

(19) World Intellectual Property
Organization
International Bureau



(43) International Publication Date
29 January 2004 (29.01.2004)

PCT

(10) International Publication Number
WO 2004/009875 A2

(51) International Patent Classification⁷: **C25D**

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(21) International Application Number:
PCT/US2003/022996

(22) International Filing Date: 24 July 2003 (24.07.2003)

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(25) Filing Language: English

(81) Designated States (*national*): CN, JP, KR, SG.

(26) Publication Language: English

(30) Priority Data:
60/398,336 24 July 2002 (24.07.2002) US
10/266,477 7 October 2002 (07.10.2002) US

(84) Designated States (*regional*): European patent (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PT, RO, SE, SI, SK, TR).

Published:

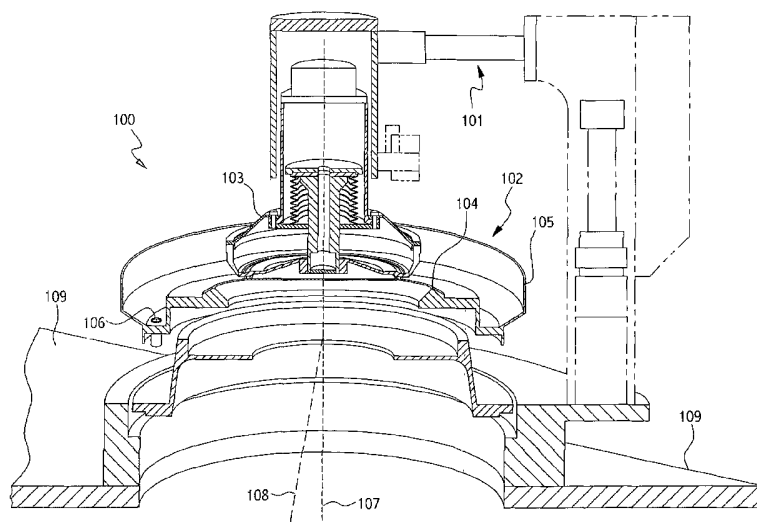
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— *without international search report and to be republished upon receipt of that report*

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For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: **TILTED ELECTROCHEMICAL PLATING CELL WITH CONSTANT WAFER IMMERSION ANGLE**



(57) **Abstract:** A method and apparatus for immersing a substrate for plating operations. The apparatus generally includes a plating cell configured contain a plating solution therein. The plating cell includes at least one fluid basin, a diffusion plate position in a lower portion of the at least one fluid basin, and an anode positioned below the diffusion plate, the anode and the diffusion plate being positioned in parallel orientation with each other and in a tilted orientation with respect to horizontal. The apparatus further includes a head assembly positioned proximate the plating cell, the head assembly including a base member, an actuator positioned at a distal end of the base member, and a substrate support assembly in mechanical communication with the actuator, the substrate support assembly being configured to support a substrate in the at least one fluid basin for processing in an orientation that is generally parallel to the diffusion plate.

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TILTED ELECTROCHEMICAL PLATING CELL WITH CONSTANT WAFER IMMERSION ANGLE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims benefit of United States provisional patent application serial number 60/398,336, filed July 24, 2002, which is herein incorporated by reference.

BACKGROUND OF THE INVENTION

Field of the Invention

[0002] Embodiments of the invention generally relate to an electrochemical plating cell, and more particularly, to an electrochemical plating cell having an axis of symmetry that is skewed or tilted from vertical.

Description of the Related Art

[0003] Metallization of sub-quarter micron sized features is a foundational technology for present and future generations of integrated circuit manufacturing processes. More particularly, in devices such as ultra large scale integration-type devices, *i.e.*, devices having integrated circuits with more than a million logic gates, the multilevel interconnects that lie at the heart of these devices are generally formed by filling high aspect ratio (greater than about 4:1, for example) interconnect features with a conductive material, such as copper or aluminum, for example. Conventionally, deposition techniques such as chemical vapor deposition (CVD) and physical vapor deposition (PVD) have been used to fill these interconnect features. However, as the interconnect sizes decrease and aspect ratios increase, *i.e.*, up to about 15:1 or greater, void-free interconnect feature fill via conventional metallization techniques become increasingly difficult. As a result thereof, plating techniques, such as electrochemical plating (ECP), for example, have emerged as promising

processes for void free filling of sub-quarter micron sized high aspect ratio interconnect features in integrated circuit manufacturing processes.

[0004] In an ECP process, for example, sub-quarter micron sized high aspect ratio features formed into the surface of a substrate (or a dielectric layer deposited thereon) may be efficiently filled with a conductive material, such as copper, for example. ECP plating processes are generally two stage processes, wherein a seed layer is first formed over the surface features of the substrate, and then the surface features of the substrate are exposed to an electrolyte solution, while an electrical bias is simultaneously applied between the substrate and a copper anode positioned within the electrolyte solution. The electrolyte solution is generally rich in copper ions to be plated onto the surface of the substrate, and therefore, the application of the electrical bias causes these copper ions to be plated onto the seed layer, thus filling the features.

[0005] One critical aspect of an ECP process is the substrate immersion process, which generally includes securing the substrate to a cathode contact and immersing the substrate and at least a portion of the cathode contact during into an electrolyte solution. During this process, it is desirable to immerse the substrate into the electrolyte solution in a relatively quick manner. However, it is extremely important to immerse the substrate into the electrolyte solution without leaving or forming any bubbles or air pockets on the substrate surface, as bubbles or air pockets on the substrate surface are generally known to cause plating uniformity problems. Therefore, conventional electrochemical plating cells generally utilize a pivotally mounted head assembly configured to immerse the substrate and cathode contact ring during into the electrolyte solution in a pivoting motion. This pivoting motion generally operates to begin immersion of the substrate at first edge and continue the immersion process across the surface of the substrate until the entire surface area is immersed in the electrolyte solution.

[0006] However, as a result of the pivot point that is utilized to generate the pivotal substrate immersion process, the angle at which the substrate engages the electrolyte solution during the immersion process varies from the time the substrate initially engages the electrolyte solution until the time at which the substrate is

completely immersed in the electrolyte solution. This varying immersion angle creates difficulty in bubble prevention processes, and further, may facilitate plating nonuniformities resulting from the varying angle of the substrate relative to the anode during the immersion process.

[0007] Therefore, there is a need for an apparatus and method for electrochemically plating metal onto substrates, wherein the apparatus and method includes an immersion process configured to maintain the surface of the substrate in an orientation parallel to an anode throughout the immersion and plating processes.

SUMMARY OF THE INVENTION

[0008] Embodiments of the invention generally provide an apparatus for immersing a substrate for plating operations. The apparatus generally includes a plating cell configured contain a plating solution therein. The plating cell includes at least one fluid basin, a diffusion plate position in a lower portion of the at least one fluid basin, and an anode positioned below the diffusion plate, the anode and the diffusion plate being positioned in parallel orientation with each other and in a tilted orientation with respect to horizontal. The apparatus further includes a head assembly positioned proximate the plating cell, the head assembly including a base member, an actuator positioned at a distal end of the base member, and a substrate support assembly in mechanical communication with the actuator, the substrate support assembly being configured to support a substrate in the at least one fluid basin for processing in an orientation that is generally parallel to the diffusion plate.

[0009] Embodiments of the invention further provide an apparatus for electrochemically plating a metal onto a substrate. The apparatus includes a plating cell configured contain a plating solution therein, the plating cell being mounted in a tilted orientation with respect to horizontal, and a head assembly positioned proximate the plating cell and being configured to support a substrate for processing in the plating cell, the head assembly having a symmetric axis that is tilted with respect to vertical.

[0010] Embodiments of the invention further provide a method for immersing a substrate into an electrochemical plating solution. The method includes securing a substrate to a substrate support assembly, the substrate support assembly being

configured to support the substrate in a plane that is tilted at a first tilt angle from horizontal. The method further includes longitudinally extending the substrate support assembly into an electroplating bath contained within an electroplating cell to immerse a production surface of the substrate, the electroplating cell being configured such that an anode, a diffusion plate, and an inner basin are mounted at a second tilt angle with respect to horizontal, wherein the second tilt angle is substantially orthogonal to the first tilt angle.

BRIEF DESCRIPTION OF THE DRAWINGS

[0011] 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 embodiments, some of 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.

[0012] Figure 1 illustrates a partial perspective sectional view of an exemplary plating cell of the invention.

[0013] Figure 2 illustrates a sectional view of an exemplary electrolyte container of the invention.

[0014] Figure 3 illustrates a sectional view of an exemplary head assembly and contact ring configured to electrically contact a production surface of the substrate being plated during plating operations.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0015] The present invention generally provides an electrochemical plating cell having a vertical axis of symmetry that is tilted or skewed from a conventional orthogonal orientation relative to a generally horizontal surface upon which the ECP cell sits. The tilted axis, which is generally tilted between about 3° and about 30° from vertical or 90°, generally provides for an ECP cell having a corresponding tilted head assembly and a tilted electrolyte solution container positioned thereunder. Each of the components of the head assembly and the electrolyte solution container, *i.e.*, the contact ring, anode, separation membranes, diffusion plates, etc. are

correspondingly tilted such that the surface of a substrate positioned on a substrate support member/contact ring in mechanical communication with the head assembly is maintained in a substantially parallel orientation with an upper surface of the anode positioned within the electrochemical plating solution bath.

[0016] Figure 1 illustrates an exemplary tilted ECP cell 100 and head assembly 101 of the invention. Head assembly 101 is generally positioned immediately above a cell or container 102 configured to maintain an electrochemical plating solution therein. Head assembly 101 is generally configured to support a substrate support assembly 103 on a lower distal extending portion. Head assembly 101 may provide pivotal movement, rotational movement, and axial movement to substrate support assembly 103, as desired. Electrolyte solution container or cell 102 generally includes an inner solution basin 104 positioned circumferentially within an outer solution basin 105. The inner solution basin 104, which is generally configured to maintain a plating solution used to support the plating process therein, generally overflows and upper portion of inner basin 104 into outer basin 105. As such, outer basin 105 generally includes a drain 106 positioned in a lower portion thereof, wherein drain 106 is configured to remove the excess electrolyte plating solution received in outer basin 104.

[0017] Figure 1 also illustrates the orientation of head assembly 101 and substrate support assembly 103 relative to the electrolyte solution container 102. For example, symmetric axis 107 generally runs through the center of electrolyte solution container 102, substrate support assembly 103, and the vertical portion of head assembly 101. As such, the components surrounding symmetric axis 107 are generally symmetric about axis 107. Further, symmetric axis 107 is generally tilted or skewed from a vertical axis 108, wherein the vertical axis 108 is generally orthogonal to a horizontally positioned base plate 109. The tilt angle, *i.e.*, the angle between symmetric axis 107 and vertical axis 108, is generally between about 3° and about 30°. However, embodiments of the invention contemplate that the tilt angle may be between about 5° and about 25°, between about 5° and about 10°, or between about 5° and about 15°, for example. However, embodiments of the invention are not intended to be limited to any particular range of tilt angle, as the

inventors contemplate that the tilt angle may be any range between about 3° and about 30°.

[0018] Figure 2 illustrates an embodiment of the exemplary electrolyte container or cell 102 of the invention. As briefly described with respect to Figure 1, the electrolyte container 102 generally includes an inner basin 104 positioned radially inward from an outer basin 105. The inner basin 104 generally operates to contain a plating solution therein in a manner that allows the substrate support assembly 103 to position a substrate within the plating solution during plating operations. The inner basin 104 generally includes sloped sides that terminate at a common upper point 206, and therefore, the electrolyte solution supplied to the area within inner basin 104 may flow over the common upper point 206 in order to create a substantially planar upper fluid surface and maintain a constant volume of electrolyte solution in the inner basin 104. The electrolyte solution flowing over the common upper point 206 is received in the outer basin 105 and drained therefrom via drain 106. The central portion of inner basin 104 generally includes an open volume or bath 207 where the electrolyte solution used for plating operations is contained. The lower portion of inner basin, *i.e.*, the portion below the sloping sides, generally includes a short vertically extending wall. This wall portion of basin 104 generally corresponds to the position where a substrate to be plated will be positioned, *i.e.*, the wall portion will be positioned immediately below and substrate being plated. Therefore, in order to control field lines near the perimeter of the substrate during plating operations, the diameter of the wall is generally selected to be slightly less than the diameter of a substrate being plated. For example, for a 200mm substrate, the diameter of the wall will generally be between about 190mm and about 200mm. The lower portion of volume 207 is generally bounded by a diffusion plate 208, which may, for example, consist of a disk shaped porous ceramic plate that may essentially operate as a virtual anode. Additionally, diffusion plate 208 may be configured to provide some degree of control over plating parameters such as deposition uniformity, for example, through material selection, positioning of the diffusion plate, and the pore size.

[0019] Immediately below diffusion plate 208 is a second open volume 209, where the electrolyte solution used for plating operations is introduced into prior to

traveling through diffusion plate 208 to contact the substrate for plating operations. Fluid for plating operations, *i.e.*, the electrolyte plating solution, is generally supplied to open area 209 via one or more electrolyte solution inlets 214, which is generally in fluid communication with an electrolyte supply source (not shown). The fluid supplied to open area 209 for plating operations generally includes a base electrolyte solution along with one or more plating additives configured to control various plating parameters. The plating additives, which are generally organic additives, may include levelers, suppressers, accelerators, and/or other additives generally used to control an electrochemical plating process.

[0020] An anode assembly 211 is generally positioned below open space 209 and is configured to supply metal ions to the plating solution for plating operations. The anode assembly 211 may be separated from the open volume 209 via a membrane 210. The anode assembly 211 generally includes a disk shaped metal anode member, which may be copper or phosphorized copper, for example, in a copper ECP system. The positioning of membrane 210 generally operates to provide an open volume between the lower surface of membrane 210 and an upper surface of anode 211. This space between membrane 210 and the upper surface of anode 211 is generally in fluid communication with at least one second fluid inlet 212 configured to supply a fluid solution to the volume immediately above the anode 211 and below the membrane 210. Additionally, the area below membrane 210 and above anode 211 may also be in fluid communication with at least one fluid drain 213 configured to remove fluid from the area immediately above anode 211. As such, cooperative operation of fluid supply inlet 212 and fluid drain 213 allows for the fluid introduced into the region immediately above anode 211 to be removed therefrom by fluid drain 213, without the fluid transferring through the membrane 210 into open area 209. This configuration allows for isolation of the anode assembly 211 from the cathode region of the plating cell, and more particularly, allows for isolation of contaminants generated at the surface of the anode, *i.e.*, organic additive breakdown, copper balls, etc., from traveling from the anode surface and depositing on the production surface of the substrate and generating a defect.

[0021] Further, the fluid supplied to open area 209 is generally an electrochemical plating-type solution. However, the solution supplied to open area

209 does not generally contain the plating solution additives that are included in the solution that is used in the plating operation, *i.e.*, the solution supplied to open area 209. Furthermore, the membrane 210 is generally an ion exchange-type membrane, and therefore, fluid flow through membrane 210 is generally prohibited. Rather, membrane 210 generally allows only ions to flow therethrough, *i.e.*, hydrogen ions and copper ions in a copper ECP system. Therefore, the positioning of membrane 210 generally operates to isolate the anode 211 from the substrate being plated, which is operating as a cathode, as the substrate is generally in electrical communication with a cathode terminal of a power supply and the anode is in electrical communication with the anode terminal of the power supply. As such, the volume proximate the substrate being plated may generally be characterized as a cathode chamber, while the volume proximate the anode, *i.e.*, the volume below membrane 210 and above the upper surface of anode 211, may generally be characterized as an anode chamber. This isolation of anode 211 from the substrate being plated generally operates to prevent additives in the plating solution that degrade upon contact with the anode from traveling to the substrate being plated and causing plating defects. The positioning of the membrane 210 between the anode and the substrate allows for the capture or prevention of these degraded solution additives from traveling from the anode 211 to the substrate surface. Furthermore, the implementation of fluid inlet 212 in conjunction with fluid drain 213, both of which are exclusively in fluid communication with the anode compartment, *i.e.*, the volume immediately above the anode surface and immediately below the lower surface of membrane 210, further facilitates prevention of degraded solution additives from traveling from the anode to the substrate being plated. More particularly, inasmuch as the fluid provided to the anode compartment is circulated out of the anode compartment without traveling into the cathode compartment, degraded solution additives are removed from the plating cell altogether before they have a chance to circulate through the membrane 210 into the cathode compartment and cause defects on the plating surface.

[0022] The respective components of plating cell 102 are generally tilted to an angle that may generally correspond to the tilt angle of head assembly 300. For example, plating cell 102 may be tilted from a conventional horizontal position to a

position where one side of the plating cell 102 is elevated higher than an opposing side of plating cell 102. As illustrated in Figure 1, the side of plating cell 102 positioned closest to the base portion of head assembly 101 may be slightly elevated, such that angle, *i.e.*, a tilt angle, formed between the substantially horizontal base portion 109 and the now tilted plating cell 102 is between about 3° and about 30°. The tilt angle of plating cell 102 may be configured to correspond with the tilt angle of axis 107 of head assembly 101. Once tilted, fluid dispensed into inner basin 104 will generally run over an upper portion of inner basin 104 at the lowest point. As such, the electrolyte solution supplied to inner basin 104 will generally run over the inner basin 104 on the left side of basin 104 in the exemplary plating cell illustrated in Figure 1, as the left side of plating cell 102 is lower than the right side, *i.e.*, the side closest to the base of head assembly 101. Therefore, in order to maintain an adequate depth of the plating solution within inner basin 104 in the presence of the tilted configuration, one side of the inner basin 104 is generally manufactured to be taller than an opposing side. In this configuration the taller side of the inner basin 104 may be positioned on the lower side of the tilted cell 102, and thus, allow for an adequate volume of fluid to be maintained within inner basin 104. Further, since outer basin 105 is also tilted, fluid drain 106 is generally located on the low side of the tilted cell 102, so that the fluid that overflows inner basin 104 into outer basin 105 may be collected by drain 106 as it flows downwardly thereto.

[0023] In addition to both inner basin 104 and outer basin 105 being tilted in accordance with the tilt angle, the remaining components of plating cell 102 are also generally tilted to a corresponding angle. For example, as illustrated in Figure 2, the anode assembly 211, membrane 210, and diffusion plate 208 are also generally tilted to the corresponding tilt angle. Therefore, since the tilt angle of the components of the plating cell 102 generally corresponds to the tilt angle of head assembly 300, substrate secured to head assembly 300 will generally have a plating surface that is in parallel orientation with the diffusion plate 208, membrane 210, and anode assembly 211. However, it is to be noted that inasmuch as plating cell 102 is tilted, the fluid contained within inner basin 104 will generally have an upper surface that is not parallel to the diffusion plate 208, membrane 210, or anode assembly

211. Rather, the upper surface of the fluid contained within inner basin 104 will remain parallel to the horizontal surface 109 upon which plating cell 102 is mounted.

[0024] Additionally, plating cell 102 is generally configured as a low-volume plating cell. More particularly, the volume of electrolyte solution contained within inner basin 104, *i.e.*, the volume of electrolyte solution within basin 104 is used for plating operations, is generally less than about one to two liters for a basin having a diameter of about 300 mm, which is substantially smaller than conventional cells that generally hold about 6 liters. Therefore, given the diameter of inner basin 104 of about 300 mm, the depth of the electrolyte solution within inner basin 104 having about 1 liter of electrolyte solution therein will generally be less than about 2.5cm. More particularly, the depth of the electrolyte solution within inner basin 105 may be between about 1 mm and about 20 mm, or between about 5mm and about 15mm, for example. Solution depths are generally measured from the top of the diffusion plate 208 to the fluid level. However, since cell 102 is tilted, the depth is generally measured on the top side of the tilted cell 102, and as such, the depth will generally represent a minimum depth of the solution within basin 104. In this configuration, when head assembly 101 operates to position a substrate for plating operations within the electrolyte solution contained by inner basin 104, the surface of the substrate being plated will generally be positioned between about 1 mm and about 10 mm away from the upper surface of diffusion plate 208. However, one side of the production surface of the substrate will generally be immersed in the solution to a greater depth than an opposing side (perimeter points on a diameter of the substrate) of the production surface of the substrate. This results from maintaining the substrate generally parallel to the anode 211 and diffusion plate 208 surface, while the cell 102 is tilted, which results in a fluid surface that is not parallel to the anode 211, diffusion plate 208, or the substrate surface being plated. The low-volume plating cell 102 provides several advantages, namely, reduced electrolyte solution required for plating.

[0025] Figure 3 illustrates a sectional view of an exemplary substrate support member 103 of the invention. Substrate support member 103 may include a head assembly 300 and contact ring 301 configured to electrically contact a production surface of the substrate being plated during plating operations. Head assembly 300

generally supports a longitudinally actuated thrust plate 302 at a lower end. Thrust plate 302 is in mechanical communication with actuator 305, which is generally configured to impart rotational and longitudinal movement to thrust plate 302, *i.e.*, actuator 305 is able to both rotate thrust plate 302 as well as move thrust plate 302 up and down along the longitudinal axis of head assembly 300. The longitudinal movement of thrust plate 302 generally operates to move thrust plate 302 between a processing position and a substrate loading position. The processing position generally corresponds to a position wherein the thrust plate 302 is raised or moved away from a lower surface of the contact ring so that a substrate may be positioned on the contact ring. The processing position generally corresponds to a position where the thrust plate 302 is lowered to a position proximate the contact ring 301 in order to secure a substrate to contact ring 301 for processing. The lower surface to thrust plate 302 generally includes at least one seal member of 303 positioned proximate the perimeter of thrust plate 302. Head assembly 300 further includes a contact ring 301 positioned circumferentially outward of thrust plate 302 and generally below the lower surface of thrust plate 302. Contact ring 301 includes a plurality of radially positioned contact pins 304, which are generally in electrical communication with a cathode terminal of a power supply (not shown).

[0026] In another embodiment of the invention, head assembly 300 may be configured to electrically contact the nonproduction surface of a substrate being plated. In this embodiment, thrust plate 302 and contact ring 301 are generally replaced by an annular substrate support member (not shown) affixed to the lower portion of head assembly 300. The substrate support member, which is attached to actuator 305, generally includes a plurality of radially positioned contact pins positioned on the lower surface of the substrate support member, *i.e.*, the surface of the substrate support member facing away from head assembly 300. The lower surface of the substrate support member may further include a plurality of vacuum channels formed into the middle or interior region of the lower surface, as well as one or more seals positioned proximate the perimeter of the lower surface. In this embodiment, the plurality of vacuum channels may be used to vacuum chuck a substrate to the lower surface of the substrate support member. The process of vacuum chucking the substrate to the lower surface of the substrate support

member generally causes the radially positioned contact pins to electrically engage the backside of the substrate. The electrical power supplied to the backside of the substrate is then communicated to the production surface of the substrate via a conductive layer that is deposited over the bevel edge and onto the backside of the substrate.

[0027] In operation, the tilted ECP cell of the invention allows for immersion of a substrate into an electrochemical plating solution, while maintaining a constant angle between the substrate surface and the surface of the electrolyte solution contained in the plating cell. Further, the ECP cell of the invention allows for the surface of the substrate to be maintained in a generally parallel orientation with the upper surface of the anode during the substrate immersion and plating processes. Maintaining these orientations of the substrate surface relative to the electrolyte solution and the upper surface of the anode provides for a bubble free immersion process and eliminates plating uniformity problems generated by conventional pivot entry/immersion-type electrochemical plating systems that do not maintain the substrate surface parallel to the anode surface during the immersion process.

[0028] The process of electrochemically plating metal onto the substrate begins with positioning the substrate to be plated in the ECP cell of the invention. The positioning process generally includes engaging the substrate with a robot (not shown), and placing the substrate to be plated onto the lower surface of the cathode contact ring 301. Contact ring 301 generally includes a gradually tapering lower portion, as illustrated in Figure 3, which operates to center the substrate within the annular contact ring during the placement process. Further, the lower surface of contact ring 301, which is generally horizontal, includes the plurality of electrical contact pins 304 extending therefrom. The contact pins 304 are generally positioned in an annular pattern around the lower surface of contact ring 301, and therefore, when the substrate to be plated is positioned on contact ring 301, the contact pins 304 generally contact the outer perimeter portion of the production surface of the substrate. However, with the substrate simply resting on the contact pins 304, there is generally not enough downward force to maintain sufficient electrical contact between contact pins 304 and the production surface of the substrate for electrochemical plating. Therefore, once the substrate is positioned on

contact ring 301, thrust plate 302 may be lowered by actuator 305 into a processing position. The process of lowering thrust plate 302 into a processing position generally includes contacting the nonproduction side of the substrate positioned on contact ring 301, and mechanically biasing the production side of the substrate against the contact ring 301 and pins 304. This mechanical biasing process may, for example, include inflation of a bladder assembly positioned on the lower surface of thrust plate 301, wherein inflation of the bladder generally operates to push or urge the substrate against the contact pins 304 of contact ring 301. Further, the process of mechanically biasing the substrate against contact pins 304 may also operate to engage one or more seals 303 positioned on the lower surface of thrust plate 302 with the nonproduction or backside of the substrate.

[0029] Once the substrate is biased against contact pins 304 and seals 303 have engaged the backside of the substrate, the process of immersing the substrate into the electrolyte solution contained within inner basin 104 may be conducted. The immersion process generally includes submerging the substrate in the electrolyte solution contained within inner basin 104, while simultaneously applying an electrical loading bias to the substrate. The loading bias is generally configured to cause a minimal amount of plating on the substrate during the immersion process, such that any etching affects resulting from exposure of a seed layer on the substrate to the acidic electrolyte solution may be avoided, as the discontinuities in the seed layer resulting from these etching processes is known to cause plating uniformity problems. Therefore, once an electrical power supply configured to provide the loading biased to the substrate is activated, actuator 305 may be activated in order to cause the thrust plate 302 and contact ring assembly 301 to be submerged or immersed in the electrolyte solution contained within inner basin 304.

[0030] The submerging or immersion process generally includes extending the contact ring 301 and thrust plate assembly 302 downwards away from head assembly 300, such that contact ring 301 and thrust plate 302, as well as a substrate positioned therebetween, may be submerged in the electrolyte solution. Further, the contact ring 301 and thrust plate assembly 302 may be configured to be rotated during the extension and immersion process, as well as during subsequent plating processes. As a result of the tilting of plating cell 102 and head assembly

300, as the substrate positioned on contact ring 301 is gradually immersed into the electrolyte solution via the longitudinal extension of contact ring 301 from head assembly 300, the angle between the substrate surface and the surface of the electrolyte solution contained within inner basin 104 is maintained constant. As such, bubbles and air pockets that may be formed proximate the substrate surface during the immersion process may be gradually and constantly urged upward via the immersion angle of the substrate relative to the electrolyte solution surface and caused to exit to the substrate surface at the perimeter thereof.

[0031] Furthermore, since the upper surface of anode 211 is also tilted to an angle corresponding to the tilted angle of both head assembly 300 and container 102, the upper surface of anode 211 remains parallel to the surface of the substrate during the entire immersion process, as well as during subsequent plating processes. This parallel orientation between the substrate being immersed and the upper surface of the anode provides for improved plating uniformity characteristics over conventional pivot-type immersion plating cells, as the anode in pivot-type immersion plating cells is not maintained parallel to or at a constant angle relative to the substrate being immersed in the electrolyte solution. This parallel orientation is important, as plating characteristics on a substrate are known to be directly proportional to the distance from the anode to the plating surface. Therefore, maintaining the plating surface in parallel orientation with the anode during both the immersion and plating processes has shown to provide improved uniformity characteristics in electric chemical plating processes.

[0032] Although illustrations of the present invention generally depict the head assembly 300 and electrolyte container 102 both being tilted to a corresponding or equal angle, embodiments of the invention contemplate that the head assembly 300 and electrolyte container 102 may be tilted at different or the same angles. For example, embodiments of the invention contemplate that the vertical axis of head assembly 300, *i.e.*, the axis of head assembly 300 running through the middle of head assembly 300 from the lower portion proximate thrust plate 302 upward through the middle of the main body of head assembly 300, may be tilted from a true vertical orientation, *i.e.*, a vertical axis that is generally orthogonal to a horizontal plane (such as base 109) at an angle of between about 3° and about 35° from the

vertical axis. More particularly, the tilt angle may be between about 5° and about 30°, between about 5° and about 20°, or between about 5° and about 15°, for example. Further, as noted above, the tilt angle of the electrolyte container 102 may also be between about 3° and about 35°, wherein the tilt angle of the electrolyte container generally corresponds to the angle from a horizontal at which the electrolyte container 102 is tilted upward on one side. For example, the tilt angle of the electrolyte container 102 may be measured as the angle between the substantially planar upper surface of anode 211 and the horizontal surface of baseplate 109. The tilt angle of electrolyte container 102 may be in the same range as the tilt angle for head assembly 300.

[0033] 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.

Claims:

1. An apparatus for electrochemically plating a metal onto a substrate, comprising:
 - a plating cell configured contain a plating solution therein, the plating cell having an anode positioned therein, the anode having an upper surface that is tilted with respect to horizontal; and
 - a head assembly positioned proximate the plating cell and being configured to support a substrate for processing in the plating cell, the head assembly being configured to support a substrate at a tilt angle with respect to horizontal.
2. The apparatus of claim 1, wherein a tilt angle of the anode corresponds to a tilt angle of the substrate supported by the head assembly.
3. The apparatus of claim 1, wherein the plating cell and the head assembly are both tilted to a tilt angle, the tilt angle being between about 3° and about 35°.
4. The apparatus of claim 3, wherein the tilt angle is between about 5° and about 30°.
5. The apparatus of claim 3, wherein the tilt angle is between about 15° and about 30°.
6. The apparatus of claim 1, wherein the head assembly is configured to immerse the substrate into a plating solution contained in the plating cell at a constant immersion angle.
7. The apparatus of claim 1, wherein the plating cell comprises:
 - an inner basin configured to maintain a volume of plating solution;
 - an outer basin circumferentially positioned about the inner basin, the outer basin being configured to receive overflow plating solution from the inner basin;
 - a diffusion plate positioned in the inner basin;
 - an anode assembly positioned below the diffusion plate,
 - wherein the inner basin, outer basin, diffusion plate, and anode assembly are mounted at a tilt angle with respect to horizontal.
8. The apparatus of claim 1, wherein the head assembly comprises:
 - a thrust plate mounted to an actuator; and

a cathode contact ring mounted to the actuator,
wherein the thrust plate and the cathode contact ring share a common axis
that is mounted at a tilt angle relative to vertical.

9. An electrochemical plating apparatus, comprising:

a plating cell configured contain a plating solution therein, the plating cell
comprising:

at least one fluid basin;

a diffusion plate position in a lower portion of the at least one fluid
basin; and

an anode positioned below the diffusion plate, the anode and the
diffusion plate being positioned in parallel orientation with each other and in a tilted
orientation with respect to horizontal; and

a head assembly positioned proximate the plating cell, the head assembly
comprising:

a base member;

an actuator positioned at a distal end of the base member; and

a substrate support assembly in mechanical communication with the
actuator, the substrate support assembly being configured to support a
substrate in the at least one fluid basin for processing in an orientation that is
generally parallel to the diffusion plate.

10. The electrochemical plating apparatus of claim 9, wherein an upper surface of
the diffusion plate and an upper surface of the anode are positioned at an angle
relative to an upper surface of a fluid contained win the at least one fluid basin.

11. The electrochemical plating apparatus of claim 9, wherein a symmetry axis of
the plating cell is positioned at a tilt angle relative to horizontal of between about 3°
and about 35°.

12. The electrochemical plating apparatus of claim 9, wherein a symmetry axis of
the plating cell is positioned at a tilt angle relative to horizontal of between about 5°
and about 30°.

13. The electrochemical plating apparatus of claim 9, wherein the plating cell is
positioned at a tilt angle relative to horizontal of between about 15° and about 30°.

14. The electrochemical plating apparatus of claim 9, wherein the head assembly is positioned at a tilt angle with respect to horizontal, the tilt angle being between about 3° and about 35°.
15. The electrochemical plating apparatus of claim 14, wherein the tilt angle is between about 5° and about 30°.
16. The electrochemical plating apparatus of claim 14, wherein the tilt angle is between about 15° and about 30°.
17. The electrochemical plating apparatus of claim 14, wherein the head assembly is configured to immerse the substrate at a constant immersion angle relative to an upper surface of the plating solution contained in the at least one fluid basin.
18. The electrochemical plating apparatus of claim 9, wherein the substrate support assembly comprises:
- a contact ring in electrical communication with a cathode terminal of a power supply, the contact ring being configured to support and electrically contact a substrate on a production surface of the substrate during a plating process;
 - a thrust plate positioned to bias a substrate to be plated against the contact ring for plating operations; and
 - an actuator in mechanical communication with the contact ring and thrust plate, the actuator being configured to impart longitudinal and rotational movement to the contact ring and thrust plate.
19. The electrochemical plating apparatus of claim 9, wherein the substrate support assembly comprises an disk shaped substrate support member having a lower substrate support surface, the lower substrate support surface including at least one vacuum channel formed therein and a plurality of electrical contact pins radially positioned proximate a perimeter of the lower surface.
20. A method for immersing a substrate into an electrochemical plating solution, comprising:

securing a substrate to a substrate support assembly, the substrate support assembly being configured to support the substrate in a plane that is tilted at a tilt angle from horizontal; and

extending the substrate support assembly into an electroplating bath contained within an electroplating cell to immerse a production surface of the substrate, the electroplating cell being configured such that an anode is mounted at the tilt angle.

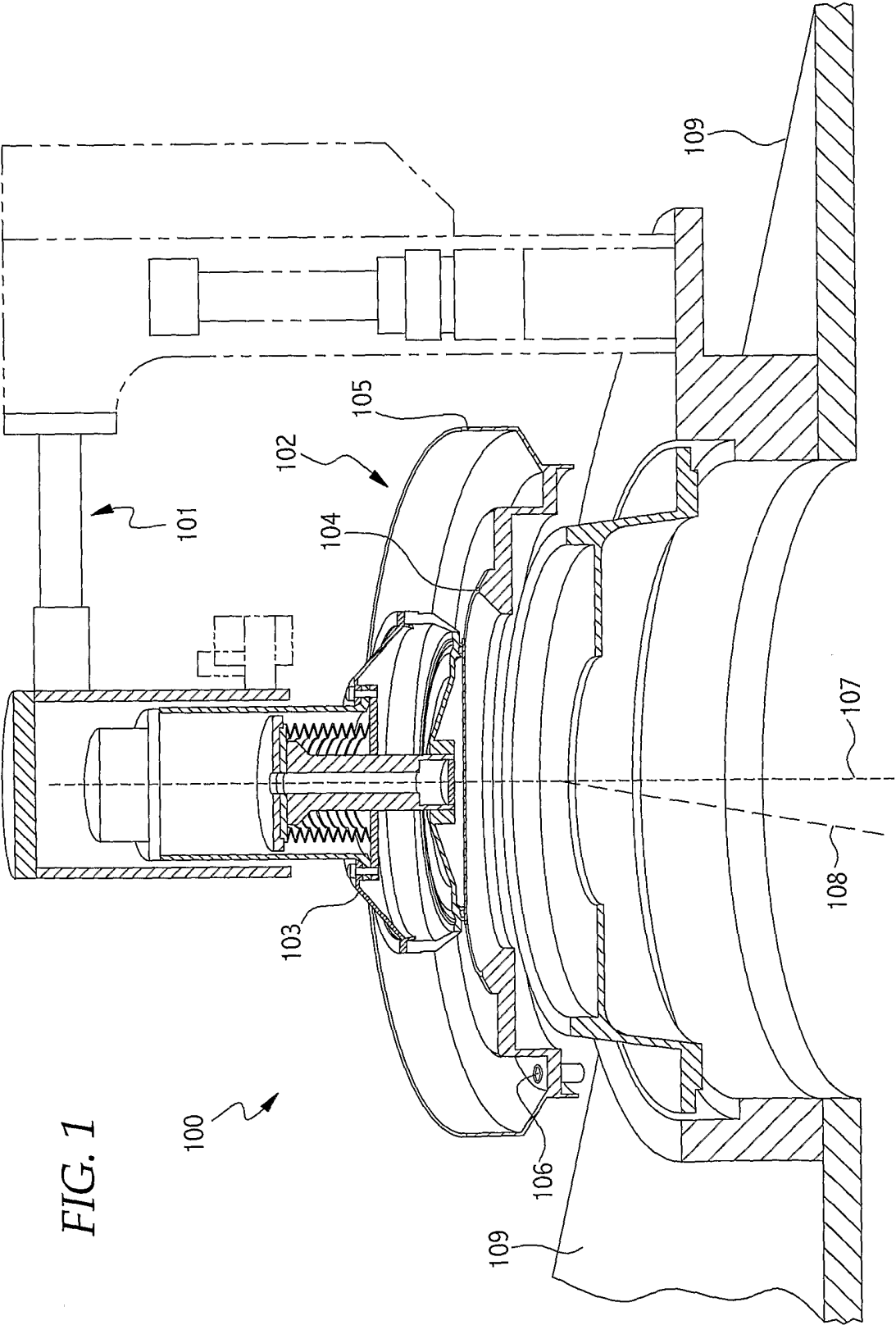
21. The method of claim 20, wherein the substrate support assembly is configured to immerse the substrate in to the electroplating bath at a constant immersion angle relative to an upper surface of the plating bath and position the substrate substantially parallel to the anode for plating operations.

22. The method of claim 20, further comprising maintaining the production surface of the substrate substantially parallel to the anode during the longitudinal extension of the substrate support assembly.

23. The method of claim 20, wherein the tilt angle is between about 5° and about 35°.

24. The method of claim 20, wherein the tilt angle is between about 15° and about 30°.

25. The method of claim 20, wherein extending the substrate support assembly into an electroplating bath further comprises immersing the substrate into a plating solution at a constant immersion angle relative to an upper surface of the plating solution.



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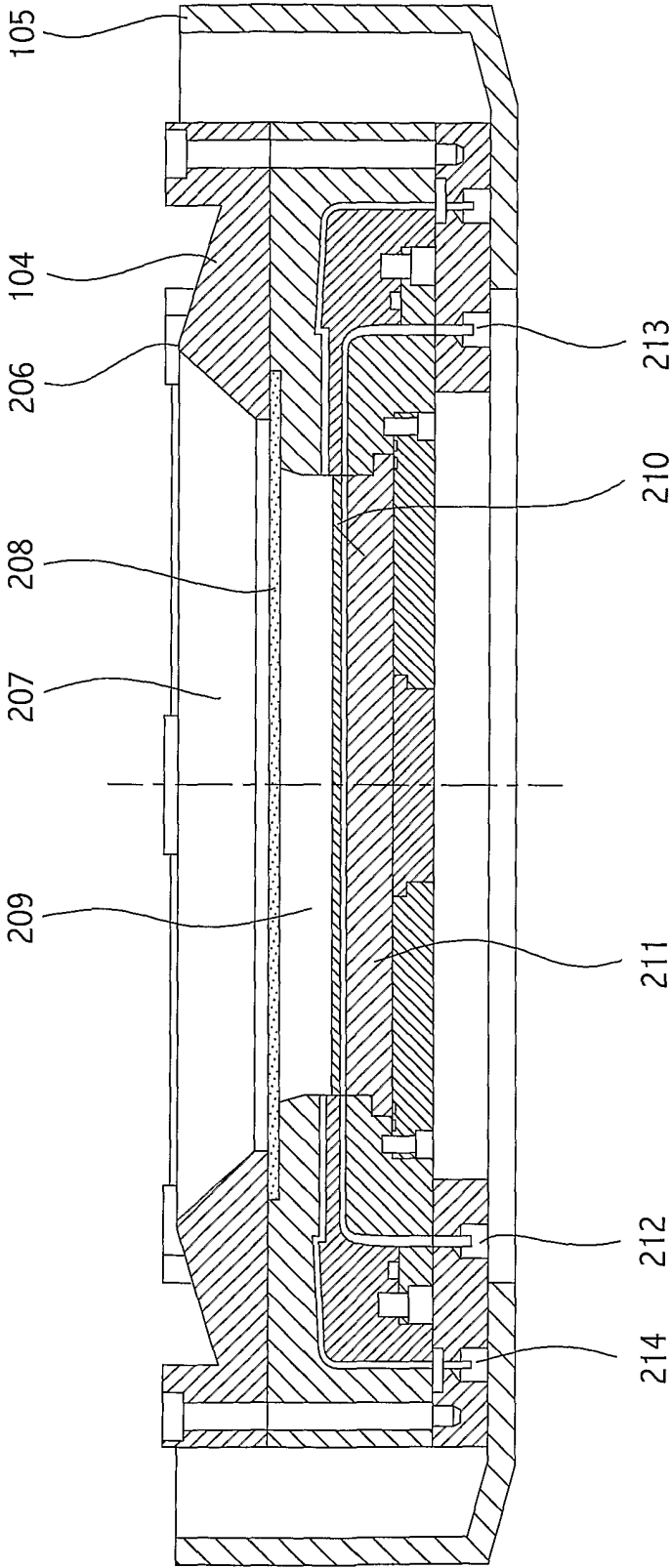


FIG. 2

FIG. 3

