-micron sized semiconductor features is a key technology for the next generation of very large scale integration (VLSI) and ultra large scale integration (ULSI) semiconductor devices. However, next generation ULSI and VLSI devices require a substantial decrease in interconnect dimensions, thereby imposing substantial manufacturing demands. Further, the features, such as vias and other interconnects, that lie at the heart of these technologies require precise processing. Reliable formation of these features is important to the success of VLSI and ULSI devices, and to the continued effort to increase circuit density and quality of individual substrates. Electroplating and electroless plating techniques have been found to efficiently and effectively fill features on semi-conductor devices.

**[0005]** Copper has a lower resistivity, e.g., 1.7 $\mu\Omega$-cm compared to 3.1 $\mu\Omega$-cm for aluminum, and can carry a higher current density than aluminum. Therefore, it is generally desirable to use copper to form interconnects in semiconductor devices, rather than aluminum. Conventional copper electroplating solutions typically consist of copper sulfate, sulfuric acid and additives to aid in depositing copper on the surface of a substrate and in filling sub-micron sized features, e.g., vias and interconnects. The additives may include any combination of, but not limited to, levelers, brighteners, inhibitors, suppressors, enhancers, accelerators, and surfactants. The additives are typically organic molecules that adsorb onto the surface of the substrate. Certain additives may decrease the ionization rate of metal atoms, thereby inhibiting the deposition process, whereas other additives may increase the deposition rate of metal.

**[0006]** One problem encountered in electroplating copper on a substrate is that the flow of electroplating solution over the substrate may not be uniform. Non-uniform flow of the electroplating solution provides uneven distribution of the copper ions to the substrate, which can lead to variations in the plating rate on the substrate. Variations in the plating rate may result in an uneven depth of copper deposition on the substrate. In addition, the substrate features often have an uneven topography, which may lead to voids in the feature upon plating.

**[0007]** There is a need, therefore, for an apparatus and a method for selectively depositing a metal onto a substrate to provide uniform metal deposition across the substrate.

## SUMMARY OF THE INVENTION

**[0008]** Embodiments of the invention generally provide an apparatus for plating metal on a substrate having a plating cell configured to contain a plating solution therein, an anode disposed in the plating solution, and an anode spacer positioned in the plating cell. The anode spacer has an anode surface and a substrate contact surface positioned immediate a deposition surface of the substrate. The anode spacer is configured to communicate the plating solution to the surface of the substrate.

**[0009]** Embodiments of the invention further provide an apparatus for controlling metal deposition on a substrate. The apparatus includes an anode spacer, wherein the anode spacer has a periphery substantially equivalent to the periphery of the substrate. The anode spacer is generally configured to communicate a plating solution therethrough, and the anode spacer generally includes an anode surface and a substrate contact surface positioned immediate a deposition surface of the substrate.

**[0010]** Embodiments of the invention further provide a method for plating a metal on a substrate, wherein the method includes including positioning a substrate in a plating cell, positioning an anode spacer immediate a deposition surface of the substrate, and flowing a plating solution through the anode spacer to plate a metal onto the deposition surface.

**[0011]** Embodiments of the invention further provide an apparatus for plating metal on a substrate. The apparatus generally includes a plating cell configured to contain a plating solution therein, an anode disposed in the plating solution; and an anode spacer positioned in the plating cell. The anode spacer generally includes an anode surface, a substrate contact surface positioned a distance from a deposition surface of the substrate sufficient to uniformly plate a metal to a desired thickness, and a plurality of pores to communicate the plating solution to the deposition surface having an electrical resistance lower than the electrical resistance of the plating solution.

**[0012]** Embodiments of the invention further provide a method for plating a metal layer on a substrate. The method generally includes positioning a substrate having recessed locations and raised locations in a plating cell, positioning an anode spacer having a plurality of pores immediate a deposition surface of the substrate, and flowing a plating solution having a higher resistance than the plurality of pores through the plurality of pores, thereby plating the recessed locations until the substrate is in contact with the plurality of pores.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0013]** So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to the embodiments thereof, which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention, and are therefore, not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

**[0014]** **FIG. 1** is a cross sectional view of a cell for electroplating a metal onto a substrate.

**[0015]** **FIG. 2** is a cross sectional view of the anode spacer of an exemplary embodiment of the present invention.

**[0016]** **FIG. 3** is a cross sectional view of the anode spacer of an alternative embodiment of the present invention.

[0017] **FIG. 4** is a cross sectional view of the anode spacer of an alternative embodiment of the present invention.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0018] **FIG. 1** illustrates a partial cross sectional schematic view of an exemplary electroplating cell **100** of the invention. The electroplating cell **100** generally includes a container body **142** having an opening on a top portion of the container body **142** to receive and support a lid **144**. The container body **142** is preferably made of an electrically insulative material, such as a plastic, Teflon, or ceramic. The lid **144** serves as a top cover having a substrate supporting surface **146** disposed on the lower portion thereof. A substrate **148** is shown in parallel abutment to the substrate supporting surface **146**, and may be secured in this orientation via conventional substrate chucking methods. The container body **142** is preferably cylindrically shaped in order to accommodate the generally circular substrate **148** at one end thereof. However, other substrate shapes can be used as well.

[0019] An electroplating solution inlet **150** is disposed at the bottom portion of the container body **142**. An electroplating solution may be pumped into the container body **142** by a suitable pump **151** connected to the inlet **150**. The solution may flow upwardly inside the container body **142** toward the substrate **148** to contact the exposed deposition surface **154**. A consumable anode **156** may be disposed in the container body **142** and configured to dissolve in the electroplating solution in order to provide metal particles to be deposited onto the substrate **148** to the plating solution. The anode **156** generally does not extend across the entire width of the container body **142**, thus allowing the electroplating solution to flow between the outer surface of the anode **156** and the inner surface of the container body **176** to the deposition surface **154**. Alternatively, an anode **156** consisting of an electrode and consumable metal particles may be encased in a fluid permeable membrane, such as a porous ceramic plate, to provide metal particles to be deposited onto the substrate to the plating solution. A porous non-consumable anode may also be disposed in the container body **142** so that the electroplating solution may pass therethrough. However, when a non-consumable anode is included, the electroplating solution should include a metal particle supply to continually replenish the metal particles to be deposited on the substrate **148**.

[0020] The container body **142** generally includes an egress gap **158** bounded at an upper limit by a shoulder **164** of a cathode contact ring **152**. The gap **158** generally leads to an annular weir **143** that is substantially coplanar with (or slightly above) the substrate seating surface **168**, and thus, the deposition surface **154**. The weir **143** is positioned to ensure that the deposition surface **154** is in contact with the electroplating solution when the electroplating solution is flowing out of the egress gap **158** and over the weir **143**. During processing, the substrate **148** is secured to the substrate supporting surface **146** of the lid **144** by a plurality of vacuum passages **160** formed in the surface **146**, wherein passages **160** are generally connected at one end to a vacuum pump (not shown). The cathode contact ring **152**, which is shown disposed between the lid **144** and the container body **142**, is connected to a power supply **149** to provide power to the substrate **148**. The contact ring **152** generally has a perimeter flange **162** partially disposed through the lid **144**, a sloping shoulder **164** conforming to the weir **143**, and an inner substrate seating surface **168**, which defines the diameter of the deposition surface **154**. The shoulder **164** is provided so that the inner substrate seating surface **168** is located below the flange **162**. This geometry allows the deposition surface **154** to come into contact with the electroplating solution before the solution flows into the egress gap **158** as discussed above. However, as noted above, the contact ring design may be varied from that shown in **FIG. 1** without departing from the scope of the present invention. Thus, the angle of the shoulder portion **164** may be altered or the shoulder portion **164** may be eliminated altogether so that the contact ring is substantially planar. Where a planar design is used, seals may be disposed between the contact ring **152**, the container body **142** and/or the lid **144** to form a fluid tight seal therebetween.

[0021] The substrate seating surface **168** preferably extends a minimal radial distance inward below a perimeter edge of the substrate **148**, but a distance sufficient to establish electrical contact with a metal seed layer on the substrate deposition surface **154**. The exact inward radial extension of the substrate seating surface **168** may be varied according to application. However, in general this distance is minimized so that a maximum deposition surface **154** is exposed to the electroplating solution. In an exemplary embodiment, the radial width of the seating surface **168** is 2 mm from the edge.

[0022] Embodiments of the invention further include an anode spacer **170** disposed between the anode **156** and the deposition surface **154**. The anode spacer **170** includes and anode surface **172** and a substrate contact surface **174**. The anode surface **172** is positioned facing the anode **156**. The substrate contact surface **174** is positioned immediate the deposition surface of the substrate **154**. As used herein, substrate contact surface **174** generally refers to the surface of the anode spacer **170** nearest the deposition surface **154**. The substrate contact surface **174** is defined further in reference to the specific embodiments described below. As used herein, "immediate" refers to the substrate contact surface **174** being in physical contact and generally parallel to the deposition surface **154** when the substrate has been plated to a desired thickness, i.e., the substrate contact surface **174** may be in physical contact with the deposition surface **154** in some locations and may not be in physical contact with the deposition surface **154** in other locations, at any given time during plating, but substantially all of the substrate contact surface **174** will be in physical contact with the deposition surface **154** when the plating is complete.

[0023] The anode spacer **170** is generally constructed to be substantially rigid, wherein, the term "rigid" indicates sufficient structural rigidity of the anode spacer **170** to limit deformation or bending of the anode spacer **170** under the normal operational conditions in the process cell **100**. Such deformation would bend the anode spacer **170** so that the center is nearer the nearest location on the substrate **148** than the periphery is to its closest location on the substrate **148**. The anode spacer **170** generally has a periphery substantially equivalent to the periphery of the substrate **148**. The anode spacer **170** may be formed from any suitable, nonconductive, substantially rigid material, such as PEEK, i.e., polyethelether ketone, commercially available from Victrex, of Greenville, S.C., for example, or similar plastic materials.

[0024] The anode spacer **170** may be any vertical height and width sufficient to position the substrate contact surface **174** immediate with the deposition surface of the substrate **154**. The anode spacer's **170** vertical height may be between about 1 inch and about 12 inches. The anode spacer **170** may be disposed at any location in the container body **142** so that the substrate contact surface **174** is positioned immediate with deposition surface **154**. For example, the substrate contact surface **174** of the anode spacer **170** may be positioned to physically contact the thickest portions of the deposition surface prior to plating **154**, or the anode spacer **170** may be positioned so that the substrate contact surface **174** is a predetermined distance away from the thickest portion of the deposition surface **154**, where the predetermined distance is equal to a distance that will provide a desired thickness copper to be plated on the substrate **148**. In another embodiment, the anode spacer **170** may be positioned between the substrate seating surfaces **168**. It is also envisioned that the anode spacer **170** may be positioned above the inner substrate seating surface **168**, below and in contact with the substrate **148**. The anode spacer **170** may also be located anywhere in the container body **142** between the anode **156** and the substrate **148**, such that the substrate contact surface **174** is positioned immediate the deposition surface **154**. In an alternative embodiment, the anode spacer **170** may be secured to the cylindrical wall of the container body **142** so that the substrate contact surface **174** is immediate the deposition surface **146**. The anode spacer **170** may be applied to various process cells, having various anode configurations.

[0025] Embodiments of the invention further contemplate rotating the anode spacer **170** in relation to the substrate **148**, thereby providing more uniform metal deposition on the deposition surface **154**. Rotating the anode spacer **170** ensures that all locations on the deposition surface **154** have an even layer of metal deposition. Alternatively, the anode spacer **170** may be moved horizontally in relation to the substrate **148** to provide uniform metal deposition on the deposition surface **154**. Further still, the anode spacer **170** may be agitated to provide uniform metal deposition of the deposition surface **154**.

[0026] **FIG. 2** illustrates a cross sectional view of a substrate **148** and an anode spacer **170**. The anode spacer **170** includes a plurality of pores **200**, through which the plating solution flows. Substantially all of the plating solution flows through the pores to contact the substrate deposition surface **154**. The pores are sized to permit ions generated by the anode **156** to pass therethrough. However, larger portions of the anode **156**, such as shavings, byproducts, and other debris remaining in the solution (otherwise known collectively as anode sludge), do not flow through the anode spacer **170**, thereby keeping them from contacting the deposition surface **154**. The anode spacer **170** is designed with pores **200** having a diameter of between about 0.25 inches and about 1 inch. The anode spacer **170** may be formed of a metal, alloy, ceramic, plastic, or other suitable material. Although relatively few pores **200** are depicted in **FIG. 2**, in actuality, there may actually be a much larger number of pores **200**. Preferably, the pores **200** are arranged in a geometric array, and are horizontally spaced from each neighboring pore **200** by about 1/10 to about 1/2 of the pore's diameter. The pores **200** are generally of equal length and diameter. The substrate contact surface **174** of the anode spacer **170** is located adjacent the substrate deposition surface **154**, although the substrate contact surface **174** may be positioned a distance from the deposition surface **154** equal to the desired thickness of metal to be plated. The substrate contact surface **174** extends substantially across the anode spacer **170**.

[0027] The pores **200** may be lined with a conductive material to deliver electrical current from the anode **156** to the deposition surface **154** via the conductive pore surface or via the electroplating solution flowing through the pore **200**. The conductive pore lining may include any suitable conductive material for communicating plating solution therethrough, without attracting metal ions from the plating solution. The conductive material may be a metal, such as gold, platinum, or graphite.

[0028] In operation, the contact ring **152** is negatively charged to act as a cathode. As the electroplating solution is flowed across the substrate surface **154**, the ions in the electroplating solution are attracted to the surface **154** by the negative charge. The ions then react with the surface **154** to form the desired film. In addition to the anode **156** and the cathode contact ring **152**, an auxiliary electrode **167** may be used to control the shape of the electrical field over the deposition surface **154**. An auxiliary electrode **167** is shown disposed through the container body **142** adjacent an exhaust channel **169**. By positioning the auxiliary electrode **167** adjacent to the exhaust channel **169**, the electrode **167** able to maintain contact with the electroplating solution during processing and affect the electrical field.

[0029] Generally, ionic current flows to the deposition surface **154** via the conductive pore surface. At recessed substrate locations **204**, the pore lining is not in contact with the deposition surface **154**, therefore ionic current and electroplating solution flow to the deposition surface **154**. As a result, plating proceeds. When the conductive pore **200** is in contact with the deposition surface **154**, i.e., at raised substrate locations **202**, ionic current does not flow to the deposition surface **154**, and therefore, no metal is plated on the substrate **148** at that location **202**. Therefore, plating will continue at the recessed location **204** until the conductive lining of the pore **200** is in contact with the substrate deposition surface **154**, thereby filling the recessed locations **202** and forming a uniform metal layer on the substrate **148**.

[0030] In one embodiment, the resistance of the pores **200** is lower than the resistance of the electroplating solution in order to maximize the ionic current traveling to the deposition surface **154** via the conductive pore lining. Maximizing the electrical current traveling via the pore lining ensures that the recessed areas of the deposition surface **204** will plate until the pore **200** is in contact with the deposition surface **154**. At the point that the pore **200** contacts the deposition surface **154**, plating ceases because insufficient ionic current will travel to the deposition surface **154** to plate the metal. In an exemplary embodiment of the invention, the resistance of the conductive pores is about 10 times less than the resistance of the electroplating solution, thereby providing a higher current traveling to the lowest substrate surfaces via the pore lining.

[0031] Alternative embodiments of the invention may include a plurality of anode spacers **170** located immediate the deposition surface **154**. A plurality of anode spacers **170** may be included to provide local uniformity to individual portions of the deposition surface **154**, rather than having the highest portion of the deposition surface **154** determine the thickness of the entire substrate **148**. The spacers **170** may be positioned to cooperatively cover the deposition surface, either when stationary or upon rotation.

[**0032**] **FIG. 3** illustrates an alternative embodiment of the present invention. In this embodiment, the conductive inner surface of the pores **300** extends beyond the body of the anode spacer **170**. The plating solution flows from the anode **156** through the extended pores **300** to the deposition surface **154**. The substrate contact surface **174** is the position on the pore **300** closest the deposition surface, i.e., the part of the anode spacer **170** that will contact the deposition surface **154**. The pore extensions are generally of equal length and consist of the same conductive material as the body of the pore **300**. Alternative embodiments of the invention contemplate pores **300** of varying length, e.g., the pores **300** may be spring loaded **302**, to provide varying levels of local uniformity to the substrate **148**. Metal deposition generally will not occur on the pore extensions, because the conductive material is such that it does not attract metal ions. An example of a suitable material is graphite. The pore extensions may continue from the pore body or may be separate from the pore body.

[**0033**] Generally, current flows to the deposition surface **154** via the conductive pore extensions. At recessed substrate locations **204**, ionic current flows to the deposition surface **154**, and therefore, plating proceeds. When the conductive pore lining **300** is in contact with the deposition surface **154**, i.e., at raised substrate locations **202**, ionic current no longer flows to the deposition surface **154**, and therefore, no metal is plated on the substrate **148** at that location **202**. As a result, plating will continue at the recessed locations **204** until the conductive lining of the pore **300** is in contact with the substrate deposition surface **154**, thereby filling the recessed locations **202** and forming a uniform metal layer on the substrate **148**.

[**0034**] **FIG. 4** illustrates another embodiment of the present invention. The anode spacer **170** does not include pores, and therefore, no electroplating solution flows through the anode spacer **170**. In this embodiment, the anode spacer **170** comprises a plurality of cylindrical spacers consisting of a conductive material that are configured to extend from the anode **156** to the substrate deposition surface **154**. The conductive material may include any suitable conductive material conducting electrical current, without attracting metal ions from the plating solution. The conductive material may be a metal, such as gold, platinum, or graphite. No metal deposition will occur on the anode spacers **170** because the conductive material is such that it does not attract metal ions.

[**0035**] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

**1**. An apparatus for plating metal on a substrate, comprising:

a plating cell configured to contain a plating solution therein;

an anode disposed in the plating solution; and

an anode spacer positioned in the plating cell, the anode spacer comprising:

an anode surface; and

a substrate contact surface positioned immediate a deposition surface of the substrate, the anode spacer configured to communicate the plating solution therethrough.

**2**. The apparatus of claim 1, wherein the anode spacer is substantially rigid.

**3**. The apparatus of claim 1, wherein the anode spacer has a periphery substantially equivalent to a periphery of the substrate.

**4**. The apparatus of claim 1, wherein the substrate contact surface is positioned a distance from the substrate deposition surface equal to the thickness of the metal to be plated on the deposition surface.

**5**. The apparatus of claim 1, wherein an electrical current passes through a plurality of conductive pores formed into the anode spacer.

**6**. The apparatus of claim 1, wherein an electrical current passes through a plurality of conductive pores formed in the anode spacer and the plurality of conductive pore have an electrical resistance lower than an electrical resistance of the plating solution.

**7**. The apparatus of claim 1, wherein a plurality of pores disposed in the anode spacer interconnect the anode surface and the substrate contact surface.

**8**. The apparatus of claim 7, wherein each of the plurality of pores are of equal longitudinal length.

**9**. The apparatus of claim 7, wherein each of the plurality of pores are of equal diameter.

**10**. The apparatus of claim 7, wherein the plurality of pores are lined with a conductive material.

**11**. The apparatus of claim 7, wherein the plurality of pores are lined with at least one of gold, platinum, and graphite.

**12**. The apparatus of claim 7, wherein the plurality of pores are lined with a conductive material extending past the substrate contact surface.

**13**. The apparatus of claim 12, wherein the plurality of pores have an adjustable length.

**14**. The apparatus of claim 12, wherein each of the plurality of pores are lined with graphite extending past the substrate contact surface an equal longitudinal distance.

**15**. The apparatus of claim 1, wherein the anode spacer comprises a plurality of anode spacers.

**16**. The apparatus of claim 1, wherein the anode spacer further comprises a plurality of spacers extending from the anode toward the deposition surface.

**17**. The apparatus of claim 16, wherein the plurality of spacers are composed of a conductive material.

**18**. The apparatus of claim 16, wherein the plurality of spacers are composed of a conductive material selected from the group essentially comprising gold, platinum, and graphite.

**19**. A method for plating a metal layer on a substrate, comprising:

positioning a substrate in a plating cell;

positioning an anode spacer immediate a deposition surface of the substrate;

and

flowing a plating solution through the anode spacer to plate a metal onto the deposition surface.

**20**. The method of claim 19, further comprising rotating the anode spacer in relation to the deposition surface.

**21**. The method of claim 19, wherein flowing a plating solution through the anode spacer comprises flowing the plating solution through a plurality of pores extending through the anode spacer.

**22**. The method of claim 19, wherein flowing a plating solution through the anode spacer comprises flowing the plating solution through a plurality of pores extending through the anode spacer lined with a conductive material.

**23**. The method of claim 19, wherein flowing a plating solution through the anode spacer comprises flowing the plating solution through a plurality of pores extending through the anode spacer lined with a conductive material selected from the group essentially comprising gold, platinum, and graphite.

**24**. The method of claim 19, further comprising generating an electrical bias between an anode and the substrate.

**25**. The method of claim 19, further comprising generating an electrical current to pass from an anode to the substrate through a plurality of conductive pores in the anode spacer.

**26**. The method of claim 19, wherein the metal is copper.

**27**. The method of claim 19, wherein positioning the anode spacer comprises positioning a plurality of anode spacers.

**28**. The method of claim 19, wherein positioning the anode spacer comprises positioning a plurality of anode spacers in contact with the anode extending toward the deposition surface.

**29**. The method of claim 28, wherein the plurality of spacers are composed of a conductive material.

**30**. The method of claim 28, wherein the plurality of spacers are composed of gold, platinum, or graphite, or a combination thereof.

**31**. An apparatus for controlling metal deposition on a substrate, comprising an anode spacer, wherein the anode spacer has a periphery substantially equivalent to the periphery of the substrate, the anode spacer is configured to communicate a plating solution therethrough, and the anode spacer includes an anode surface and a substrate contact surface positioned immediate a deposition surface of the substrate.

**32**. The apparatus of claim 31, wherein the anode spacer is substantially rigid.

**33**. The apparatus of claim 31, wherein a plurality of pores interconnect the anode surface and the substrate contact surface.

**34**. The apparatus of claim 33, wherein each of the plurality of pores are of equal longitudinal length.

**35**. The apparatus of claim 33, wherein each of the plurality of pores are of equal diameter.

**36**. The apparatus of claim 33, wherein the plurality of pores are lined with a conductive material.

**37**. The apparatus of claim 33, wherein the plurality of pores are lined with gold, platinum, or graphite, or a combination thereof.

**38**. The apparatus of claim 33, wherein the plurality of pores are lined with a conductive material extending beyond the substrate contact surface.

**39**. The apparatus of claim 38, wherein the plurality of pores have an adjustable length.

**40**. The apparatus of claim 33, wherein each of the plurality of pores are lined with graphite extending past the substrate contact surface an equal longitudinal distance.

**41**. The apparatus of claim 31, wherein the anode spacer comprises a plurality of anode spacers.

**42**. The apparatus of claim 31, wherein the anode spacer further comprises a plurality of cylindrical spacers of equal longitudinal length and diameter.

**43**. The apparatus of claim 42, wherein the plurality of spacers are composed of a conductive material.

**44**. The apparatus of claim 42, wherein the plurality of spacers are composed of a conductive material selected from the group essentially comprising gold, platinum, and graphite.

**45**. An apparatus for plating metal on a substrate, comprising:

a plating cell configured to contain a plating solution therein;

an anode disposed in the plating solution; and

an anode spacer positioned in the plating cell, the anode spacer comprising:

an anode surface;

a substrate contact surface positioned a distance from a deposition surface of the substrate sufficient to uniformly plate a metal to a desired thickness; and

a plurality of pores to communicate the plating solution to the deposition surface having an electrical resistance higher than the electrical resistance of the plating solution.

**46**. The apparatus of claim 45, wherein the anode spacer is substantially rigid.

**47**. The apparatus of claim 45, wherein the anode spacer has a periphery substantially equivalent to a periphery of the substrate.

**48**. The apparatus of claim 45, wherein the plurality of pores are of equal longitudinal length.

**49**. The apparatus of claim 45, wherein each of the plurality of pores are of equal diameter.

**50**. The apparatus of claim 45, wherein the plurality of pores are lined with a conductive material.

**51**. The apparatus of claim 45, wherein the plurality of pores are lined with at least one of gold, platinum, and graphite.

**52**. The apparatus of claim 45, wherein the plurality of pores are lined with a conductive material extending past the substrate contact surface.

**53**. The apparatus of claim 52, wherein the plurality of pores have an adjustable length.

**54**. The apparatus of claim 52, wherein each of the plurality of pores are lined with graphite extending past the substrate contact surface an equal longitudinal distance.

**55**. The apparatus of claim 45, wherein the anode spacer comprises a plurality of anode spacers.

**56**. A method for plating a metal layer on a substrate, comprising:

positioning a substrate having recessed locations and raised locations in a plating cell;

positioning an anode spacer having a plurality of pores immediate a deposition surface of the substrate; and flowing a plating solution having a higher resistance than the plurality of pores through the plurality of pores thereby plating the recessed locations until the substrate is in contact with the plurality of pores.

**57**. The method of claim 56, further comprising rotating the anode spacer in relation to the deposition surface.

**58**. The method of claim 56, wherein the plurality of pores extend through the anode spacer.

**59**. The method of claim 56, wherein flowing a plating solution through the plurality of pores comprises flowing the plating solution through a plurality of pores lined with a conductive material extending through the anode spacer.

**60**. The method of claim 56, wherein flowing a plating solution through the plurality of pores comprises flowing the plating solution through a plurality of pores extending through the anode spacer lined with a conductive material selected from the group essentially comprising gold, platinum, and graphite.

**61**. The method of claim 56, wherein positioning the anode spacer comprises positioning a plurality of anode spacers in contact with the anode extending toward the deposition surface.

**62**. The method of claim 61, wherein the plurality of spacers are composed of a conductive material.

* * * * *