(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
24 September 2009 (24.09.2009)

PCT

(10) International Publication Number
WO 2009/114965 A1

(51) International Patent Classification:
C25D 7/12 (2006.01) *C25D 17/00* (2006.01)
C25D 19/00 (2006.01) *H01L 21/00* (2006.01)

(21) International Application Number:
PCT/CN2008/070531

(22) International Filing Date:
19 March 2008 (19.03.2008)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant *(for all designated States except US)*: **ACM RESEARCH (SHANGHAI) INC.** [CN/CN]; Bld. 4, No. 1690 Cailun Road, Zhangjiang High-tech Park, Shanghai 201203 (CN).

(72) Inventors; and

(75) Inventors/Applicants *(for US only)*: **MA, Yue** [US/CN]; Room 2202, Building 6, #60, Miaopu Road, Pudong District, Shanghai 201203 (CN). **HE, Chuan** [CN/CN]; Bld. 4, No. 1690 Cailun Road, Zhangjiang High-tech Park, Shanghai (CN). **PANG, Zhenxu** [CN/CN]; Bld. 4, No. 1690 Cailun Road, Zhangjiang High-tech Park, Shanghai (CN). **SHI, Guangtao** [CN/CN]; Bld. 4, No. 1690 Cailun Road, Zhangjiang High-tech Park, Shanghai (CN). **XIA, Jiexu** [CN/CN]; Bld. 4, No. 1690 Cailun Road, Zhangjiang High-tech Park, Shanghai (CN). **NUCH, Voha** [US/CN]; Bld. 4, No. 1690 Cailun Road, Zhangjiang High-tech Park, Shanghai (CN). **WANG, Hui** [US/CN]; Bld. 4, No. 1690 Cailun Road, Zhangjiang High-tech Park, Shanghai (CN).

(74) Agent: **SHANGHAI PATENT & TRADEMARK LAW OFFICE, LLC**; 435 Guiping Road, Xuhui, Shanghai 200233 (CN).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

(54) **Title**: ELECTROCHEMICAL DEPOSITION SYSTEM

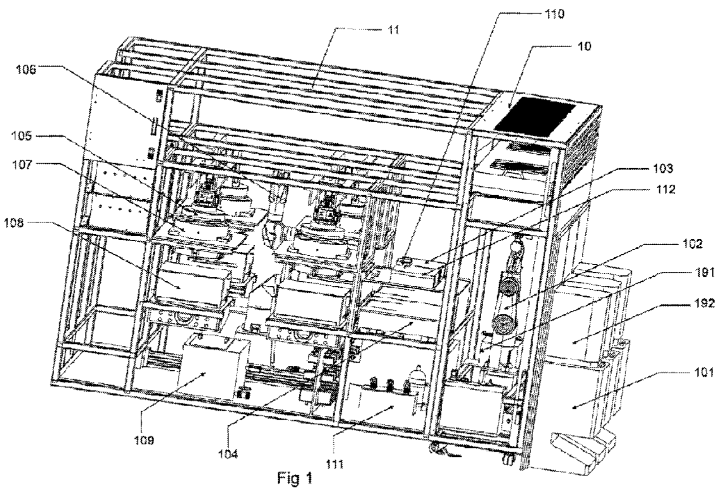

Fig 1

(57) **Abstract**: An electrochemical deposition system which has a 3-D stacked architecture comprises a factory interface (10) for receiving semiconductor wafers, a mainframe (11) comprising a mainframe transfer robot (102,106) and a plurality of wafer holder assemblies (105) which disposed on the top thereof, a plurality of electroplating cells (107) disposed within the mainframe, a plurality of cleaning cells (107) disposed within the mainframe and located below the electroplating cells, a plurality of thermal treatment chambers disposed in between the mainframe and the factory interface, and a fluid distribution system fluidly connected to the electroplating cells and the cleaning cells, wherein the mainframe transfer robot transfers semiconductor wafers from the factory interface and within electroplating cells, the cleaning cell, the thermal chambers and delivery and storage cassettes. As a result, the system of present invention is expandable to accommodate newly-added processing units without over much increased footprint.

WO 2009/114965 A1

Electrochemical deposition system

Field of invention

The present invention relates to a system for deposition of a metallic layer onto semiconductor workpieces, more particularly a system for electrochemical or electroless deposition of metallic thin films on semiconductor wafers from electrolyte solutions, chemically etching parts of the deposited films, cleaning the surface of the deposited films and thermally treating the deposited films.

Related art

On-chip interconnects comprises multilayer of metallic wirings embedded in one or more insulating materials on the top of transistor circuit of logic or memory chips. As the circuit density in ultra large scale integrated (ULSI) circuits increases, the size of the features in the pattern of metallic wirings, such as vias and trenches, decreases to submicron level, and the levels of metallization increase. Furthermore, RC delay has become the most dominant effect in degrading the circuit speed as the length of conductive wirings in integrated circuits continues to grow. Copper is a favorable material for interconnect metallization because of its low resistivity and high electromigration resistance. While copper is good for interconnect metallization, it poses many challenges to metallization during device fabrication.

The main challenge for copper implementation is the deposition system to uniformly fill trench and via features without voids and seams across the entire semiconductor substrate, known as wafer, in a damascene process, or frequently dual damascene process at acceptable manufacture flow cost.

Typical electroplating systems usually comprise a plurality of plating cells for metal electrochemical or chemical ("electroless") deposition and cleaning cells for rinse, clean and bevel etch after deposition.

Examples of such electroplating systems are disclosed in U.S. Patent No. 6258220 and U.S. Patent No. 6527920. Such systems include a mainframe with a mainframe transfer robot, a loading station disposed in connection with the mainframe, a plurality of electrochemical processing cells disposed in connection with the mainframe, a plurality of spin-rinse-dry and bevel etch chambers disposed in the mainframe, and a rapid thermal treatment subsystem attached adjacent the loading station. The locations of the processing cells, spin-rinse-dry and bevel etch chambers and the probably added units are designed in one plane, and such a design takes large clean room space for providing satisfactory throughout to meet the demands of the processing system. Said electroplating systems are used in today's IC manufacturing.

Because such a system utilizes a 2-D architecture with all process units placed on one plane, while it is expanded to accommodate newly added process units, the footprint of the system increases, thereby limiting its expandability practically. Additionally, a plurality of permanent heavy-duty supporting posts, erected from the base plate where the processing chambers are built upon, are needed in said electroplating system to support a plurality of plating cell head assemblies that receive wafers from a robot and carry the wafers into the electrolyte. These posts are bulky as they must provide stabilization and consistence to the cell head assemblies they support in order to control precisely the movement of the cell head assemblies. These supporting posts not only take spaces inside the frame enclosure, but also limit the reachability to the mainframe transfer robot, the wafer holder assemblies and the plating cells and make the maintenance of the system inconvenient.

Furthermore, when the dimensions of the vias and trenches in the pattern on a semiconductor wafer become smaller, the features of the wafer become difficult to be completely wetted when the wafer carried by the chuck of the wafer holder assembly immerses into the electrolyte. This incomplete wetting will lead to defects and voids in the features in the deposited metal films. An typical method to wet a wafer is to pre-rinse the wafer in an added spin-rinse-dry cell before electroplating, as described in US 2004/0069644 and US 2007/7223323. And another example of method to wet a wafer is splashing water to the wafer surface by an added nozzle just before the wafer is carried into plating electrolyte, as described in US 2006/7146994. But pre-wetting by liquid rinse still cannot wet very small features completely, and the rinse liquid may dilute the plating electrolyte both globally in a high volume factory and locally, leading to new problems. So these disclosed methods still cannot completely solve the problem of incomplete wetting without significantly introducing process variation and adding manufacturing cost.

The present invention was disclosed against this background.

Summary

In view of the aforementioned problems, it is an object of the present invention to provide a new architecture of an electrochemical deposition system that may treat larger scale semiconductor wafers with great efficiency to provide high throughput with a small footprint.

In order to achieve the aforementioned object, an electrochemical deposition system according to the present invention which has a three dimensional (3-D) stacked architecture that comprises a factory interface for receiving semiconductor wafers, a mainframe comprising a mainframe transfer robot, a plurality of wafer holder assemblies which are disposed on the top thereof, a plurality of electroplating cells disposed within a first layer of the 3-D stacked architecture at the upper part of the mainframe, a plurality of cleaning and bevel etch cells disposed within a second layer of the 3-D stacked architecture at the lower part of the mainframe, a plurality of thermal treatment chambers disposed within either the first layer, or the second layer, or both layers in the part of the mainframe connected to the factory interface, a plurality of vapor phase pre-wetting modules disposed within the mainframe, a fluid distribution system to provide electrolyte to the plating cells and process fluids to the cleaning cells, a gas delivery system to provide gas mixture to the thermal treatment chambers. The mainframe transfer robot transfers the semiconductor wafers between the factory interface, the wafer holder assemblies, the cleaning cells and the thermal treatment chambers.

Comparing to the system disclosed in the prior art, an advantage of the system of the present invention which has a 3-D stacked architecture is that it has a smaller footprint and may treat larger scale semiconductor wafers with great efficiency to provide high throughput because additional footprint took by some processing cells such as plating cells is saved, and another advantage of the system of the present invention is that it could be expandable to accommodate newly-added processing units without overmuch increased footprint because the newly–added processing units could be disposed on the corresponding layer or layers other than on only one layer as in the prior art, and yet another advantage of the system of the present invention is that it can be serviced and maintained conveniently because the wafer holder assemblies are disposed on the top of the mainframe, eliminating the need of bulky supporting posts which greatly limit tool accessibility, and they can be moved to the corners of the mainframe during user intervention.

The further characteristic of said electrochemical deposition system according to the present invention is that the thermal treatment chamber comprises a heating plate and a heating fluid dispenser for double-side heating the semiconductor wafer, a cooling plate and a cooling fluid dispenser for double-side cooling the semiconductor wafer, at least two wafer holders for receiving the semiconductor wafer and transferring the semiconductor wafer from the heating plate to the cooling plate, and at least two actuators for controlling the movement of the wafer holders. As a result, the system in accordance with the present invention may provide a uniform post electroplating thermal treatment process to improve the electrical and physical properties of the deposited metal films on semiconductor wafers by double-side thermal treating of the wafer, and the thermal treatment chamber could thermally treat multiple wafers simultaneously so that the number of thermal treatment chambers in the mainframe is reduced and throughput of the system of the present invention is increased. And the processing wafer is transferred onto the heating plate in the thermal treatment chamber by the mainframe robot before the beginning of the process and transferred out from the cooling plate in the thermal treatment chamber by the front robot after the process ends. No mainframe/factory-interface hand-off station is needed post processing, so that the robot handoff points are reduced and the transfer efficiency of the system is improved.

The still further characteristic of said electrochemical deposition system according to the present invention is that it may also comprise a vapor phase pre-wet device connected to a vapor generating and delivery system to realize liquid molecules adsorption onto the front surface of a semiconductor wafer that will be processed in the electroplating cell from vapor phase. The adsorbed, or condensed liquid molecules form a thin pre-wetting layer on the front surface of the semiconductor wafer before the semiconductor wafer bearing such a film is put into contact to the electrolyte solution. As a result, the system in accordance with the present invention could provide the reliable process to deposit copper films in ultra-small features on the semiconductor wafer surface without voids caused by incomplete wetting.

While novel features of the invention are set forth in the preceding, the invention, both as to organization and content, can be further understood and appreciated, along with other objects and features thereof, from the following detailed description and examples when taken in conjunction with the attached drawings.

Description of Drawings

FIG.1 is a schematically perspective view of an electrochemical deposition system of the invention.

FIG. 2 is a side view of an electrochemical deposition system of the invention.

FIG. 3 is a schematically perspective view of an electroplating cell of an electrochemical deposition system of the invention.

FIG. 4 is a schematically perspective view of a wafer holder assembly of an electrochemical deposition system of the invention.

FIG. 5 is a schematically perspective view of thermal treatment module of an electrochemical deposition system of the invention.

FIG. 6 is a schematic diagram of the fluid supply system in the electrochemical deposition system of the invention.

FIG. 7 is a schematic diagram of the electrical control system in the electrochemical deposition system of the invention.

Detailed description of Exemplary Embodiments

With reference to FIG. 1-FIG. 2, the electrochemical deposition system in accordance with the present invention comprises a factory interface 10 and a mainframe 11. The factory interface includes a plurality of wafer load ports 101, a wafer transfer robot 102, and a wafer aligner 191, all enclosed in a class 1 mini-environment. The mainframe comprises a mainframe transfer robot 106, a plurality of electroplating cells 107, a plurality of cleaning cells 108, a plurality of thermal treatment chambers 104 and at least one vapor pre-wet module 110. The electroplating cells 107 and the cleaning cells 108 are positioned within the first layer and second layer of the mainframe 11 separately, with one electroplating cell 107 stacked over one cleaning cell 108. The thermal treatment chambers 104 are positioned in the mainframe 11 and connected to the factory interface 10. Furthermore, the system comprised a delivery cassette 103 and a temporary storage cassette 112 which are attached to the factory interface 10 and located over the thermal treatment chambers 104. The delivery cassette 103 is used for transportation of a semiconductor wafer from the factory interface 10 into the mainframe 11. And the temporary storage cassette 112 is used to store affected wafers in case of excursion taking place to any one of the process chambers. In this case the mainframe transfer robot 106 will place wafers that are partially processed in the whole electroplating process into the temporary storage cassettes 112 for further treatment. The system further comprises a fluid distribution system that is connected to the process cells and provides plating electrolyte to the plating cells and chemical solutions to the cleaning cells. The system further comprises a gas mixing and delivery system which is connect to the thermal treatment chambers and provides mixed process gas to the thermal treatment chambers.

The factory interface 10 includes a plurality of load ports 101 for receiving and positioning wafer pods 192, a front interface robot 102 and at least one wafer aligner 191. In the present embodiment, the factory interface 10 comprises three load ports 101 and one wafer aligner 191. The pod 192, which preferably is the industrial wafer FOUP (front opening unified pod) accommodating multiple wafers, is transferred and disposed onto one of the load ports 101 after previous treatment of process of the wafers is ended, such as physical vapor deposition, chemical vapor deposition, or atomic layer deposition of a thin conductive layer on the wafer surface before the electro-chemical plating process. The front interface robot 102 is a typical transfer robot commonly known to the persons skilled in the field which comprises one or two arms.

All process modules are located inside the mainframe. Referring to Fig. 2 again, each of the electroplating cells 107 locates vertically over one of the cleaning cells 108. In the present embodiment, the mainframe 11 comprises four electroplating cells 107 and four cleaning cells 108 corresponding to the number of loading ports 101. It should be understood that the number of the electroplating cells 107 in the mainframe 11 of the chemical-electroplating system in accordance with the invention are not limited by the exemplary embodiment. The person skilled in the field could increase or decrease the number of the cells according to the desired throughput of the system. And it should be noticed that stacked plating cells 107 and cleaning cells 108 save places for the mainframe 11 and reduce the footprint of the electrochemical deposition system. And it will be noted in the following specification that the 3-D architecture of the system with the plating cells 107 stacked over the cleaning cells 108 are expandable to accommodate newly-added processing units without overmuch increased footprint.

The mainframe 11 also comprises pluralities of wafer holder assemblies 105, each of which is disposed above one of the electroplating cells 107 and mounted on the top of the mainframe 11. In this embodiment of the electrochemical deposition system in accordance with this present invention, the mainframe 11 comprises four wafer holder assemblies 105 corresponding to the number of the electroplating cell 107.

Referring to Fig. 4, the wafer holder assembly 105 comprises a semiconductor wafer chuck assembly, which further comprises a semiconductor wafer chuck 511 and a cathode contact (not shown), and an actuator. The actuator may comprise step motors 521, 523 and servo motor 525. The cathode contact may comprise a plurality of soft stainless steel coil springs to maintain a uniform cross section profile which improves electrical contact to the wafer and reduces damage to the underlying film stack caused by compressive stress from mechanical contact. The wafer chuck may comprise a bottom section and a top section and the wafer is held between the bottom section and the top section, thereby the wafer chuck assembly suitably being configured to open, close and rotate the wafer chuck for inserting, removing and rotating the wafer, and the cathode contact being disposed between the bottom section and the top section of the wafer chuck and could electrically contact to the wafer front-side when the wafer chuck is closed by the actuator before the electro-chemical plating process starts. Electrical information from contact locations is monitored and fed back to the control system. Additionally, the wafer holder assembly 105 could be moved to the corner of the mainframe 11 for performance maintenance. The semiconductor wafer could be held by the chuck 511 and moved along Z axis and rotated along the X axis and Z axis respectively with the chuck 511 droved by the step motors 521, 523 and servo motor 525 of the actuator. For a more detailed description of wafer chuck component which comprises a wafer chuck and a cathode contact, see US06495007, entitled “Methods and apparatus for holding and positioning semiconductor wafer during electropolishing and/or electroplating of the workpieces”, the entire content of which is incorporated herein by reference. In present invention, the entire wafer holder assembly is supported by the mounting arm 527 which connects the wafer holder assembly 105 to the top of the mainframe. It should be noted that the configuration of wafer holder assembly 105 being disposed on the top of the mainframe strengthens reachability of the mainframe transfer robot 106 to the wafer holder assemblies and the plating cells and saves spaces due to needless of supporting post.

The mainframe 11 also comprises a vapor phase pre-wet device which may be integrated on the wafer holder assembly 105 or be an independent module (as shown in drawing). This pre-wet device is connected to a vapor generating system and provides liquid vapor to front surface of a semiconductor wafer for posing an ultra-thin pre-wetting layer on the front surface to improve the wetting performance during electroplating process. Pre-wetting by liquid vapor can wet very small features, such as vias and trenches, completely and does not cause appreciable dilution to the plating electrolyte. Therefore the system of the present invention will satisfy the needs to eliminate any incomplete wetting-related defects brought about by the increase of circuit density in ULSI.

Referring to FIG.3, in the present embodiment, the electroplating cell 107 comprises an electrolyte chamber 700. The electrolyte chamber 700 comprises a plurality of annular electrodes 711 and a plurality of annular insulating walls 713 which separate the whole electrolyte chamber 700 into a plurality of independent regions, each of which containing a single annular electrode 711. The electrode 711 are charged by a plurality of power supplies (not shown) respectively by applying different waveforms and turning on or off in different sequence or at different time during the electroplating process.

For a more detailed description of the said electrolyte chamber, also see US06495007, entitled “Methods and apparatus for holding and positioning semiconductor wafer during electropolishing and/or electroplating of the workpieces”, the entire content of which is incorporated herein by reference.

However, the electrolyte chamber 700 in the deposition system according to the present invention have some difference with the said electrolyte chamber in the prior art. The electrolyte chamber 700 in the deposition system according to the present invention is separated into a lower cell body 701 which receives low cell feed electrolyte and an upper cell body 702 which receives upper cell feed electrolyte by a bubble coalescence assembly 720.

An inlet and an outlet connected to each independent region of the lower cell body 701 of the electrolyte chamber 700. Electrolyte is pumped into each independent region of the electrolyte chamber 700 by a pump from an electrolyte tank (which will be described in details in the following passage) through the inlet and then flows out through the outlet and finally returns to said electrolyte tank to realize an independent electrolyte circulation in each region of the lower cell 701 body of the electrolyte chamber 700.

For each region of the upper cell body 702 there is an electrolyte inlet which is controlled by a LMFC (Liquid Mass Flow Controller) respectively to each separate region so that the electrolyte flow rate in each region of the upper cell body 702 to surface of a processing wafer can be controlled independently. The LMFCs are acid and corrosion resistant. Both the lower cell body 701 and the upper cell body 702 are made of or coated with electrical isolative and acid and corrosion resistant materials, such as PVC or PVDF.

The bubble coalescence assembly 720 comprises a cone-shape frame having pluralities of V-shape grooves and a porous membrane attached closely on the cone-shape frame. A tube is disposed at the top of the bubble coalescence assembly 720 which is connected to the outside of the electroplating cell 107. Bubbles generated at the electrodes 713 during electroplating will first coalesce in V-shaped grooves and move upward to the top and then exit the chamber through the said tube.

The cleaning cell 108 comprises a cell body having a window for transferring semiconductor wafer into or out of the cleaning cell 108 and a wafer holding part disposed at the center of the cell body which could be rotated by an actuator disposed at the bottom of the cleaning cell 108 with a speed of 10 to 4000 rpm. The wafer holding part comprises 3 pins with a small angled step at the top of each pin which positions the wafer within the cleaning cell 108 and a mechanical chuck disposed on each pin which could be activated by spinning. And when the wafer holding part spins, the mechanical chuck closes and holds the wafer tightly to prevent relative motion between the semiconductor wafer and the pins; when the wafer holding part stops spinning, the mechanical chuck opens and the wafer could be pick up by the mainframe transfer robot.

The cleaning cell 108 is configured with one front side nozzle, one backside nozzles, and one movable nozzle. The front side nozzle which is disposed on and extends from the upper portion of the cell body of the cleaning cell 108 provides DI water to the front surface of a semiconductor wafer. The backside nozzle which is disposed on and extends from the lower portion of cell body of the cleaning cell 108 provides DI water to the backside of the semiconductor wafer. The movable nozzle which is disposed on the central section of the cell body of the cleaning cell 108 and can radially move to the edge of a processing wafer provides mixed acid and dioxide to the edge bevel of the semiconductor wafer while working and moves away from the center of body of the cleaning cell during the semiconductor wafer transfer. The movement of the movable nozzle is controlled by an actuator. The cleaning cell 108 also comprises a lid disposed at the top of the body which prevents fluid splashing out of the cleaning cell and contaminating the parts of the present system. For more detailed description of the said cleaning cell 108, see WO 03/087436, entitled “Electropolishing and/or electroplating apparatus and methods”, the entire content of which is incorporated herein by reference.

The mainframe 11 also comprises a fluid distribution system which comprises a electrolyte tank 109 located at the bottom part of the mainframe 11, which supplies plating electrolyte to each electroplating cell 107. With reference now to FIG 6, the electrolyte tank 109 is separated into a lower cell electrolyte tank 191 and a upper cell electrolyte tank 192. The lower cell electrolyte tank 191 is fluidly connected to the lower cell bodies of the electroplating cells 107 to provide lower cell feed electrolyte to the electroplating cells 107, and the upper cell electrolyte tank 192 is fluidly connected to the upper cell body of the electroplating cells 107 to provide upper cell feed electrolyte to the upper cell bodies of the electroplating cells 107 for electroplating. The lower cell electrolyte tank 191 and the upper cell electrolyte tank 192 is connected to electroplating cell 107 with an electrolyte supply line 311 and 321 through pump 313 and valves respectively which comprise a two-way valve 315, a check valve 316 and control valve 312. Preferably, the electrolyte line connecting the maintank 109 to the electroplating cell 107 is coupled with a filter 317 to filter the impurities and a flow-meter 314 with analog output to monitor the flow rate. The maintank 109 is configured with a temperature sensor and a chiller to maintain the temperature of the electrolyte both in the lower cell electrolyte tank and the upper cell electrolyte tank at a fixed temperature. The lower cell electrolyte tank and upper cell electrolyte tank also respectively connects to a metrology tool 351 by two additional pipes 321 to provide a sample of the electrolyte to the metrology tool 351 which may monitor the concentration of components of the electrolyte in the lower cell electrolyte tank and upper cell electrolyte tank.

The fluid distribution system also comprises a chemical tank 330 where acid and dioxide are mixed homogeneously and then are provided to the movable nozzle in cleaning cells 108. The chemical tank 330 connects to the chemical metrology tool 351 through a pipe 352 to provide a sample of the mixed chemicals made from the acid and dioxide to the metrology tool 351 to monitor the concentration of the components of the mixed chemicals. The mixed chemicals in the chemical tank 330 is transferred to the movable nozzle of the cleaning cell 108 through pump 353 and serial valves which preferably include a two-way manual valve 355, control valve 352 and two-way pneumatic valve 359 for removing the deposited metal at the edge bevel of the wafer after electroplating. Preferably, the pipe connected the chemical tank 330 and the cleaning cell 108 interconnects a filter 357 to filter the impurities and a flow-meter 354 with analog output to monitor the flow rate.

The system in accordance with the present invention also comprises a dosing system 361. The dosing system 361 electrically connected to an electrical control module (which will be described in details in the following context) will dose the required amount of metal ions or organic additives to lower cell electrolyte tank and upper cell electrolyte tank of the electrolyte tank 109 depending on algorithm provided by operator and the analyzing results from the chemical analyzing tool 351 to keep the stable electro-deposition performance of the electrolyte and the edge bevel removal performance of the mixed chemicals.

Referring to Fig. 5, in the present embodiment, there are two thermal treatment chambers 104 which are positioned in parallel in the mainframe 11 and connected to the factory interface 10. The thermal treatment chamber 104 preferably comprises a rectangle shape body with two windows, one window facing against the mainframe 11 which is the heating cell window 421 and the other window facing against the factory interface 10 which is the cooling cell window 523. The thermal treatment chamber 104 also comprises a heating plate 411 disposed within the body of thermal treatment chamber 104 which is near the heating cell window 421, a cooling plate 413 disposed within the body which is near the cooling cell window

423, and two wafer holders 431,433 respectively disposed at opposite sides of the heating plate 411 or cooling plate 413. The wafer holders 431,433 are used for receiving a semiconductor wafer from the mainframe transfer robot 106, loading the wafer onto the heating plate 411 or cooling plate 413, transferring the wafer from heating plate 411 to cooling plate 413 and transferring the wafer to the front interface robot 102. The wafer holder 411 or 413 comprises an arm 439 which is connected to an actuator 438 comprising two step or servo motors, and is configured with a supporting ring 437 with a plurality of support fingers thereon. The wafer holder 431 of the thermal treatment chamber 104 may rotates and moves vertically with the control of the actuator 438. The thermal treatment chamber 104 also comprises a lid 441with two fluid distribution parts 448,449 on the lid 441 and a fluid line 443 fluidly connected with the fluid distribution parts 448,449. Each fluid distribution part 449 is positioned over one of heating plate 411 and the cooling plate 413 to provide required fluid into the thermal treatment chamber, such as mixture of N_2 and H_2. The distribution part 449 over the heating plate 411 provides hot fluid to the front surface of the wafer to realize a double side heating of the wafer, with the heating plate heating the backside of the wafer. The distribution part 448 over the cooling plate 413 provides cool fluid to the front side of the wafer to realize a double side cooling, with the cooling plate cooling the backside of the wafer. This double-side thermal treatment mechanism provides a uniform thermal treatment process and reduces the thermal stress induced bowing of the wafer, and, together with the ability of thermal treating multiple wafers in the thermal treatment chamber, greatly increases the efficiency and throughput of the thermal treatment chamber.

The mainframe 11 further comprises an electrical control module at the back of the mainframe. The block diagram of the electrical control module is shown in the Fig. 4. The electrical control module typically comprises a host computer with a user interface in connection with the module, robot control system, motor driver, I/O interface chassis and plating power control board. The host computer is the key control equipment of the electrical control module, which provides all the I/O ports, RS232 ports and the motion control board. Host computer transmits the signals via I/O interface chassis to every process cell which needs the control signal for flow control, such as the electrolyte flow control of the electroplating cell and DI water or acid flow control of nozzles of the cleaning cell. Plating power control board, which electrically connected to the I/O interface chassis and the electroplating cell 107, provides adjustable high voltage/current for the high power consumptions for the electroplating cell 107. The host computer transmits all signals of the control parameters via robot control system to control the mainframe transfer robot and front interface robot. However, robot control system may be a stand-alone computer which communicates with host computer via RS232 port, so the robot control system still could control the mainframe transfer robot and the front interface robot without the host computer. The motor driver, which electrically connects to the host computer and servo/step motors of the electroplating cell, cleaning cell and the thermal treatment chamber respectively, transfers the control signal from the motion control board of host computer to servo/step motors of the thermal treatment chamber, the clean cell or the electroplating cell, and the encoding signal that servo/step motors feedback to host computer.

It should be noted that the whole electrochemical deposition process should be performed in a clean environment, so the system according to the present invention is preferably enclosed by panels. There are transparent windows configured on part of the panels so that the electrochemical plating process could be under monitoring by the operator. The panels are removable or configured to provide openings for convenience of performance maintenance.

In operation, the front interface robot 102 transfers a wafer from the pods 192 to the wafer aligner 191. Then the wafer received by the wafer aligner 191 is rotated to a prearranged orientation by the wafer aligner 191 to facilitate the wafer to be precisely controlled in the next processes. After wafer alignment, the front interface robot 102 will transfer the wafer into wafer delivery cassettes 103 for further transportation into the mainframe 11.

The mainframe transfer robot 106 transfers a semiconductor wafer from the wafer delivery cassette 103 into wafer holder assembly 105 or from an electroplating cell 107 to a cleaning cell 108 of the mainframe or from the cleaning cell 108 into the thermal treatment chamber 104. The robot 106 is a transfer robot commonly known to persons skilled in the relevant field of technology, which preferably comprises a plurality of transfer arms. In this present embodiment, the mainframe transfer robot 106 comprises two transfer arms, which can be operable independently. The mainframe transfer robot 106 may rotate around a Z-axis shown in FIG. 2 and move up and down vertically. The two robot arms of the mainframe transfer robot 106 may be controlled to extend and retract for transferring semiconductor wafers into or out of the electroplating cells 107 or the cleaning cells 108, also to flip the semiconductor wafers to meet the requirements of different processes, for example, semiconductor wafers should be disposed downwardly in the electroplating process, but upwardly in the cleaning process.

For the process, firstly, the wafer holder assembly 105 stays at a receiving position and the chuck 511 of the wafer holder assembly 105 is at an open status. The mainframe transfer robot 106 picks up a semiconductor wafer from the delivery cassette 103 which disposed in between the mainframe 106 and the factory interface 10, flips it face downward and transfers it to the vapor phase pre-wet device, where the pre-wet device is an independent module as shown in the figure. The pre-wet device splashes vapor to the front surface of the wafer and forms a thin layer of pre-wet liquid on it. Then the mainframe robot transfers the wafer into the chuck of wafer holder assembly 105, and positions it on the cathode contact in the wafer holder assembly. After the arms of the mainframe transfer robot 106 retracts out of the wafer holder assembly 105, the chuck of the wafer holder assembly 105 closes and holds the semiconductor wafer in tight contact with the cathode spring. And the backside of the semiconductor wafer is well sealed to prevent the backside of the wafer in contact with electrolyte during plating. The servo motor 525 begins rotating and thereby wafer holder assembly 105 starts spinning the wafer. The step motor 523 rotates to carry the wafer holder assembly 105 to a certain angle relative to the z direction and then step motor 521 moves the wafer holder assembly 105 along the z direction to a pre-process position to make the edge of the chuck 511 just over the liquid level of electroplating cell 107. Thereafter motor 523 starts rotating the wafer holder assembly 105 back to vertical position, and brings the wafer holder assembly 105 into the electroplating cell 107 and thereby makes the front surface of the semiconductor wafer in contact with the electrolyte in the upper cell body 702 of the electroplating cell 700. After that, the electroplating process starts. By controlling the waveform, working sequence and time of multiple anodes and electrolyte flow rate, a uniform metal film could be deposited on the semiconductor wafer. For more detailed electroplating process, see patent US06391166, entitled “plating apparatus and methods”, and the entire content of which is incorporated herein by reference.

In another embodiment, the vapor phase pre-wet device is integrated on the wafer holder assembly. In process the mainframe robot picks up the wafer from the delivery cassette and transfers it into the wafer holder assembly. Before the wafer holder assembly carries the wafer into the electrolyte, the pre-wet device moves in and slashes vapor onto the wafer surface. When the pre-wet process is done, the wafer holder assembly then carries the wafer into the electrolyte and the same electroplating process is carried out as above.

After the electroplating process is completed, the wafer holder assembly 105 moves up and brings the semiconductor wafer out of the electrolyte of the electroplating cell 107. When the wafer holder assembly 105 moves to a spin position, it rotates with the processed wafer with a large rpm to remove the residual electrolyte on the wafer surface. Then the wafer holder assembly 105 moves to the receiving position and the chuck 511 opens. The arm of the mainframe transfer robot 106 extends into the wafer holder assembly 105, transfers the semiconductor wafer out and flips it to face upward.

Then the mainframe transfer robot 106 moves down until it reaches the level of the window of the cleaning cell 108, the arms of mainframe transfer robot 106 extends and transfers the semiconductor wafer into the cleaning cell 108. When the semiconductor wafer is transferred into the cleaning cell 108, the arm of mainframe transfer robot 106 moves down a little bit, places the semiconductor wafer on the three pins of the cleaning cell 108 and then moves out. The wafer holding part of the cleaning cell 108 which holds the wafer with three pins starts rotating controlled by the actuator. The mechanical chuck on the pins turns on and holds the semiconductor wafer tightly to prevent relative motion. Then the front surface nozzle of the cleaning cell turns on and splashes DI water from DI water facility onto the front side of the semiconductor wafer to pre-rinse and remove residual plating electrolyte. After the pre-rinse, the movable nozzle of the cleaning cell moves to the edge of the semiconductor wafer and splashes mixed chemicals from the chemical tank onto the edge bevel of the semiconductor wafer to etch off the deposited metal film on the edge bevel. The wafer holding part of the cleaning cell 108 spins with a large rpm to confine the chemicals at a narrow range along the edge of the wafer to prevent etching of the deposited metal film in the inner area. When the metal film at the bevel is completely removed, the movable nozzle moves away from the center of the cleaning cell and both front and back face nozzles turn on and splash DI water on both sides of the semiconductor wafer to rinse off the residual chemicals from etching. When the cleaning process is completed, the wafer holding part stops spinning and the mechanical chuck opens. The mainframe transfer robot 106 extends into the cleaning cell 108, picks up the semiconductor wafer and transfers it out of the cleaning cell 108.

When the electroplating and cleaning process of a wafer (first wafer) is ended, the mainframe transfer robot 106 will transfer the first wafer into the thermal treatment chamber 104 through the heating cell window 421 and place it on the first wafer holder 433. While the arms of the mainframe transfer robot 106 move out of the thermal treatment chamber 104, the first wafer holder 433 moves down to a pre-heating position to pre-heat the first wafer for a scheduled time. After the pre-heating process is ended, the first wafer holder 433 moves down and positions the wafer onto the heating plate 411 such that the wafer is in contact with the heating plate 411 and heated for a scheduled time. Once heating process of the first wafer is ended, the first wafer holder 433 moves up and transfers the wafer onto the cooling plate 413 for cooling process. And it should be noted that the heating plate 411 is free now. While the first wafer is in cooling process, another wafer (second wafer) which has been treated with the electroplating and cleaning process is transferred into the thermal treatment chamber 104 by the mainframe transfer robot 106 and received by the second wafer holder 431 and starts pre-heating and heating process. Thus the thermal treatment chamber 104 does thermal treatment for two wafers simultaneously. When cooling process of the first wafer is ended, the first wafer holder 433 moves up and brings it to a transfer position and the front interface robot 102 extends into and transfers semiconductor it out of the thermal treatment chamber 104. And the cooling plate 413 is free now. After heating process of the second wafer is ended, the second wafer holder 431 transfers it onto the cooling plate 413 for cooling process. While the second wafer is in cooling process, another wafer (third wafer) is transferred into the thermal treatment chamber 104, received by the first wafer holder 433 and is treated with the same processes (pre-heating, heating, and cooling process). The process performed in the thermal treatment chamber 104 described above depends on the assumption that the time for heating is longer than that for cooling. If the time for cooling is longer than that for heating, the difference in the process is that, when the first wafer has been heated on the heating plate 411 and is transferred to the cooling plate 413, the second wafer will not be transferred into the thermal treatment chamber 104 immediately until the remaining cooling time for the first wafer is smaller than the heating time. When the thermal treatment process of a wafer is ended, the wafer is transferred out of the thermal treatment chamber 104 through the cooling cell window 423 and placed into the pod 192 by the front interface robot 102 for the next manufacture step, such as chemical mechanical polishing.

While the foregoing is directed to the preferred embodiment of the present invention, other and further embodiments of the invention may be devised with out departing from the basic scope thereof. The scope of the invention is determined by the claims that follow.

What is claimed is:

1. An electrochemical deposition system which has a 3-D stacked architecture comprising:

a factory interface for receiving semiconductor wafers;

a mainframe comprising a mainframe transfer robot and a plurality of wafer holder assemblies for holding semiconductor wafers in an electroplating process which disposed on the top thereof;

a plurality of electroplating cells disposed within a first layer of the 3-D stacked architecture at the upper part of the mainframe;

a plurality of cleaning cells disposed within a second layer of the 3-D stacked architecture at the lower part of the mainframe;

a plurality of thermal treatment chambers disposed within either said first or the second layer and connected to the factory interface;

at least one vapor phase pre-wet device;

a fluid distribution system to provide electrolyte solutions to the electroplating cells and to provide process fluids to the cleaning cells respectively; and

a gas delivery system to provide a gas mixture to the thermal treatment chambers;

wherein, the mainframe transfer robot transfers semiconductor wafers from the factory interface between the wafer holder assemblies, the cleaning cells, the thermal treatment chambers, and delivery and storage cassettes.

2. The system of claim 1, wherein the electroplating cell further comprises an electrolyte chamber comprising a plurality of annular insulating walls which separate the electrolyte chamber into a plurality of independent regions and a plurality of annular electrodes respectively

disposed within each said independent region and separated into an upper cell body receiving catholyte and a lower cell body receiving anolyte by a bubble coalescence assembly which is used to collect and remove the bubbles generated from the electrolyte chamber.

3. The system of claim 2, wherein said bubble coalescence assembly comprises a cone-shape frame configured with pluralities of V-shape grooves and an porous membrane attached on the cone-shape frame.

4. The system of claim 2, wherein the anodes are independently charged by a plurality of power supplies.

5. The system of claim 2, wherein the upper cell body of said electrolyte chamber is configured with a plurality of electrolyte inlets for introducing electrolyte into said regions, wherein flows of electrolyte are controlled independently.

6. The system of claim 1, wherein said system comprises a vapor phase pre-wet device independently disposed on the mainframe or integrated on the wafer holder assembly and used for pre-wetting front surface of a wafer before electroplating process.

7. The system of claim 1, wherein the thermal treatment chamber further comprises:

at least one heating plate for heating a semiconductor wafer;

at least one cooling plate for cooling the semiconductor wafer;

at least two workpiece holders for receiving the wafer and transferring the semiconductor wafer from the heating plate to the cooling plate; and

at least two actuators for controlling the movement of the semiconductor wafer holder.

8. The system of claim 7, wherein the thermal treatment chamber has a cooling window faced against the factory interface and a heating window faced against the mainframe.

9. The system of claim 1, wherein said system comprises a plurality of wafer cassettes attached to the factory interface and disposed over the thermal treatment chambers to facilitate transfer and storage of semiconductor wafers between the factory interface and the mainframe.

10. The system of claim 1, wherein said factory interface comprises:

a plurality of load ports where semiconductor wafers are positioned;

at least one semiconductor wafer aligner for orienting semiconductor wafers; and

a front interface robot that transfers a semiconductor wafer from a wafer pod to the wafer aligner, or from the wafer aligner to the transfer cassettes, or from the thermal treatment chamber to the load port.

11. The system of claim 1, wherein one of the cleaning cells correspondingly located right below one of the electroplating cells.

12. The system of claim 1, wherein said cleaning cell provides spin rinse cleaning and removing the unwanted edge deposition of metals.

13. The system of claim 1, wherein said fluid distribution module comprises a maintank for providing electroplating electrolyte to the electroplating cells.

14. The system of claim 13, wherein said maintank further comprises a catholyte cell for providing catholyte to the upper cell body and an anolyte cell for providing anolyte to the electrolyte chamber

15. The system of claim 13, wherein said fluid distribution module further comprises a chemical mixing room to mix chemicals that will be introduced into the cleaning cell to etch off the deposited metal film on the bevel of a semiconductor wafer.

16. The system of claim 13, wherein said system further comprises a metrology tool and an dosing system, the maintank is fluidly connected to the metrology tool which monitors the concentration of components of the fluid in the maintank, and the dosing system which provide electrolyte components to the maintank according to user input, the information about concentration outputted by the metrology tool, and the desired concentration of components of the electrolyte in the maintank.

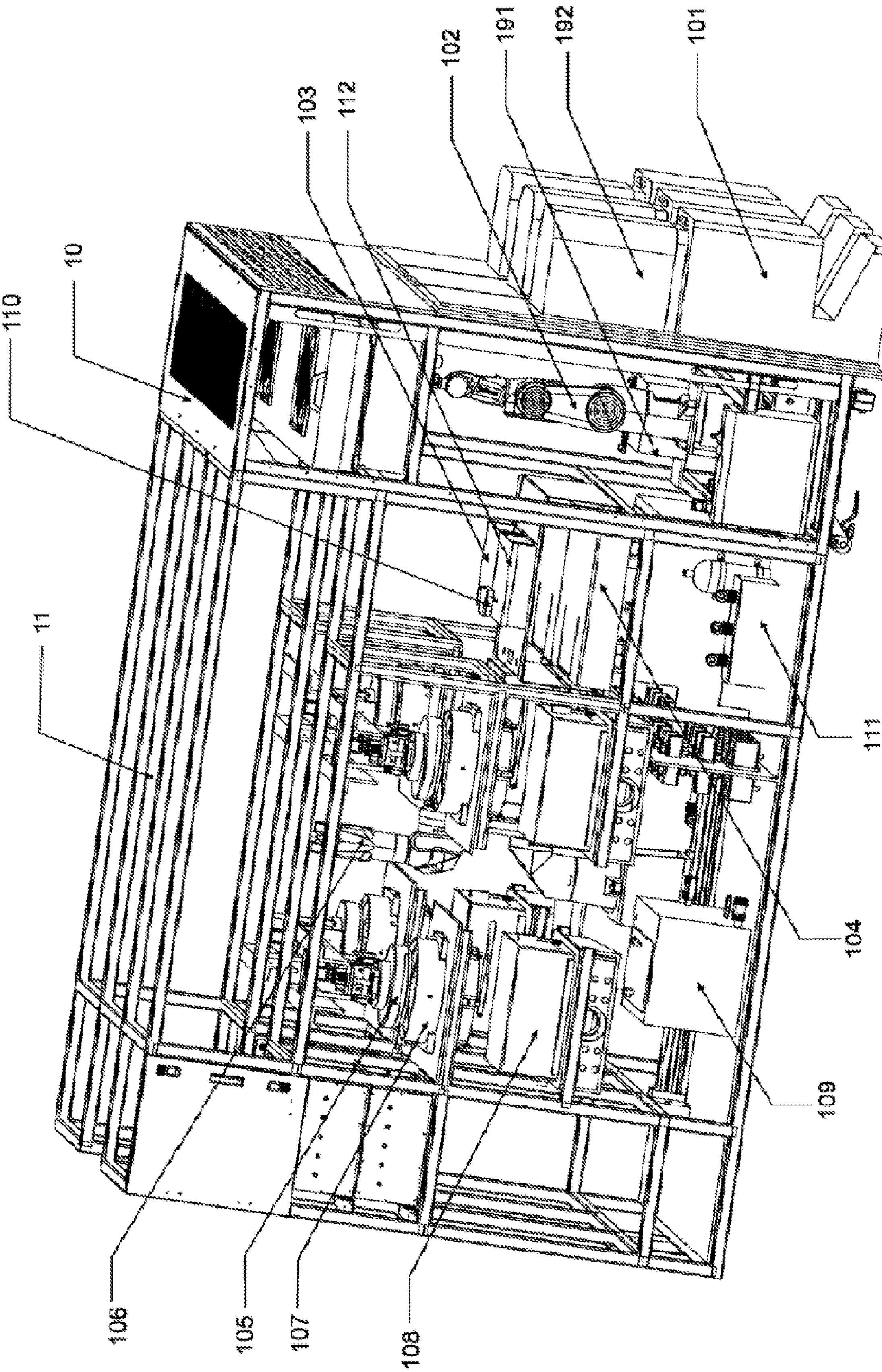

Fig 1

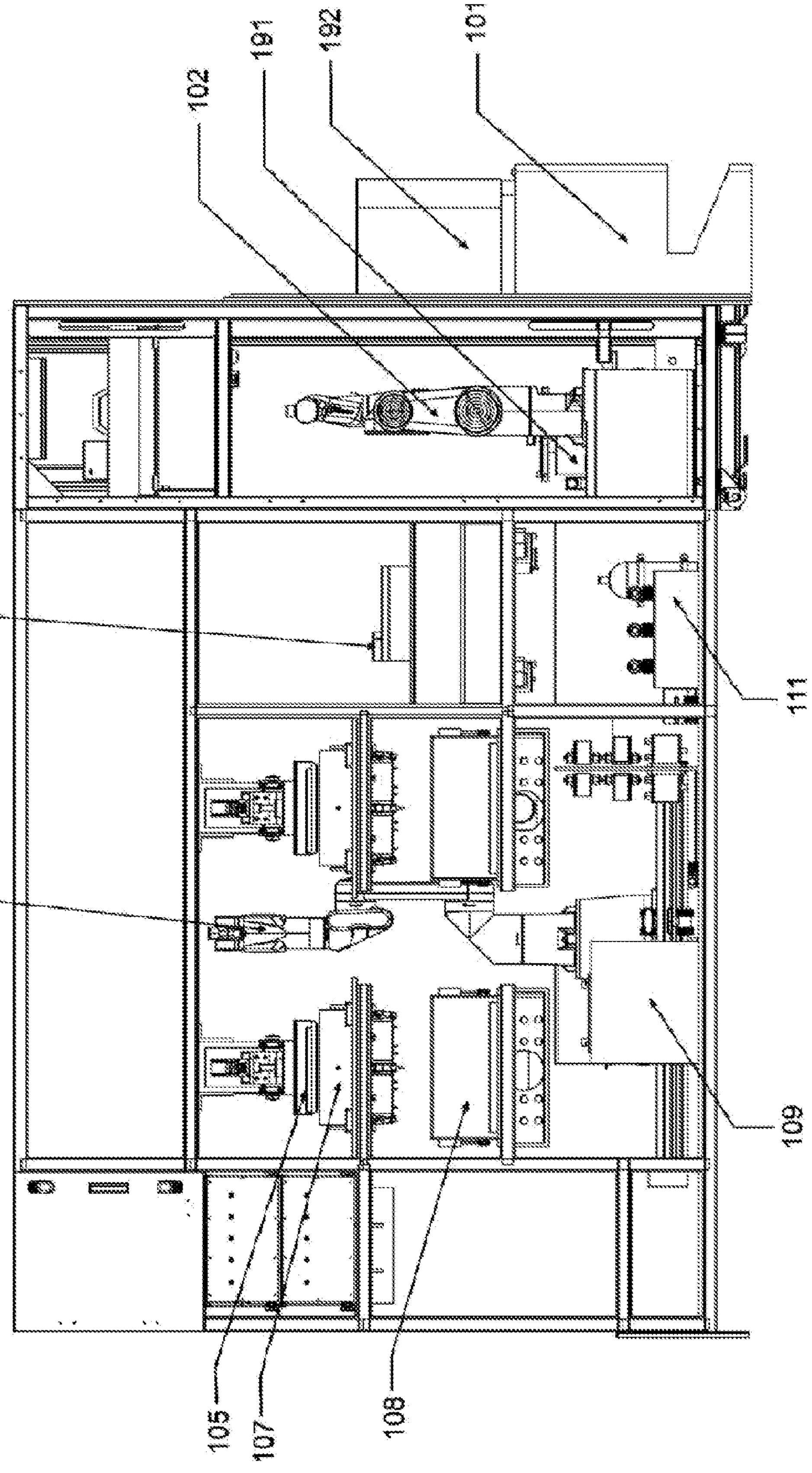

Fig 2

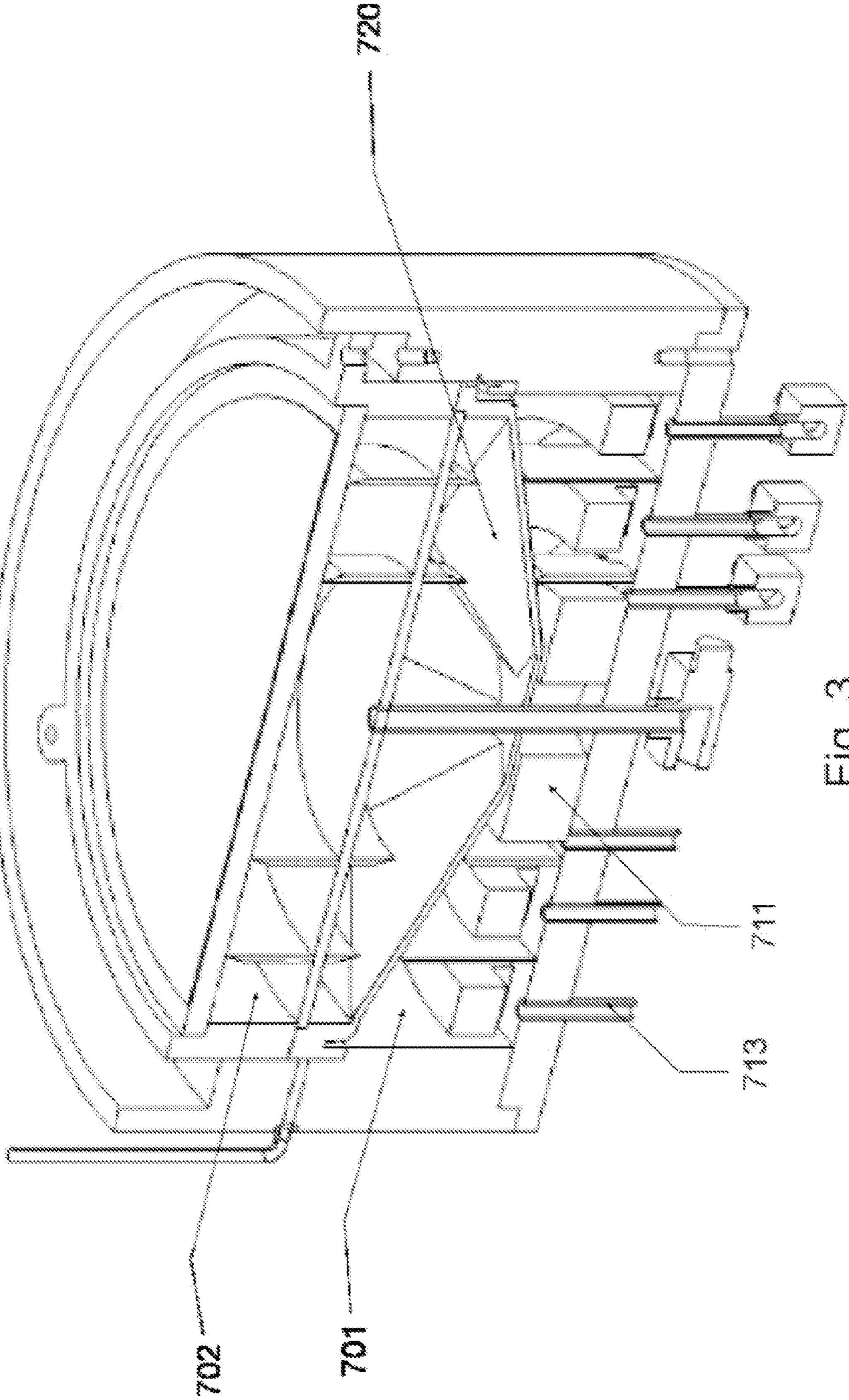

Fig. 3

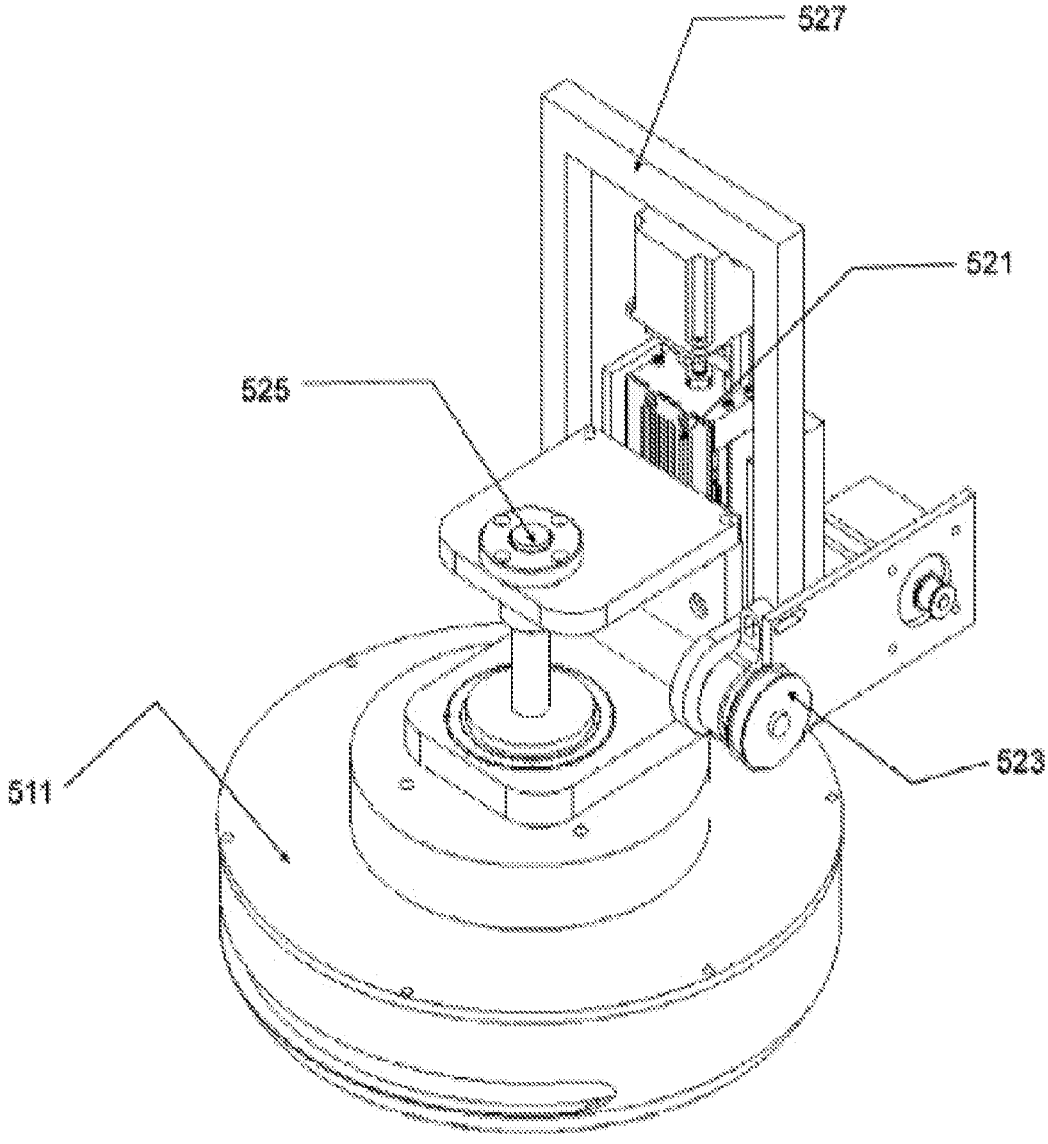

Fig 4

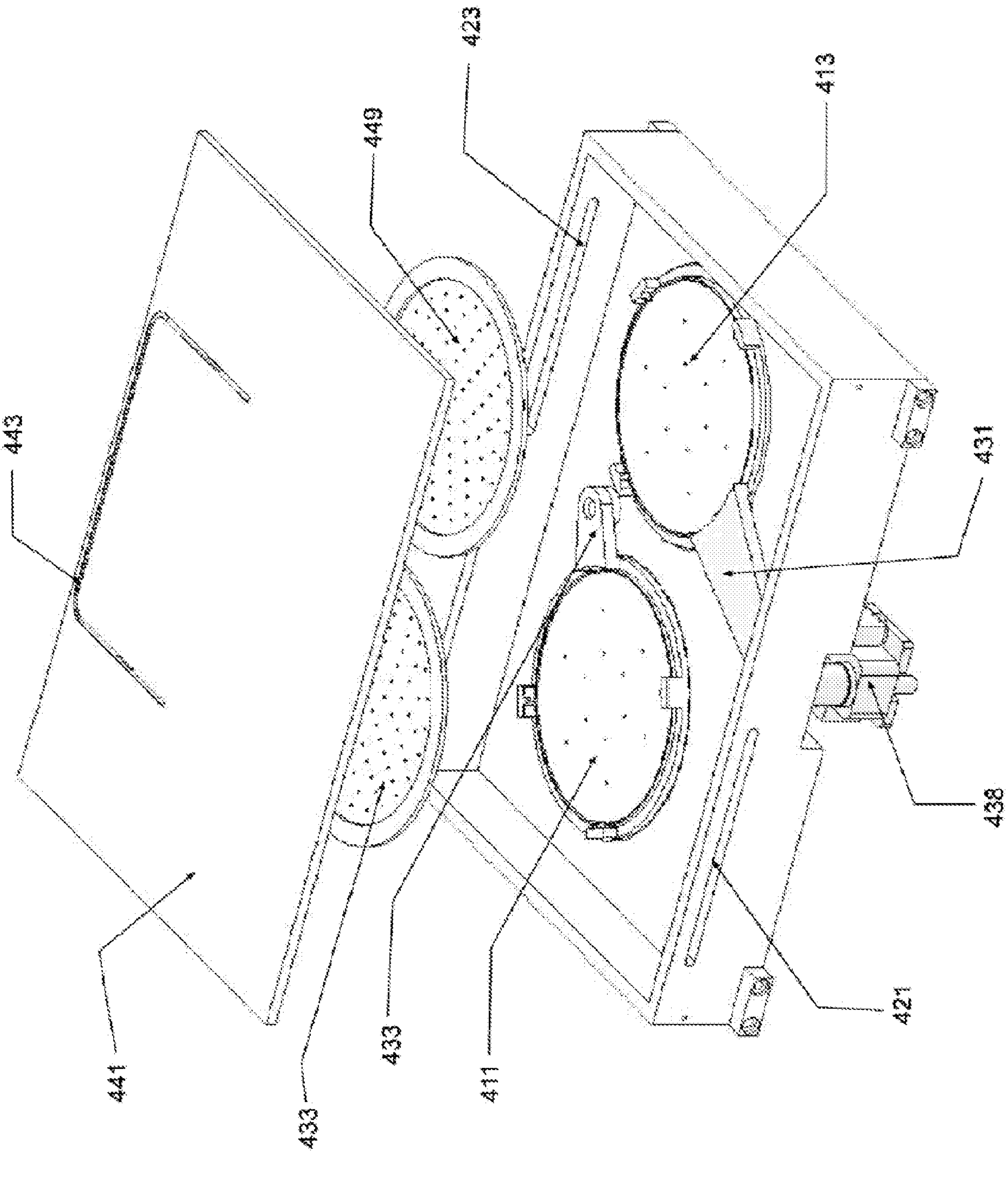

Fig 5

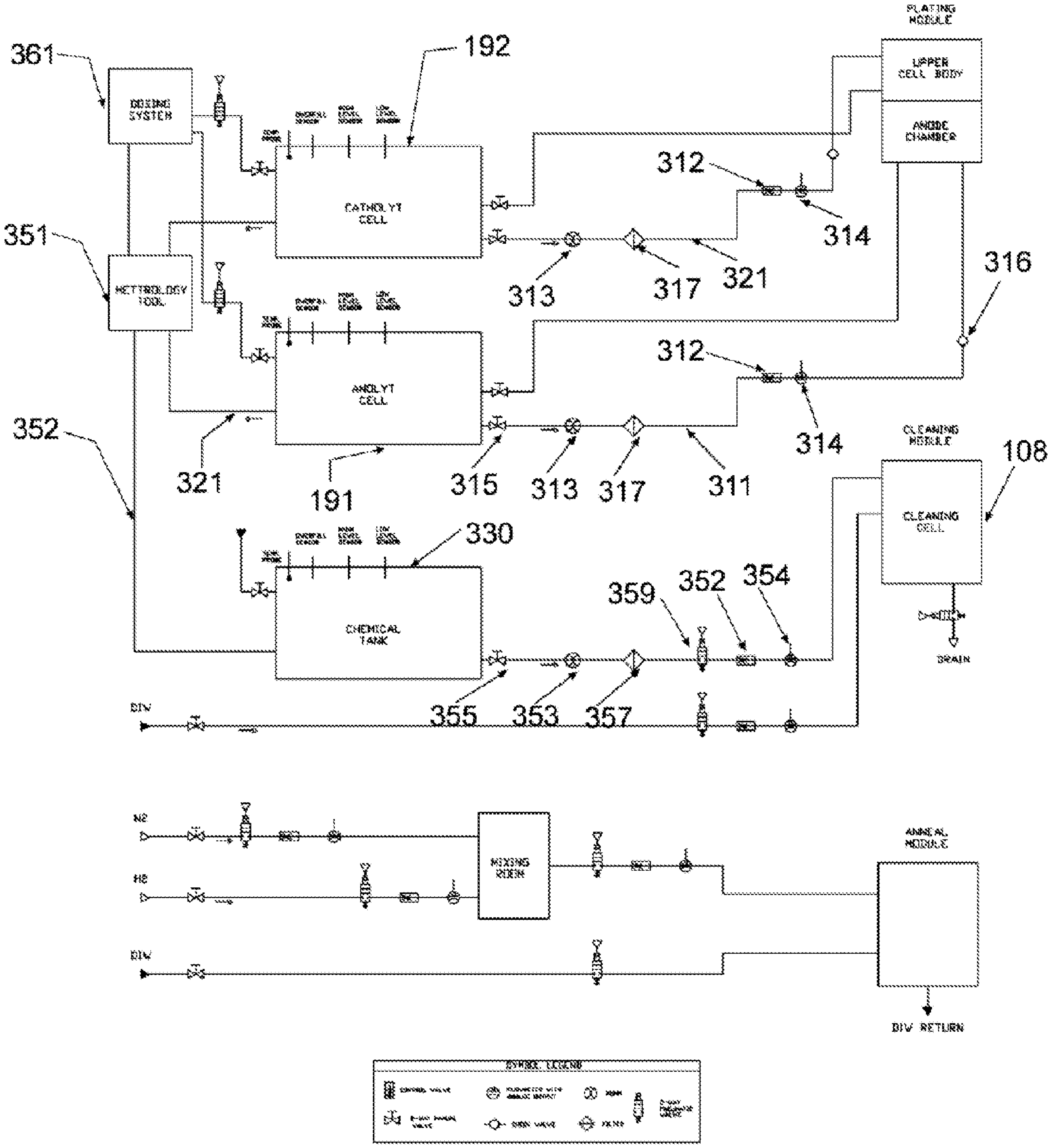
361
192
PLATING MODULE
UPPER CELL BODY
ANODE CHAMBER
DOSING SYSTEM
CATHOLYT CELL
312
314
351
METROLOGY TOOL
313
317
321
316
ANOLYT CELL
312
352
321
191
315
313
317
311
314
CLEANING MODULE
108
CLEANING CELL
330
CHEMICAL TANK
359
352
354
DRAIN
DIW
355
353
357
N2
H2
MIXING ROOM
ANNEAL MODULE
DIW
DIW RETURN
SYMBOL LEGEND

Fig 6

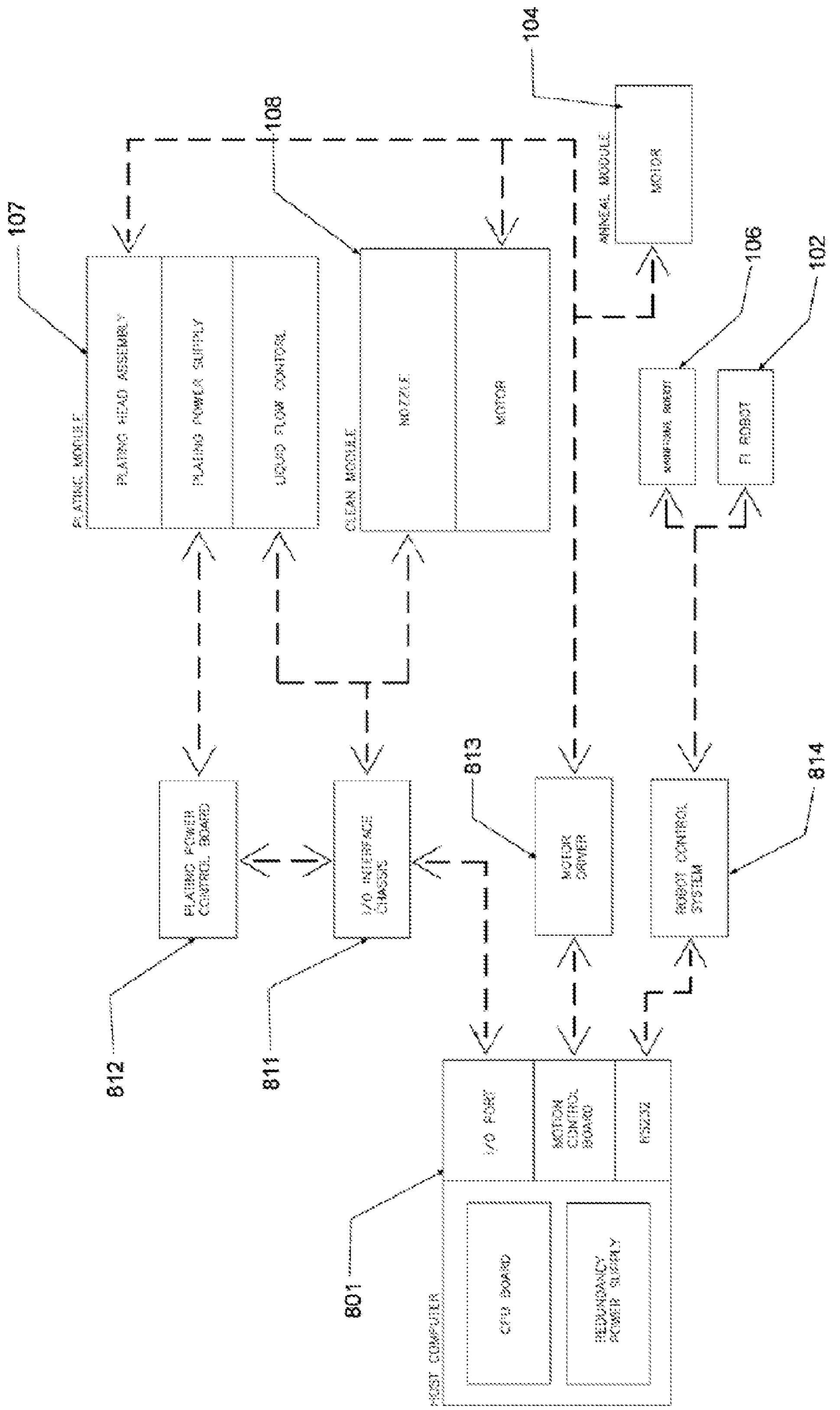
107
108
104
PLATING MODULE
PLATING HEAD ASSEMBLY
PLATING POWER SUPPLY
LIQUID FLOW CONTROL
CLEAN MODULE
NOZZLE
MOTOR
ANNEAL MODULE
MOTOR
106
102
MAINFRAME ROBOT
FI ROBOT
813
814
PLATING POWER CONTROL BOARD
I/O INTERFACE CHASSIS
MOTOR DRIVER
ROBOT CONTROL SYSTEM
812
811
801
HOST COMPUTER
I/O PORT
MOTION CONTROL BOARD
RS232
CPU BOARD
REDUNDANCY POWER SUPPLY

Fig 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2008/070531

A. CLASSIFICATION OF SUBJECT MATTER

See extra sheet

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC:C25D5/-,7/-,17/-,19/-;C23C18/-,H01L21/

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

CNPAT,CNKI,WPI,EPODOC,PAJ: electrocheimical , electroplating, eletroless, wafer?, semicomductor?, robot,

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim
A	CN 1981070 A(APPLIED MATERIALS IN) 13 June 2007(13.06.2007) decription, page 10-14,figures 1-7	1-16
A	CN 1985026 A(APPLIED MATERIALS IN) 20 June 2007(20.06.2007) the whole document	1-16
A	US 6527920 B1(NOVELLUS SYSTEMS INC) 04 Mar.2003(04.03.2003) the whole document	1-16
A	CN 1922344 A(APPLIED MATERIALS IN) 28 Feb.2007(28.02.2007) the whole document	1-16

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&"document member of the same patent family

Date of the actual completion of the international search
28 Nov 2008(28.11.2008)

Date of mailing of the international search report
18 Dec. 2008 (18.12.2008)

Name and mailing address of the ISA/CN
The State Intellectual Property Office, the P.R.China
6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China
100088
Facsimile No. 86-10-62019451

Authorized officer
ZHU, Minghui
Telephone No. (86-10)62085484

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN2008/070531

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN 1981070 A	13.06.2007	WO2005073430A2	11.08.2005
		US2005263066A1	01.12.2005
		JP2007519831T	19.07.2007
		KR20060129410A	15.12.2006
		US7323058B	29.01.2008
		US2006033678A	16.02.2006
CN 1985026 A	20.06.2007	US2004016637A1	29.01.2004
		WO2004057060A2	08.07.2004
		WO2004075266A2	02.09.2004
		WO2004094702A2	04.11.2004
		TW200415262A	16.08.2004
		TW200422443A	01.11.2004
		JP2006511717T	06.04.2006
		EP1694885A	30.08.2006
		US7223323B2	29.05.2007
		TW265216B	01.11.2006
		JP2007525591T	06.09.2007
US 6527920 B1	04.03.2003	US6821407B	23.11.2004
		US6890416B	10.05.2005
		US6964792B	15.11.2005
CN 1922344 A	28.02.2007	US2005081785a	21.04.2005
		WO2005038094A2	28.04.2005
		EP1685280A2	02.08.2006
		KR20060097029A	13.09.2006
		JP2007509236T	12.04.2007
		US7341633B2	11.03.2008

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2008/070531

A. CLASSIFICATION OF SUBJECT MATTER

C25D7/12(2006.01)i

C25D19/00(2006.01)i

C25D17/00(2006.01)i

H01L21/00(2006.01)i