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(54) **METHOD FOR PLATING METAL ONTO WAFERS**

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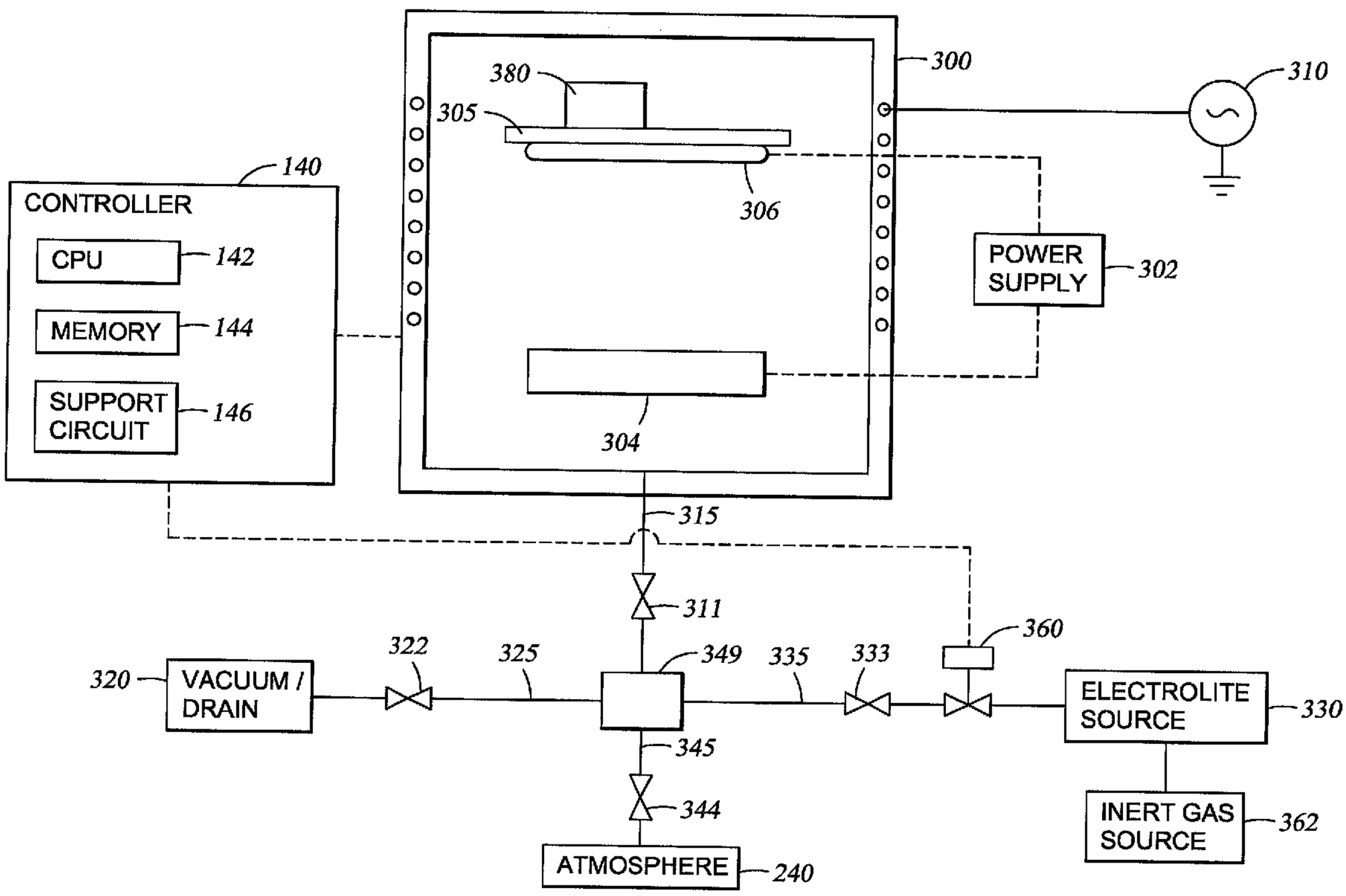
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(57) **ABSTRACT**

A method for chemical plating a substrate is provided. Embodiments of the method include evacuating an enclosure having a substrate disposed therein under vacuum, filling the enclosure with an electrolyte solution having a pressure between about 0.5 atm and about 200 atm, chemical plating a metal layer on a surface of the substrate, and draining the electrolyte solution from the enclosure. In another aspect, the method includes energizing an ultrasonic source to agitate the electrolyte solution substantially simultaneous with the step of chemical plating a metal layer on a surface of the substrate. In still another aspect, the method includes varying the pressure of the plating cell to agitate the electrolyte solution. In yet another aspect, the method includes increasing a pressure of the electrolyte solution by heating the electrolyte solution.



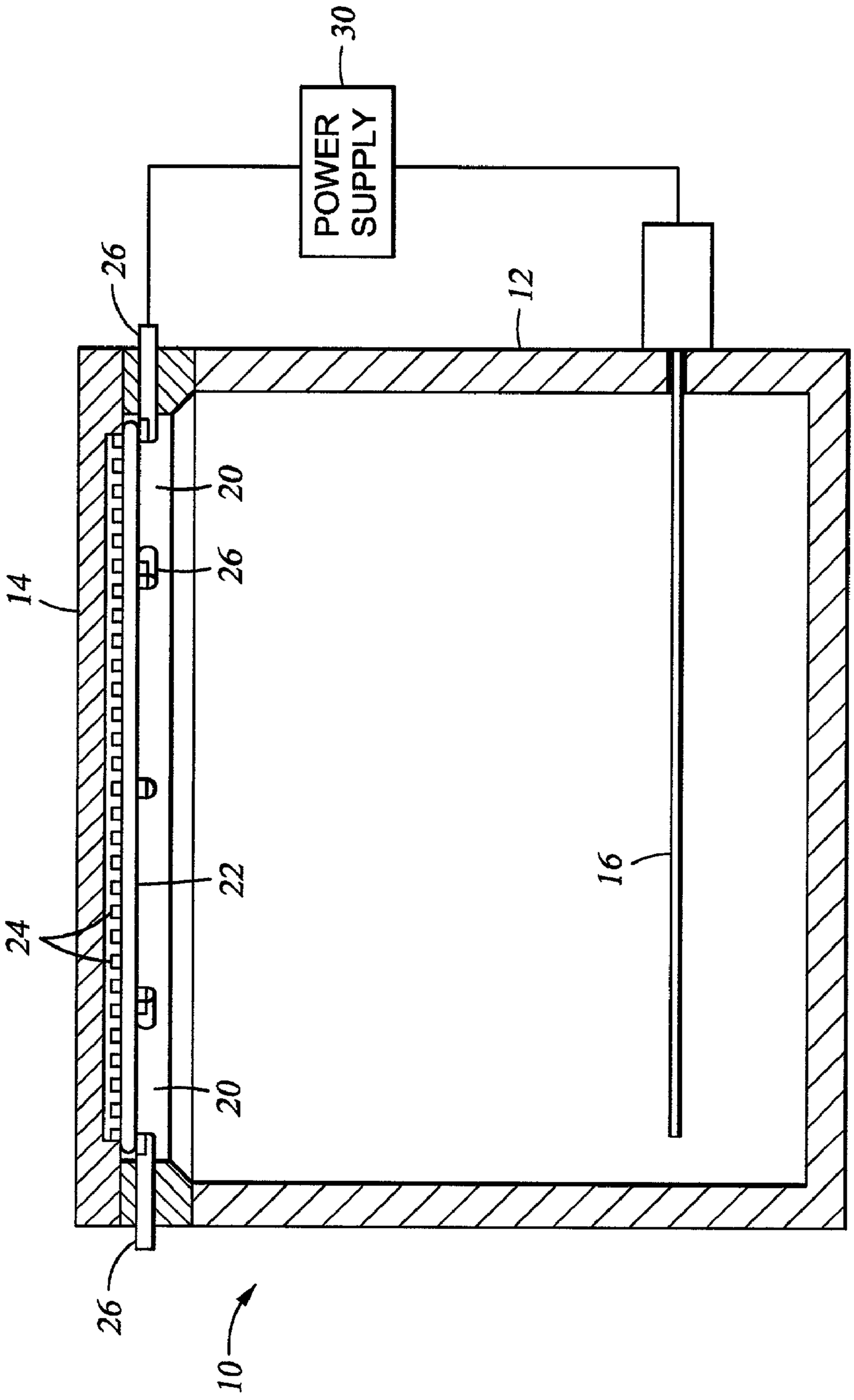


Fig. 1
(PRIOR ART)

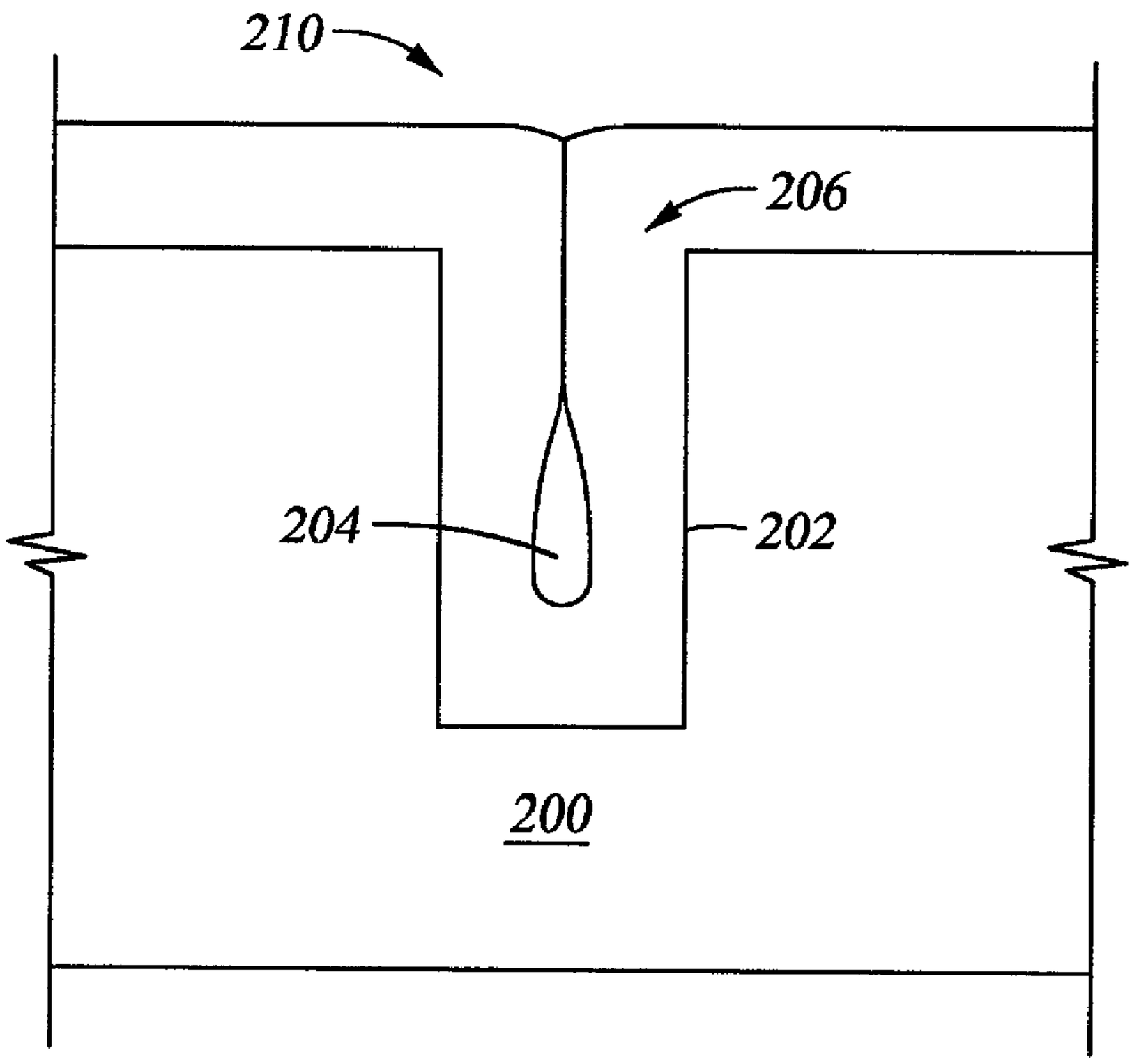


Fig. 2
(PRIOR ART)

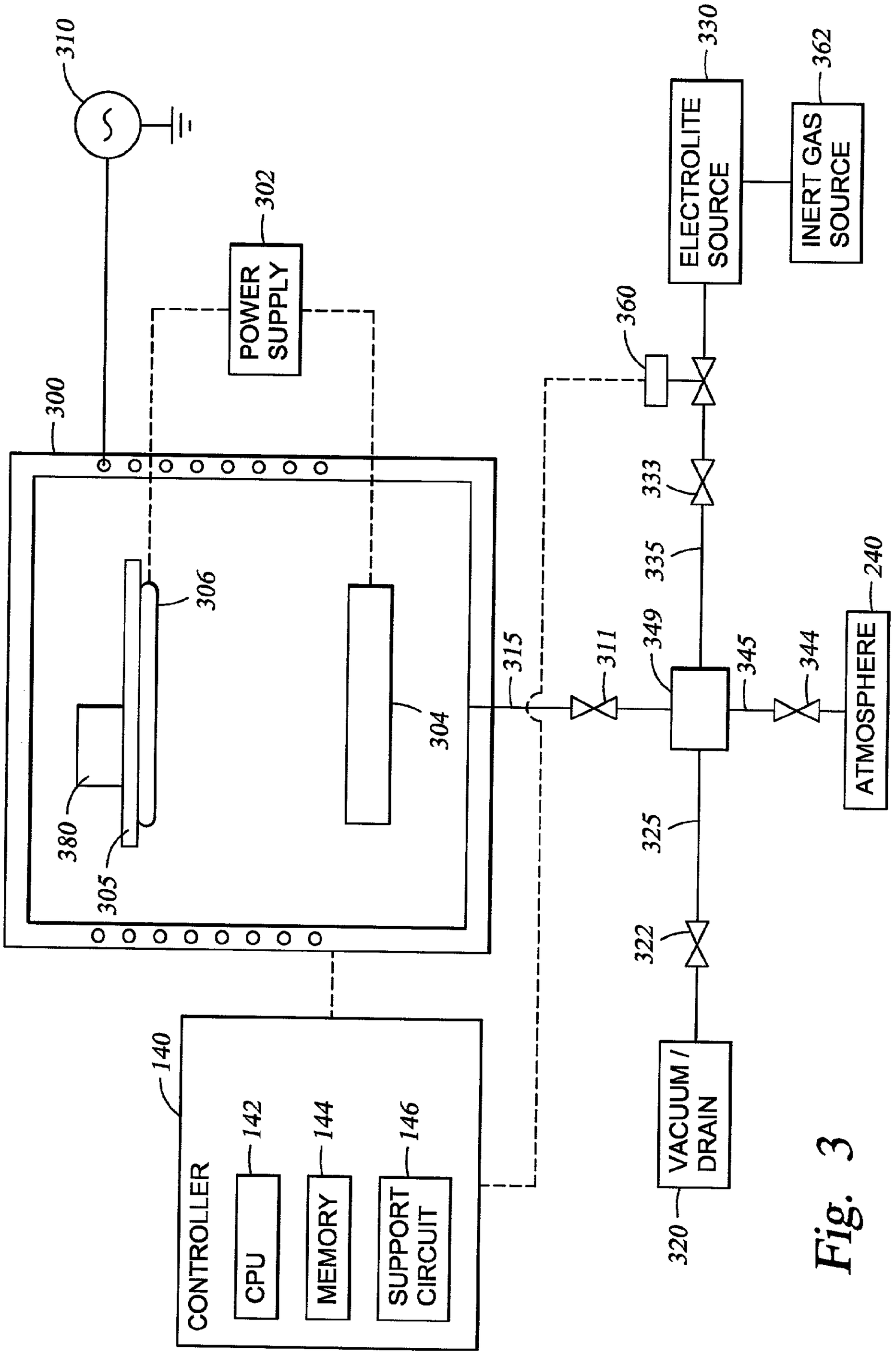
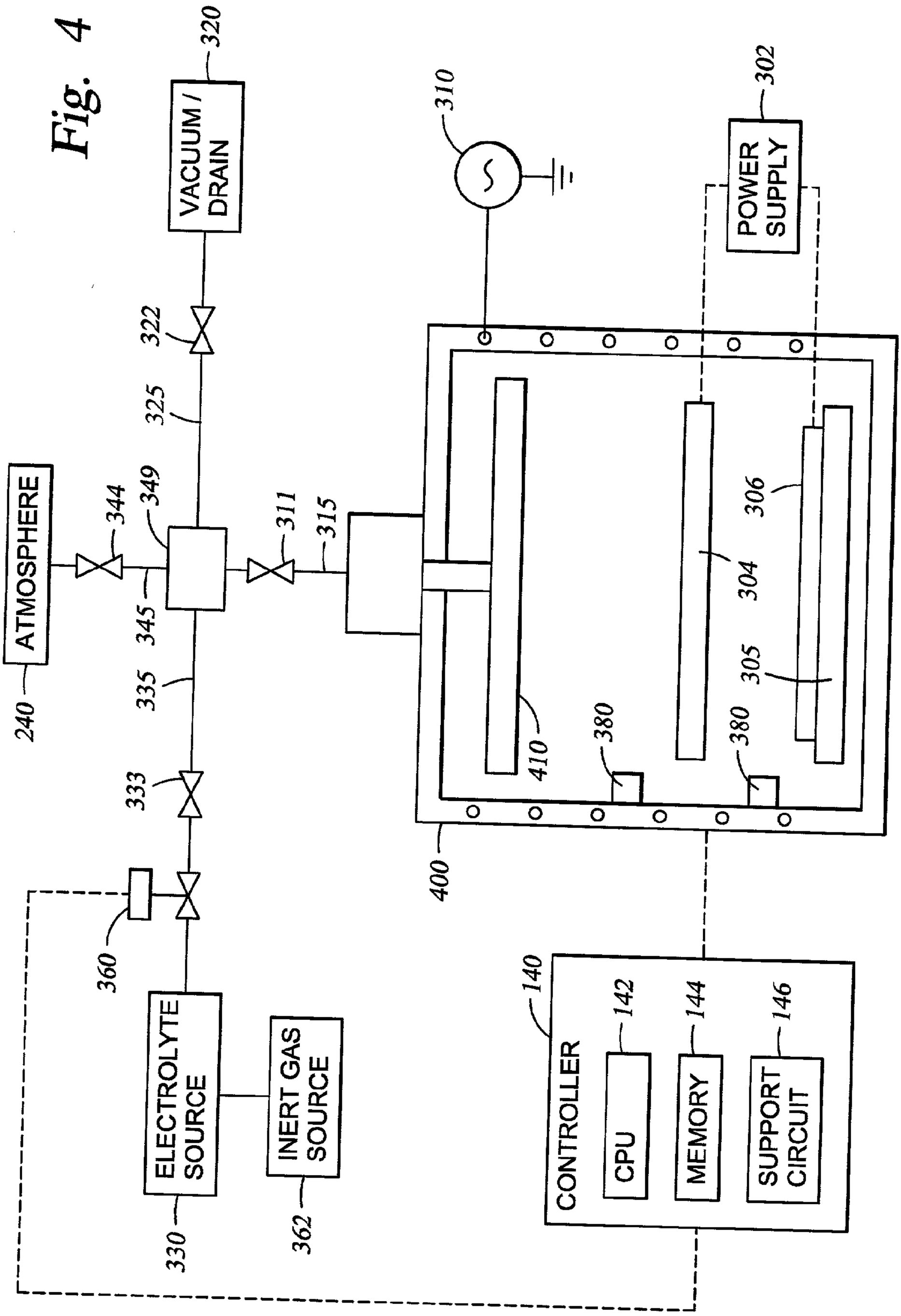

310
302
POWER SUPPLY
300
306
304
315
311
349
345
344
240
ATMOSPHERE
335
333
330
362
360
325
322
320
VACUUM / DRAIN
380
305
140
CONTROLLER
142
CPU
144
MEMORY
146
SUPPORT CIRCUIT
ELECTROLITE SOURCE
INERT GAS SOURCE

Fig. 3

Fig. 4


VACUUM / DRAIN
320
322
325
ATMOSPHERE
240
344
349
345
335
333
360
311
315
310
302
POWER SUPPLY
306
304
305
380
380
410
400
ELECTROLYTE SOURCE
INERT GAS SOURCE
330
362
140
CONTROLLER
142
CPU
144
MEMORY
146
SUPPORT CIRCUIT

METHOD FOR PLATING METAL ONTO WAFERS

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] Embodiments of the present invention relate to a method for chemical plating. More particularly, embodiments of the present invention relate to a method for chemically depositing metals into high aspect ratio structures on a substrate.

[0003] 2. Description of the Related Art

[0004] Reliably producing sub-half micron and smaller structures is one of the key technologies for the next generation of very large scale integration (VLSI) and ultra large-scale integration (ULSI) of semiconductor devices. The shrinking dimensions of interconnects in VLSI and ULSI technology have placed additional demands on the processing capabilities as the limits of circuit technology are pushed. Therefore, reliable formation of these interconnects is important to VLSI and ULSI success and to the continued effort to increase circuit density and quality of individual substrates.

[0005] As circuit densities increase, the widths of vias, contacts and other structures tend to decrease while the thickness of the dielectric layers remains substantially constant. As a result, the aspect ratios for the structures, i.e., the height divided by width, increases. The increasing aspect ratios present a challenge to the industry since many traditional deposition processes, such as physical vapor deposition (PVD) and chemical vapor deposition (CVD), have difficulty filling structures where the aspect ratio exceeds 4:1, and particularly where it exceeds 10:1. Therefore, there is an ongoing effort directed toward the formation of void-free, nanometer-sized structures having high aspect ratios of 4:1 or higher.

[0006] Electrochemical plating (ECP) is one method of metal deposition onto structures having high aspect ratios. **FIG. 1** shows a cross section view of a simplified ECP bath used for semiconductor substrates **10**. Generally, the plating bath **10** includes an electrolyte container **12** having a top opening, a substrate holder **14** disposed above the electrolyte container **12**, an anode **16** disposed at a bottom portion of the electrolyte container **12** and a contact ring **20** contacting the substrate **22**. A plurality of grooves **24** are formed in the lower surface of the substrate holder **14**. A vacuum pump (not shown) is coupled to the substrate holder **14** and communicates with the grooves **24** to create a vacuum condition capable of securing the substrate **22** to the substrate holder **14** during processing. The contact ring **20** comprises a plurality of metallic or semi-metallic contact pins **26** distributed about the peripheral portion of the substrate **22** to define a central substrate plating surface. The plurality of contact pins **26** extend radially inwardly over a narrow perimeter portion of the substrate **22** and contact a conductive seed layer of the substrate **22** at the tips of the contact pins **26**. A power supply **30** is electrically connected to the anode **16** and to the pins **26** thereby providing an electrical bias to the substrate **22**. The substrate **22** is positioned above the cylindrical electrolyte container **12** and the electrolyte flow impinges perpendicularly on the substrate plating surface during operation of the plating cell **10**.

[0007] The electroplating process is typically carried out by applying a constant current density across the substrate plating surface. For example, a constant current density of about 40 mA/cm^2 is applied across the substrate plating surface to produce deposition thereon. Since the deposition rate is generally a function of the current density applied over the substrate plating surface, the current density is typically increased, typically greater than 40 mA/cm^2, to provide faster deposition and increase throughput.

[0008] Electroless chemical plating is another method of metal deposition onto structures having high aspect ratios. Electroless chemical plating differs from a typical electrochemical plating process, as described above, in that an electroless chemical plating process does not utilize electrical current. Therefore, no power source, cathode, or electrical contact to a substrate is required.

[0009] A particular problem encountered in any typical chemical plating process, such as ECP and electroless chemical plating, is the inability to provide void-free or seam-free fill of high aspect ratio structures. **FIG. 2** illustrates a typical deposition result of a high aspect ratio feature on a substrate **200**. As shown, the mouth/opening **206** of the structure **202** closes off due to an overhang or excess deposition of metal, because the deposition of metal **210** tends to grow faster at the mouth or opening of the structure. As a result, the mouth/opening of the structure is closed off and a void **204** is formed inside the structure **202**. Furthermore, the overhang or excess deposition of metal is accelerated by an increase of the current density during electroplating, thereby causing even larger voids.

[0010] There is a need, therefore, for a method for chemically depositing a metal into high aspect ratio structures on a substrate that provides void-free or seam-free fill of high aspect ratio structures.

SUMMARY OF THE INVENTION

[0011] A method for chemical plating is provided. In one aspect, the method includes evacuating an enclosure having a substrate disposed therein to a pressure less than about 1 atm; filling the enclosure with an electrolyte solution at a pressure between about 0.5 atm and about 200 atm; and chemical plating a metal layer on at least a portion of a surface of the substrate.

[0012] In another aspect, the method includes evacuating an enclosure having a substrate disposed therein under a vacuum sufficient to substantially purge gases from the enclosure; filling the enclosure with a pressurized electrolyte solution; energizing one or more ultrasonic sources disposed within the enclosure to agitate the electrolyte solution; chemical plating a metal layer on a surface of the substrate; and draining the electrolyte solution from the enclosure.

[0013] In still another aspect, the method includes evacuating an enclosure having a substrate disposed therein under vacuum; filling the enclosure with an electrolyte solution having a pressure sufficient to substantially collapse air bubbles in the electrolyte solution; and chemical plating a metal layer on at least a portion of a surface of the substrate.

[0014] In still another aspect, the method includes evacuating an enclosure having a substrate disposed therein under vacuum; filling the enclosure with an electrolyte solution having a pressure sufficient to substantially collapse air bubbles in the electrolyte solution; varying the pressure of

the electrolyte solution to agitate the electrolyte solution; and chemical plating a metal layer on a surface of the substrate.

[0015] In yet another aspect, the method includes exposing a substrate surface to a vacuum that is sufficient to substantially remove gases from the substrate surface; exposing the substrate surface to an electrolyte solution; pressurizing the electrolyte solution; and chemical plating a metal layer on at least a portion of the substrate surface.

[0016] In yet another aspect, the method includes exposing a substrate surface to a vacuum that is sufficient to substantially remove gases from the substrate surface; exposing the substrate surface to an electrolyte solution; energizing one or more ultrasonic sources to agitate the electrolyte solution; and chemical plating a metal layer on at least a portion of the substrate surface.

[0017] In yet another aspect, the method includes exposing a substrate surface to a vacuum that is sufficient to substantially remove gases from the substrate surface; exposing the substrate surface to an electrolyte solution; energizing one or more ultrasonic sources to agitate the electrolyte solution; chemical plating a metal layer on at least a portion of the substrate surface at a variable pressure between about 1 atm and about 100 atm; and draining the electrolyte solution from the enclosure.

[0018] In still yet another aspect, the method includes opening a first valve to evacuate an enclosure having a substrate disposed therein; pulling vacuum on the enclosure, closing the first valve and opening a second valve to fill the enclosure with an electrolyte solution; closing the second valve; chemical plating a metal layer on at least a portion of a surface of the substrate; opening the second valve to drain the electrolyte solution from the enclosure; and closing the second valve and opening a fourth valve to vent the enclosure prior to removing the plated substrate from the enclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0019] So that the manner in which the above recited structures of the present invention are attained and 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.

[0020] 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.

[0021] **FIG. 1** is a simplified cross section view of a typical electrochemical plating cell.

[0022] **FIG. 2** is an enlarged schematic view of a high aspect ratio feature wherein the mouth/opening of the structure closes off due to an overhang or excess deposition of copper at the mouth/opening of the structure.

[0023] **FIG. 3** is a simplified schematic view of a chemical plating cell configured to perform embodiments of the invention.

[0024] **FIG. 4** is a simplified schematic view of a chemical plating cell configured to perform an alternative embodiment of maintaining and controlling electrolyte solution pressure therein.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

[0025] A method for chemically depositing a metal, such as copper for example, into high aspect ratio structures of a substrate surface is provided. Embodiments of the method provide void-free and seam-free fill of the high aspect ratio structures. The term "high aspect ratio structures", as used herein, may include any via, contact, line, or other interconnect feature having an aspect ratio (height to width ratio) of about 4:1 or greater. A "substrate surface", as used herein, refers to any substrate surface upon which film processing is performed. For example, a substrate surface may include silicon, silicon oxide, doped silicon, germanium, gallium arsenide, glass, sapphire, and any other materials such as metals, metal alloys, and other conductive materials, depending on the application. In certain applications, such as electroless plating for example, a substrate surface may also include dielectric materials such as silicon dioxide and carbon doped silicon oxides. Unless otherwise distinguished below, the term "chemical plating" refers herein to both electrochemical plating and electroless plating.

[0026] In one aspect, embodiments of the method utilize a vacuum that is sufficient to substantially remove/purge gases from a plating volume having the structures disposed therein. The plating volume is contained within an enclosure, such as a plating cell for example, and is in fluid communication with the substrate surface to be plated. The vacuum may be between about 0.1 mtorr and about 100 mtorr, and is intended quickly evacuate unwanted gases, such as reactive compounds and/or contaminants for example, from the enclosure and from the substrate structures prior to chemical plating. Further, the vacuum allows the plating volume to quickly fill with an electrolyte solution. This rapid fill of electrolyte solution greatly improves the rate of production.

[0027] During plating, the electrolyte solution is maintained at a higher pressure to enhance the plating process. The higher pressure may be maintained using a blanket of pressurized gas, such as an inert gas like nitrogen for example, in fluid communication with the electrolyte solution. Alternatively, the higher pressure may be achieved using mechanical forces to compress the electrolyte solution. For example, a moveable piston member may be disposed in communication with the plating volume having the electrolyte solution disposed therein, and used to compress the electrolyte solution, thereby increasing the pressure of the solution.

[0028] The higher pressure drives the electrolyte solution into the substrate structures to provide a more uniform and consistent deposition. The higher pressure also collapses gas pockets or bubbles that may have formed during the fill of the electrolyte solution into the plating volume. Gas pockets or bubbles are undesirable because they create voids in the plating volume and within the substrate structures that could prevent contact with the electrolyte solution. Additionally, the higher pressure elevates the electrolyte solution temperature without evaporation or boiling to further enhance the plating process.

[0029] The higher pressure of the enclosure should be sufficient to substantially collapse air bubbles or pockets of trapped gases in the electrolyte solution and sufficient to force or push the electrolyte solution into the substrate

structures. The higher pressure should also be sufficient to allow increase of the electrolyte solution temperature without evaporating/boiling the electrolyte solution. In one aspect, the higher pressure is between about 1 atm and about 200 atm, and is applied for about 1 second to about 120 seconds or until a desired plating thickness, such as between about 100 angstroms (Å) and about 5,000 Å, is achieved.

[**0030**] In one aspect, the higher pressure may be varied to enhance the plating process. More particularly, the higher pressure of the enclosure may be varied/throttled anywhere between 100 mtorr and 200 atm. As an example, the higher pressure may be increased every 1 to 30 seconds by about 5 to about 20 percent. As another example, the higher pressure may be decreased by about 20 to about 50 percent over a period of time ranging from about 1 second to about 5 minutes. As yet another aspect, the higher pressure may be alternately increased and decreased by about 20 to about 50 percent over an interval of time ranging from about 1 second to about 5 minutes. These significant changes in pressure create pulsations that force/drive electrolyte solution into the substrate structures to provide a more uniform and consistent deposition.

[**0031**] In another aspect, ultrasonic vibration/agitation may be used to enhance the plating process. The ultrasonic vibration/agitation may be used alone or in combination with the higher pressure described above. Any conventional generation of ultrasonic agitation may be employed. For example, the ultrasonic agitation may be provided by one or more typical Piezo electric crystal transducers, which are commonly known. The source of ultrasonic agitation may be mounted to any mechanical component of the enclosure, such as to an enclosure wall, support pedestal, anode, and cathode. If more than one transducer is used, the multiple transducers may be mounted on the same or different components.

[**0032**] The ultrasonic agitation moves the substrate and the surrounding electrolyte solution in both vertical and horizontal directions. The ultrasonic energy allows the metal ions to enter small aspect ratio structures formed on the substrate by increasing the metal ions rate of diffusion. As a result, the metal ions are able to diffuse/travel more easily into and out of the small structures formed within the substrate surfaces.

[**0033**] It is believed that embodiments of the method described above may apply to any wet processing system, such as electrochemical plating and electroless chemical plating, for example. For simplicity and ease of description, however, embodiments of the invention will be further described below as it relates to electrochemical deposition using a typical plating cell described with reference to **FIG. 3**.

[**0034**] **FIG. 3** shows a simplified schematic view of a plating cell **300** capable of chemical plating according to an embodiment described herein. A specific example of an applicable plating station is a cell available on an Electra™ Cu ECP system, available from Applied Materials, Inc., located in Santa Clara, Calif. A detailed description of the deposition system is provided in commonly assigned and co-pending U.S. patent application Ser. No. 09/289,074, entitled "Electro-chemical Deposition System", filed on Apr. 8, 1999, which is incorporated by reference herein.

[**0035**] The plating cell **300** includes a power supply **302**, anode **304**, and a substrate support member **305** having a substrate **306** to be plated disposed thereon. The power supply **302** is connectable to both the anode **304** and the substrate **306**. More particularly, the power supply **302** is connectable to the substrate **306** via a conductive seed layer formed on a plating surface of the substrate **306**. As such, the substrate **306** acts as a cathode.

[**0036**] The plating cell **300** may also include a heating member **310** disposed within a wall of the plating cell **300** so not to be in direct contact with the electrolyte solution. The heating member **310** adjusts the temperature of the substrate **306** and/or the electrolyte to further enhance the deposition. The heating member **310** may be a resistive heating element or may include a heat transfer medium that circulates within one or more channels to transfer energy to the electrolyte solution within the plating cell **300**. Alternatively, the heating member **310** may be disposed within the plating cell **300**, in direct contact with the electrolyte solution. Further, the heating member **310** may be disposed within the substrate support member **305** to conductively heat the substrate **306** disposed thereon.

[**0037**] The plating cell **300** is also in fluid communication with a vacuum source **320**, an electrolyte source **330**, and an atmospheric vent **340**. The vacuum source **320** is connectable to the plating cell **300** via a conduit **325**. The conduit **325** includes an isolation valve **322** to provide an open/close capability between the vacuum source **320** and the plating cell **300**. The atmospheric vent **340** is connectable to the plating cell **300** via its own conduit **345**. Likewise, the conduit **345** includes an isolation valve **344** to provide an open/close capability between the atmospheric vent **340** and the plating cell **300**.

[**0038**] The electrolyte source **330** is connectable to the plating cell **300** via a conduit **335** having an isolation valve **333** disposed therein to provide an open/close capability between the electrolyte source **330** and the plating cell **300**. A pressurized inert gas, such as nitrogen, may be used to push the electrolyte solution from the electrolyte source **330** to the plating cell **300** and maintain the pressure of the plating cell **300**. The desired pressure within the plating cell **300** may be maintained using a pressure regulator/controller **360** in fluid communication with the pressurized inert gas source **362**. The pressure regulator may be tied to a feed back loop in communication with a controller **140**, and can be variably controlled to vary/pulsate the pressure within the plating cell **300**.

[**0039**] In one aspect, each conduit **325**, **335**, and **345** may be individually connected to the plating cell **300**. However, each conduit **325**, **335**, and **345** may be in fluid communication with the plating cell **300** via a single conduit **315** as shown in **FIG. 3**. The conduit **315** is disposed on a lower portion of the plating cell **300** and includes its own isolation valve **311** and also includes a splitter or tee **349**, as is commonly known in the art, to provide a connection to each conduit **325**, **335**, and **345**.

[**0040**] During operation, a substrate **306** having one or more structures formed thereon is disposed in an empty plating cell **300** and the plating cell **300** is sealed while all four isolation valves **311**, **322**, **333**, and **343** are closed. Preferably, the one or more structures formed on the substrate have aspect ratios between about 4:1 to about 10:1, and more preferably, greater than about 10:1. Once the plating cell **300** is sealed with the substrate **306** disposed

therein, the valve **311** and the valve **322** are opened to evacuate gas from the plating cell **300** and from the one or more structures formed on the substrate **306**, creating a vacuum within the plating cell **300**. Next, the valve **322** is closed and the valve **333** is opened to fill the plating cell **300** with the electrolyte solution, thereby pressurizing the plating cell **300**. The pressure of the plating cell **300** is maintained between about 100 mtorr and about 200 atm using the pressure regulator **360** in fluid communication with the source of pressurized inert gas **362**. The pressurized plating cell **300** forces the electrolyte solution in the structures formed on the substrate **306** and also collapses any gas pockets/bubbles formed in the electrolyte during the fill step.

[**0041**] Next, the power supply **302** is activated to provide an electrical current or bias to the anode **304** and to the substrate **306**. The bias typically ranges from about −15 volts to about 15 volts. In one aspect, the positive bias ranges from about 0.1 volts to about 10 volts and the negative bias ranges from about −0.1 to about 10 volts. Alternatively, the bias may be a current density between about 0.01 and about 40 milliamps/cm^2 for a 200 mm substrate. The bias may be varied in power and application depending on the user requirements for plating material to the substrate surface. The bias may also be applied by an electrical pulse modulation technique, which applies a constant current density or voltage for a first time period, then applies a constant reverse current density or voltage for a second time period, and repeats the first and second steps, as is described in co-pending U.S. patent application Ser. No. 09/569,833, entitled "Electrochemical Deposition For High Aspect Ratio Structures Using Electrical Pulse Modification", filed on Dec. 7, 1999, which is incorporated by reference herein. In the case of an acidic electrolyte, a bias voltage is applied to the substrate prior to introduction of the electrolyte in order to prevent etching of the seed layer.

[**0042**] Optionally, the plating cell **300** may include one or more ultrasonic transducers **380** disposed therein. The one or more transducers **380** are activated to agitate the electrolyte within the plating cell **300** using ultrasonic energy in a range of about 10 Watts to about 250 Watts at a frequency of about 25 kHz to about 200 kHz. Preferably, ultrasonic energy is launched at about 10W to about 100W at a frequency greater than about 40 kHz. The one or more ultrasonic transducers **380** are activated at about the same or substantially the same time as the power source **302** is activated. As stated above, the ultrasonic agitation helps to reduce the hydrodynamic boundary layer near the substrate surface to enhance the effects of electrolyte and additives.

[**0043**] Once a desired thickness of the metal layer is achieved, the power supply **302** and the one or more transducers **380** are de-energized. The valve **333** is closed and the valve **322** is opened to evacuate/drain the electrolyte solution from the plating cell **300**. Then, the valve **322** is closed and the valve **344** is opened to vent the plating cell **300**. Finally, the plating cell **300** is opened and the plated substrate **306** is removed.

[**0044**] The electrolyte solution is preferably a copper chemical plating solution having multi-components comprising copper electrolyte and additives such as suppressers and brighteners/accelerators. A detailed description of the chemical plating chemistry, particularly the composition of the electrolyte and additives, is provided in commonly assigned and co-pending U.S. patent application Ser. No. 09/245,780, entitled "Electrodeposition Chemistry for Improved Filling of Apertures," filed on Feb. 5, 1999, which is incorporated by reference herein.

[**0045**] The copper electrolyte provides copper ions to be deposited while the suppressers and brighteners/accelerators control the deposition profile of the copper atoms. Suppressers and brighteners/accelerators adsorb on the substrate surfaces, including the structures formed on the substrate (i.e., vias and trenches), as soon as the substrate comes into contact with the chemical plating bath. Suppressers inhibit or reduce copper deposition in areas where suppressers have been adsorbed, and brighteners/accelerators accelerate copper growth in the areas where brighteners/accelerators have been adsorbed. The activities of suppressers and brighteners/accelerators are dependent on parameters such as temperature, the pH of bath, and the chloride concentration in the bath, which directly or indirectly affect the polarization of the additives.

[**0046**] To facilitate control of the deposition process, a controller **140** comprising a central processing unit (CPU) **142**, memory **144**, and support circuits **146**, is connected to the plating cell **300**. The CPU **142** may be one of any form of computer processors that are used in industrial settings. The memory **144** is connected to the CPU **142**, and may be one or more readily available memory devices, such as random access memory (RAM), read only memory (ROM), floppy disk, hard disk, or any other form of digital storage, whether local or remote. Software instructions and data can be coded and stored within the memory **144** for instructing the CPU **142**. The support circuits **146** are also connected to the CPU **142** for supporting the processor **142** in a conventional manner. The support circuits **146** may include cache, power supplies, clock circuits, input/output circuitry, subsystems, and the like.

[**0047**] **FIG. 4** shows an alternative embodiment of maintaining and controlling pressure and temperature within a simplified schematic view of a plating cell **400**. The plating cell **400** represents an exemplary "face up" plating arrangement and includes similar components to the plating cell **300** shown in **FIG. 3** that are identified using identical reference numerals. Additionally, the plating cell **400** includes a piston member **410** at least partially disposed therein. The piston member **410** is moveable in a direction substantially normal to the substrate surface. In one aspect, the piston member **410** compresses the electrolyte solution in contact with the substrate surface, thereby increasing the pressure of the solution. In another aspect, the piston member **410** may move both in a direction toward the substrate surface and in a direction away from the substrate surface to compress and release pressure on the electrolyte solution. This movement of the piston member **410** pulsates the electrolyte solution against the substrate surface.

[**0048**] Embodiments of the invention will be further illustrated by the following non-limiting, hypothetical examples:

HYPOTHETICAL EXAMPLE 1

[**0049**] A barrier layer having a thickness of about 250 Å and comprising TaN is deposited over a substrate having an aspect ratio of about 10:1 utilizing well known processing parameters for physical vapor deposition. Preferably, the barrier layer is deposited using a Vectra® IMP chamber from

Applied Materials, Inc., located in Santa Clara, Calif. A copper seed layer of about 2,000 Å is deposited over the barrier layer, also utilizing well known processing parameters for physical vapor deposition. The substrate is then transferred to a chemical plating cell, such as one found on the Electra™ Cu ECP system, available from Applied Materials, Inc., located in Santa Clara, Calif.

[**0050**] The cell is evacuated by pulling vacuum to about 1 mtorr for about 10 seconds. Bias voltage is applied to the substrate. Electrolyte solution is introduced into the cell until the substrate is at least partially submersed in the electrolyte. The electrolyte solution is composed of 0.85M copper sulfate with a pH of about 1.75 after adding suppressers and brighteners/accelerators. The cell is then pressurized to about 200 atm. The temperature of the bath is maintained between about 25° C. and about 100° C. during plating.

[**0051**] An ultrasonic transducer mounted to the substrate support pedestal having a power of about 100W at a frequency of 50 kHz, is activated during plating and the substrate is biased using a remote power source. The substrate is biased with a forward plating current density between about 10 mA/cm^2 and about 40 mA/cm^2 for a duration between about 4 seconds and about 16 seconds, and a reverse constant voltage of about −20V for about 0.3 seconds. The cycle is repeated for a total of six times to complete the deposition process. The cell is then drained, the power supply is de-energized, and the cell is allowed to vent. Finally, the cell is opened and the plated substrate is removed.

HYPOTHETICAL EXAMPLE 2

[**0052**] A barrier layer having a thickness of about 250 Å and comprising TaN is deposited over a substrate having an aspect ratio of about 10:1 utilizing well known processing parameters for physical vapor deposition. Preferably, the barrier layer is deposited using a Vectra® IMP chamber from Applied Materials, Inc., located in Santa Clara, Calif. A copper seed layer of about 2,000 Å is deposited over the barrier layer, also utilizing well known processing parameters for physical vapor deposition. The substrate is then transferred to a chemical plating cell, such as one found on the Electra™ Cu ECP system, available from Applied Materials, Inc., located in Santa Clara, Calif.

[**0053**] The chemical plating cell is evacuated by pulling vacuum to about 1 mtorr for about 10 seconds. Bias voltage is applied to the substrate. Electrolyte solution is introduced into the cell until the substrate is at least partially submersed in the electrolyte. The electrolyte solution is composed of 0.85M copper sulfate with a pH of about 1.75 after adding suppressers and brighteners/accelerators. The cell is then pressurized to about 200 atm. The temperature of the bath is maintained between about 25° C. and about 100° C. during plating.

[**0054**] After about 15 seconds, the pressure of the cell is decreased to about 0.5 atm and held between about 1 to about 30 seconds. Then, the pressure is increased back to about 200 atm and held between about 1 and about 30 seconds. This cycle is repeated from about 1 to 50 times before draining the cell, venting the cell, and removing the substrate.

[**0055**] 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. A method for chemical plating, comprising:

evacuating an enclosure having a substrate disposed therein to a pressure less than about 1 atm;

filling the enclosure with an electrolyte solution at a pressure between about 0.5 atm and about 200 atm; and

chemical plating a metal layer on at least a portion of a surface of the substrate.

2. The method of claim 1, further comprising energizing one or more ultrasonic sources disposed within the enclosure to agitate the electrolyte solution.

3. The method of claim 1, further comprising draining the electrolyte solution from the enclosure and venting the enclosure.

4. The method of claim 1, wherein the enclosure has a variable operating pressure between about 0.5 atm and about 200 atm.

5. The method of claim 1, wherein chemical plating of a metal layer on a surface of the substrate occurs at a temperature between about 15° C. and about 100° C.

6. The method of claim 1, further comprising one or more ultrasonic sources disposed within the enclosure to agitate the substrate.

7. The method of claim 1, wherein evacuating an enclosure comprises removing reactive compounds, contaminants, or both from the enclosure.

8. The method of claim 1, further comprising varying the pressure to agitate the electrolyte solution.

9. The method of claim 8, wherein varying the pressure of the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

10. The method of claim 8, wherein varying the pressure of the electrolyte solution comprises decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

11. The method of claim 1, further comprising energizing a power source connected to the substrate.

12. A method for chemical plating, comprising:

opening a first valve to evacuate an enclosure having a substrate disposed therein,

pulling vacuum on the enclosure;

closing the first valve and opening a second valve to fill the enclosure with an electrolyte solution;

closing the second valve;

chemical plating a metal layer on at least a portion of a surface of the substrate;

opening the second valve to drain the electrolyte solution from the enclosure; and

closing the second valve and opening a fourth valve to vent the enclosure prior to removing the plated substrate from the enclosure.

13. The method of claim 12, further comprising energizing one or more ultrasonic sources disposed within the enclosure to agitate the electrolyte solution.

14. The method of claim 12, further comprising one or more ultrasonic sources disposed within the enclosure to agitate the substrate.

15. The method of claim 12, wherein chemical plating occurs at pressure of about 0.5 atm to about 200 atm.

16. The method of claim 12, wherein chemical plating occurs at a temperature of about 15° C. to about 100° C.

17. The method of claim 15, further comprising varying the pressure to agitate the electrolyte solution in fluid contact with the substrate surface.

18. The method of claim 17, wherein varying the pressure of the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

19. The method of claim 17, wherein varying the pressure of the electrolyte solution comprises decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

20. The method of claim 18, wherein increasing the pressure comprises increasing a temperature of the electrolyte solution to enhance the chemical plating.

21. The method of claim 12, further comprising energizing a power source connected to the substrate.

22. A method for chemical plating, comprising:

evacuating an enclosure having a substrate disposed therein under a vacuum sufficient to substantially purge gases from the enclosure;

filling the enclosure with a pressurized electrolyte solution;

energizing one or more ultrasonic sources disposed within the enclosure to agitate the electrolyte solution;

chemical plating a metal layer on a surface of the substrate; and

draining the electrolyte solution from the enclosure.

23. The method of claim 22, further comprising venting the enclosure prior to draining the electrolyte solution from the enclosure.

24. The method of claim 22, wherein chemical plating occurs at a variable operating pressure between about 100 mtorr and about 200 atm.

25. The method of claim 22, wherein chemical plating occurs at a temperature of about 15° C. to about 25° C.

26. The method of claim 22, further comprising energizing one or more ultrasonic sources disposed within the enclosure to agitate the substrate.

27. The method of claim 26, wherein the substrate is agitated in both a vertical and horizontal direction.

28. The method of claim 22, wherein the pressurized electrolyte solution has a pressure between about 1 atm and about 200 atm.

29. The method of claim 22, further comprising varying the pressure of the electrolyte solution to agitate the electrolyte solution.

30. The method of claim 29, wherein varying the pressure of the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

31. The method of claim 29, wherein varying the pressure of the electrolyte solution comprises decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

32. The method of claim 30, wherein increasing the pressure increases a temperature of the electrolyte solution.

33. The method of claim 22, further comprising energizing a power source connected to the substrate.

34. A method for chemical plating, comprising:

evacuating an enclosure having a substrate disposed therein under vacuum;

filling the enclosure with an electrolyte solution having a pressure sufficient to substantially collapse air bubbles in the electrolyte solution; and

chemical plating a metal layer on at least a portion of a surface of the substrate.

35. The method of claim 34, further comprising energizing one or more ultrasonic sources to agitate the electrolyte solution.

36. The method of claim 35, wherein the one or more ultrasonic sources are disposed within the chamber.

37. The method of claim 35, wherein the one or more ultrasonic sources are adapted to agitate a substrate disposed within the enclosure.

38. The method of claim 34, further comprising energizing a power source connected to the substrate.

39. The method of claim 34, further comprising varying the pressure of the electrolyte solution to agitate the electrolyte solution.

40. The method of claim 39, wherein varying the pressure of the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

41. The method of claim 39, wherein varying the pressure of the electrolyte solution comprises decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

42. A method for chemical plating, comprising:

evacuating an enclosure having a substrate disposed therein under vacuum;

filling the enclosure with an electrolyte solution having a pressure sufficient to substantially collapse air bubbles in the electrolyte solution;

varying the pressure of the electrolyte solution to agitate the electrolyte solution; and

chemical plating a metal layer on a surface of the substrate.

43. The method of claim 42, further comprising energizing one or more ultrasonic sources to agitate the electrolyte solution.

44. The method of claim 43, wherein the one or more ultrasonic sources are disposed within the chamber.

45. The method of claim 42, further comprising energizing a power source connected to the substrate.

46. The method of claim 42, wherein varying the pressure of the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

47. The method of claim 42, wherein varying the pressure of the electrolyte solution comprises decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

48. The method of claim 42, wherein varying the pressure of the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds followed by decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

49. A method for chemical plating, comprising:

exposing a substrate surface to a vacuum that is sufficient to substantially remove gases from the substrate surface;

exposing the substrate surface to an electrolyte solution;

energizing one or more ultrasonic sources to agitate the electrolyte solution;

chemical plating a metal layer on at least a portion of the substrate surface at a variable pressure between about 1 atm and about 100 atm; and

draining the electrolyte solution from the enclosure.

50. A method for chemical plating, comprising:

exposing a substrate surface to a vacuum that is sufficient to substantially remove gases from the substrate surface;

exposing the substrate surface to an electrolyte solution;

pressurizing the electrolyte solution; and

chemical plating a metal layer on at least a portion of the substrate surface.

51. The method of claim 50, wherein pressurizing the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

52. The method of claim 50, further comprising decreasing the pressure of the electrolyte solution by about 5 to about 20 percent every 1 to about 30 seconds.

53. The method of claim 50, wherein pressurizing the electrolyte solution comprises increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds followed by decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

54. The method of claim 50, wherein pressurizing the electrolyte solution increases a temperature of the electrolyte solution.

55. The method of claim 50, further comprising compressing the electrolyte solution using a piston member.

56. The method of claim 55, wherein compressing the electrolyte solution using a piston member pulsates the electrolyte solution across the substrate surface.

57. The method of claim 50, further comprising energizing one or more ultrasonic sources to agitate the electrolyte solution.

58. The method of claim 50, further comprising draining the electrolyte solution from the enclosure.

59. A method for chemical plating, comprising:

exposing a substrate surface to a vacuum that is sufficient to substantially remove gases from the substrate surface;

exposing the substrate surface to an electrolyte solution;

energizing one or more ultrasonic sources to agitate the electrolyte solution; and

chemical plating a metal layer on at least a portion of the substrate surface.

60. The method of claim 59, further comprising compressing the electrolyte solution using a piston member.

61. The method of claim 59, further comprising pressurizing the electrolyte solution by increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

62. The method of claim 59, further comprising varying a pressure of the electrolyte solution by increasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds followed by decreasing the pressure by about 5 to about 20 percent every 1 to about 30 seconds.

63. The method of claim 59, further comprising increasing a pressure of the electrolyte solution by heating the electrolyte solution.

64. The method of claim 59, further comprising increasing a pressure of the electrolyte solution by heating the substrate surface.

65. The method of claim 63, wherein the electrolyte solution is heated by the substrate surface.

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