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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
7 January 2016 (07.01.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/003631 A1

(51) International Patent Classification:
H01L 21/205 (2006.01) *H01L 21/02* (2006.01)

(21) International Application Number:
PCT/US2015/035501

(22) International Filing Date:
12 June 2015 (12.06.2015)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/020,837 3 July 2014 (03.07.2014) US
14/729,736 3 June 2015 (03.06.2015) US

(71) Applicant: **APPLIED MATERIALS, INC.** [US/US]; 3050 Bowers Avenue, Santa Clara, California 95054 (US).

(72) Inventors: **DELLA ROSA, Jason**; 956 Apricot Avenue, Campbell, California 95008 (US). **NOORBAKHSH, Hamid**; 40327 Canyon Heights Drive, Fremont, California 94539 (US). **KNYAZIK, Vladimir**; 1975 De La Pena Avenue, Santa Clara, California 95050 (US). **KIM, Jisoo**; 3840 Appian Street, Pleasanton, California 94588 (US). **LEE, Wonseok**; 130 Descanso Drive #472, San Jose, California 95134 (US). **DADU, Usama**; 1300 Crestview Road, Hollister, California 95023 (US).

(74) Agents: **TABOADA, Alan** et al.; Moser Taboada, 1030 Broad Street, Suite 203, Shrewsbury, New Jersey 07702 (US).

(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, BN, BR, BW, BY, BZ, CA, CH, CL, 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, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, 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, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

(54) Title: SHOWERHEAD HAVING A DETACHABLE HIGH RESISTIVITY GAS DISTRIBUTION PLATE

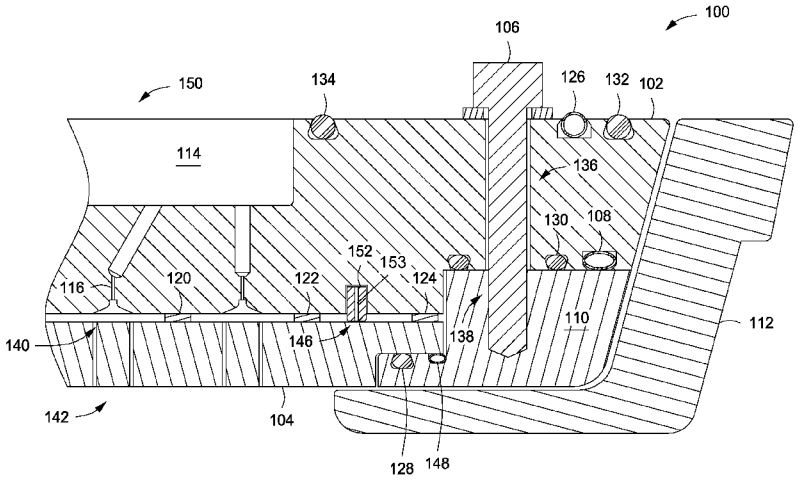


FIG. 1

(57) Abstract: Embodiments of showerheads having a detachable gas distribution plate are provided herein. In some embodiments, a showerhead for use in a semiconductor processing chamber may include a base having a first side and a second side opposing the first side; a gas distribution plate disposed proximate the second side of the base, wherein the gas distribution plate is formed from a material having an electrical resistivity between about 60 ohm-cm to 90 ohm-cm; a clamp disposed about a peripheral edge of the gas distribution plate to removably couple the gas distribution plate to the base; and a thermal gasket disposed in a gap between the base and gas distribution plate.

WO 2016/003631 A1

SHOWERHEAD HAVING A DETACHABLE HIGH RESISTIVITY GAS DISTRIBUTION PLATE

FIELD

[0001] Embodiments of the present disclosure generally relate to semiconductor processing equipment.

BACKGROUND

[0002] Conventional showerheads utilized in semiconductor process chambers (*e.g.*, deposition chambers, etch chambers, or the like) typically include a gas distribution plate permanently bonded to a base. The gas distribution plate is periodically replaced due to degradation caused by exposure to plasma during plasma processes. However, the inventors have observed that since the gas distribution plate is permanently bonded to the base, the entire showerhead assembly is replaced in order to replace the gas distribution plate, thus making the replacement process costly. In addition, arcing has been observed in applications in which a high source power process is performed using gas distribution plates with low electrical resistivity (e.g., 0.005 – 0.015 ohm-cm).

[0003] Therefore, the inventors have provided embodiments of an improved showerhead with detachable gas distribution plate.

SUMMARY

[0004] Embodiments of showerheads having a detachable gas distribution plate are provided herein. In some embodiments, a showerhead for use in a semiconductor processing chamber may include a base having a first side and a second side opposing the first side; a gas distribution plate disposed proximate the second side of the base, wherein the gas distribution plate is formed from a material having an electrical resistivity between about 60 ohm-cm to 90 ohm-cm; a clamp disposed about a peripheral edge of the gas distribution plate to removably couple the gas distribution plate to the base; and a thermal gasket disposed in a gap between the base and gas distribution plate.

[0005] In some embodiments, a process chamber may include a chamber body having a substrate support disposed within an inner volume of the chamber body;

and a showerhead disposed within the inner volume of the chamber body opposite the substrate support. The showerhead includes: a base having a first side and a second side opposing the first side, wherein the first side of the base is coupled to a component of the process chamber; a gas distribution plate disposed proximate the second side of the base, wherein the gas distribution plate is formed from a material having an electrical resistivity between about 60 ohm-cm to 90 ohm-cm; a clamp disposed about a peripheral edge of the gas distribution plate to removably couple the gas distribution plate to the base; and a thermal gasket disposed in a gap between the base and gas distribution plate.

[0006] In some embodiments, a showerhead for use in a semiconductor processing chamber may include a base having a first side and a second side opposing the first side, the second side including an yttrium fluoride coating; a gas distribution plate disposed proximate the second side of the base, wherein the gas distribution plate is formed from a material having an electrical resistivity between about 60 ohm-cm to 90 ohm-cm; an anodized clamp disposed about a peripheral edge of the gas distribution plate to removably couple the gas distribution plate to the base; a plurality of silicone thermal gaskets disposed in a gap between the base and gas distribution plate; and a plurality of pins pressed into the second side of the base and disposed in the gap to maintain a thickness of the gap when the gas distribution plate deflects toward the base.

[0007] Other and further embodiments of the present disclosure are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of the present disclosure, briefly summarized above and discussed in greater detail below, can be understood by reference to the illustrative embodiments of the disclosure depicted in the appended drawings. However, the appended drawings illustrate only typical embodiments of the disclosure and are therefore not to be considered limiting of scope, for the disclosure may admit to other equally effective embodiments.

[0009] Figure 1 depicts a showerhead with a gas distribution plate in accordance with some embodiments of the present disclosure.

[0010] Figure 2 depicts a process chamber suitable for use with a showerhead having a gas distribution plate in accordance with some embodiments of the present disclosure.

[0011] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. The figures are not drawn to scale and may be simplified for clarity. Elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0012] Embodiments of showerheads having a detachable gas distribution plate are provided herein. In at least some embodiments, the inventive showerhead may advantageously allow for the removal and replacement of the gas distribution plate, thus providing a showerhead having a longer useful life and a more cost efficient manner of replacing the gas distribution plate as compared to conventional showerheads having a permanently bonded gas distribution plate.

[0013] Figure 1 depicts a showerhead with a gas distribution plate in accordance with some embodiments of the present disclosure. The showerhead 100 generally comprises a body 102, a gas distribution plate 104 and a clamp 110 configured to removably couple the gas distribution plate to the body 102.

[0014] The body 102 comprises a first side 150, a second side 140 and a plurality of through holes 116 formed in the body 102 extending from the first side 150 to the second side 140. The plurality of through holes 116 facilitates the passage of process gases through the body 102 to the gas distribution plate 104. In some embodiments, the through holes 116 may be counter sunk (*e.g.*, countersink 118 shown) to reduce a residual electrical field at the through holes 116 and to facilitate a more uniform gas flow to the gas distribution plate 104. In some embodiments, a cavity 114 may be formed in first side 150 of the body 102 to facilitate more even distribution of process gases to the plurality of through holes 116. The body 102 may be fabricated from any suitable process compatible material, for example, such as aluminum. By fabricating the body 102 from a conductive material such as aluminum, the body 102 may function as an electrode to facilitate, for example, the

formation of a plasma from process gases provided to the showerhead 100. In some embodiments the second side 140 of the body 102 may be coated with a material to protect the second side 140 from ions, plasma, or light up. For example, in some embodiments, the coating may be an yttrium fluoride (YF_3) coating. The coating may be disposed on the second side 140 of the body 102 using various techniques. Some exemplary non-limiting methods for coating the second side 140 of the body 102 may include deposition or evaporation of the coating onto the body 102 from a target made from or otherwise including the coating material using an electron-beam induced activation of the target material.

[0015] In some embodiments, one or more channels may be formed in the surfaces of the body 102 to accommodate one or more O-rings and/or radio frequency (RF) gaskets (O-rings 130, 132, 134 and RF gaskets 108, 126 shown). When present, the O-rings 130, 132, 134 provide a seal between the body 102 and clamp 110 or surfaces of the process chamber (not shown). The O-rings 130, 132, 134, may be fabricated from any material suitable to facilitate the aforementioned seal, for example, rubber. The RF gaskets 108, 126 facilitate conductivity of RF power from, for example, an RF source to the body 102 and the clamp 110. For example, RF power may be provided from an RF power supply (such as the RF power source 286 described below) to a component coupled to the body 102 and in contact with one or more RF gaskets (*e.g.*, RF gasket 126). The RF gaskets 108, 126 may be fabricated from any suitable conductive material, for example stainless steel.

[0016] The gas distribution plate 104 facilitates distribution of process gases provided from the body 102 to, for example, a processing volume of a process chamber via a plurality of gas distribution holes 142 formed in the gas distribution plate 104. The gas distribution holes 142 may be arranged in any manner suitable to provide a desired distribution of process gases. For example, in some embodiments, the gas distribution holes 142 may be arranged in clusters disposed about the through holes 116 of the body 102 when the gas distribution plate 104 is coupled to the body 102.

[0017] The gas distribution plate 104 may be fabricated from any material suitable to resist degradation during exposure to a plasma (*e.g.*, a plasma formed in a process chamber during processing). For example in some embodiments, the gas distribution plate 104 may be fabricated from single crystalline silicon (Si). Single crystal silicon is not typically used as a material for the gas distribution plate at least in part due to single crystal silicon having a faster etch rate as compared to silicon carbide, a favored material. However, the inventors have observed that single crystalline silicon is less susceptible to surface roughness change, arcing, and micro-masking, and further provides better operability at elevated temperatures (*e.g.*, higher than about 150 degrees Celsius) as compared to conventional materials utilized to fabricate gas distribution plates, for example, such as silicon carbide (SiC). In addition, single crystal silicon is more readily available and obtainable at a lower cost as compared to the conventional materials. In addition, in embodiments where the showerhead 100 is used in substrate processes involving silicon-containing gases, fabricating the gas distribution plate 104 from silicon reduces the instances of contamination due to degradation of the gas distribution plate 104.

[0018] In some embodiments, the gas distribution plate 104 is fabricated from a single crystalline silicon material having a high electrical resistivity between about 60 ohm-cm and 90 ohm-cm to reduce arcing. As noted above, the inventors have observed that low resistivity gas distribution plates (e.g., a gas distribution plate having a resistivity of about 0.005 – 0.015 0hm-cm) will arc during processes in which the source power is greater than or equal to 2000 watts at 162 MHz. Thus, the high resistivity of the gas distribution plate 104 advantageously reduces arcing when the showerhead 100 is used in high source power processes. In some embodiments, the ingot from which the single crystalline silicon is obtained may be doped to change the resistivity of the ingot. For example, the single crystalline silicon ingot may be doped or coated with a high resistivity material such as boron to increase the resistivity of the material. In some embodiments, if the gas distribution plate 104 is formed from a low resistivity material, the gas distribution plate 104 may be treated, coated or doped with a high resistivity material to increase the resistivity of the gas distribution plate 104.

[0019] The gas distribution plate 104 may have any suitable thickness sufficient to provide a desired gas distribution and suitable useful functional life. In addition, in some embodiments, the gas distribution plate 104 may have a suitable thickness sufficient to ensure continuous contact with one or more thermal gaskets (three thermal gaskets 120, 122, 124 shown) disposed between the gas distribution plate 104 and the body 102 when the gas distribution plate 104 is coupled to the body 102. For example, in some embodiments, the thickness of the gas distribution plate 104 may be selected such that an amount of bowing of the gas distribution plate 104 caused by the forces provided by the clamp 110 at the edge of the gas distribution plate 104 is less than an amount of deformation of the thermal gaskets 120, 122, 124 when compressed, thus ensuring continuous contact with each of the thermal gaskets 120, 122, 124 when clamped. Alternatively, or in combination, in some embodiments, the thickness of the gas distribution plate 104 may be selected to provide an aspect ratio of the gas distribution holes 142 suitable to reduce plasma penetration and improve the useful functional life of the gas distribution plate 104. For example, in embodiments where the gas distribution holes 142 have a diameter of about 0.5 mm, the gas distribution plate 104 may have a thickness of about 9 mm.

[0020] The clamp 110 facilitates coupling the gas distribution plate 104 to the body 102. In some embodiments, the clamp 110 facilities such coupling via a fastener 106 provided to a through hole 136 formed in the body 102 corresponding to a threaded hole 138 formed in the clamp. The clamp 110 may be fabricated from any process compatible conductive material, for example aluminum. In some embodiments, the clamp 110 may be coated with a spray coating (*e.g.*, yttria (Y_2O_3)) to reduce degradation of the clamp 110 in a plasma environment. In some embodiments, the clamp 110 may alternatively be anodized with an aluminum oxide coating.

[0021] In some embodiments, the clamp 110 may include one or more channels formed in surfaces of the clamp 110 to accommodate one or more O-rings and RF gaskets (O-ring 128 and RF gasket 148 shown). When present, the O-ring 128 provides cushioning to the gas distribution plate104 to prevent breakage of the gas distribution plate 104 when clamped to the body 102. When present, the RF gasket 148 facilitates conductivity of RF power from the body 102, through the clamp 110,

and to the gas distribution plate 104, thus allowing the gas distribution plate 104 to function as an RF electrode. Providing the RF current path to the gas distribution plate 104 also shields a gap 146 between the body 102 and the gas distribution plate 104, which reduces arcing, for example, at the through holes 116 of the body 102. The O-ring 128 and RF gasket 148 may be fabricated from any suitable material, for example such as the materials discussed above with respect to the O-rings 130, 132, 134, and RF gaskets 108, 126.

[0022] In some embodiments, the thermal gaskets 120, 122, 124 may be disposed between the body 102 and gas distribution plate 104. When present, the thermal gaskets 120, 122, 124 may facilitate a heat exchange between the body 102 and the gas distribution plate 104, for example, to provide a more uniform thermal gradient across the gas distribution plate 104. In addition, the thermal gaskets 120, 122, 124 may provide the gap 146 between the body 102 and the gas distribution plate 104 and define separate plenums (*e.g.*, zones) for groups of through holes 116 and corresponding gas distribution holes 142. In some embodiments, the showerhead 100 may also include a plurality of pins 152 that are pressed into the body 102. The plurality of pins 152 ensures that the gap 146 remains substantially unchanged when the gas distribution plate 104 deflects toward the body 102. The pins 152 each include a through-hole 153 to ensure that any gaps behind the pins 152 are properly evacuated.

[0023] The thermal gaskets 120, 122, 124 may be fabricated from any compressible, thermally conductive material having low out-gassing at process pressures and temperatures (*e.g.*, vacuum conditions and temperatures at or above about 150 degrees Celsius). In some embodiments, the gasket may comprise a silicone containing material such as, for example, SARCON® GR-M available from Fujipoly® or other silicone rubber material having a high thermal conductivity and flame-retardant properties. The thermal gaskets 120, 122, 124 may have any shape suitable to maintain contact between the body 102 and the gas distribution plate 104. For example, in some embodiments, the thermal gaskets 120, 122, 124 may be a plurality of concentric rings having a rectangular cross section as shown in Figure 1. In some embodiments, the geometry of the thermal gaskets 120, 122, 124 may be optimized to accommodate for a difference in distance between the body

102 and the gas distribution plate 104 when clamped together due to the forces provided by the clamp 110 at the edge of the gas distribution plate 104 (*e.g.*, bowing of the gas distribution plate 104).

[0024] In some embodiments, a protective ring 112 may be disposed about the showerhead to shield portions of the body 102, clamp 110 and gas distribution plate 104. The protective ring 112 may be fabricated from any suitable process compatible material, for example, quartz (SiO_2).

[0025] Figure 2 depicts a schematic view of an illustrative process chamber 200 suitable for use with a showerhead in accordance with some embodiments of the present disclosure. Exemplary process chambers may include the ENABLER®, ENABLER® E5, ADVANTEDGE™, or other process chambers, available from Applied Materials, Inc. of Santa Clara, California. Other suitable process chambers having, or being modified to have, showerheads may similarly benefit from the present disclosure.

[0026] In some embodiments, the process chamber 200 may generally comprise a chamber body 202 having a substrate support pedestal 208 for supporting a substrate 210 thereupon disposed within an inner volume 205 of the chamber body, and an exhaust system 220 for removing excess process gases, processing by-products, or the like, from the inner volume 205 of the chamber body 202.

[0027] In some embodiments, an upper liner 264 and a lower liner 266 may cover the interior of the chamber body 202 to protect the chamber body 202 during processing. In some embodiments, the chamber body 202 has an inner volume 205 that may include a processing volume 204. The processing volume 204 may be defined, for example, between the substrate support pedestal 208 and a showerhead 214 (*e.g.*, showerhead 100 described above) and/or nozzles provided at desired locations. In some embodiments, a gas supply 288 may provide one or more process gases to the showerhead 214 for distribution of the one or more process gases to the processing volume 204 of the chamber body 202.

[0028] In some embodiments, the substrate support pedestal 208 may include a mechanism that retains or supports the substrate 210 on the surface of the substrate support pedestal 208, such as an electrostatic chuck, a vacuum chuck, a substrate

retaining clamp, or the like. Alternatively, or in combination, in some embodiments, the substrate support pedestal 208 may include mechanisms for controlling the substrate temperature (such as heating and/or cooling devices, not shown) and/or for controlling the species flux and/or ion energy proximate the substrate surface. For example, in some embodiments, the substrate support pedestal 208 may include an electrode 240 and one or more power sources (two bias power sources 238, 244) coupled to the electrode 240 via respective matching networks 236, 262. For example, the substrate support pedestal 208 may be configured as a cathode coupled to a bias power source 244 via a matching network 262. The above described bias power sources (*e.g.*, bias power sources 238, 244) may be capable of producing up to about 12,000 W at a frequency of about 2 MHz, or about 13.56 MHz, or about 60Mhz. The at least one bias power source may provide either continuous or pulsed power. In some embodiments, the bias power source alternatively may be a DC or pulsed DC source.

[0029] In some embodiments, the substrate support pedestal 208 may include a substrate support ring 280 disposed atop the substrate support pedestal 208 and configured to support at least a portion of the substrate 210 during processing. In some embodiments, one or more rings (insert ring 278 and barrier ring 242 shown) may be disposed about the substrate support pedestal 208. The one or more rings may be fabricated from any suitable process compatible material. For example, in some embodiments, the insert ring may be fabricated from silicon (Si). In some embodiments, the barrier ring 242 may be fabricated from quartz (SiO_2). In some embodiments, a grounded mesh 260 may be disposed about the periphery of the substrate support pedestal 208 and coupled to the chamber body 202.

[0030] The substrate 210 may enter the chamber body 202 via an opening 212 in a wall of the chamber body 202. The opening 212 may be selectively sealed via a slit valve 218, or other mechanism for selectively providing access to the interior of the chamber through the opening 212. The substrate support pedestal 208 may be coupled to a lift mechanism 234 that may control the position of the substrate support pedestal 208 between a lower position (as shown) suitable for transferring substrates into and out of the chamber via the opening 212 and a selectable upper position suitable for processing. The process position may be selected to maximize

process uniformity for a particular process. When in at least one of the elevated processing positions, the substrate support pedestal 208 may be disposed above the opening 212 to provide a symmetrical processing region.

[0031] In some embodiments, a protective ring 206 (*e.g.*, the protective ring 112 described above) may be disposed about, and covering at least a portion of, the showerhead 214, for example, such as the body 294 (*e.g.*, body 102 described above) or the gas distribution plate 296 (*e.g.*, the gas distribution plate 104 described above) of the showerhead 214. In some embodiments, the protective ring 206 may be supported by the upper liner 264.

[0032] In some embodiments, the showerhead 214 may be coupled to and/or supported by, a chiller plate 270. When present, the chiller plate 270 facilitates control over a temperature of the showerhead 214 during processing. In some embodiments, the chiller plate 270 comprises a plurality of channels (not shown) formed in the chiller plate 270 to allow a temperature control fluid provided by a temperature control fluid supply (chiller) 290 to flow through the chiller plate 270 to facilitate the control over the temperature of the showerhead 214.

[0033] In some embodiments, one or more coils (inner coil 274 and outer coil 272 shown) may be disposed above and/or proximate a peripheral edge of the showerhead 214. When present, the one or more coils may facilitate shaping a plasma formed within the processing volume 204 of the process chamber 200.

[0034] In some embodiments, an RF power source 286 provides RF power to the chiller plate 270 and/or the showerhead 214 via a coaxial stub 292. The RF power source 286 may operate at a power greater than or equal to about 2000 watts and a frequency of about 162 MHz and up to about 5000 W at a frequency of about 227MHz. As described above, the inventive gas distribution plate 104 will not arc during processes in which the RF power source operates at a power of about 2000 W or more at high frequencies. The coaxial stub 292 is a fixed impedance matching network having a characteristic impedance, resonance frequency, and provides an approximate impedance match between the showerhead 214 and the RF power source 286. In some embodiments, the coaxial stub 292 generally comprises an inner cylindrical conductor 298, an outer cylindrical conductor 201 and an insulator

203 filling the space between the inner cylindrical conductor 298 and the outer cylindrical conductor 201.

[0035] The inner cylindrical conductor 298 and the outer cylindrical conductor 201 may be constructive of any suitable conductive material capable of withstanding the particular process environment. For example, in some embodiments, the inner cylindrical conductor 298 and the outer cylindrical conductor 201 may be fabricated from nickel-coated aluminum. One or more taps 221 are provided at particular points along the axial length of the coaxial stub 292 for applying RF power from the RF power source 286 to the coaxial stub 292. An RF power terminal 207 and the RF return terminal 209 of the RF power source 286 are connected at the tap 221 on the coaxial stub 292 to the inner cylindrical conductor 298 and the outer cylindrical conductor 201, respectively. A terminating conductor 211 at the far end 213 of the coaxial stub 292 shorts the inner cylindrical conductor 298 and the outer cylindrical conductor 201 together, so that the coaxial stub 292 is shorted at a far end 213 of the coaxial stub 292. At the near end 215 of the coaxial stub 292, the outer cylindrical conductor 201 is connected to the chamber body 202 via an annular conductive housing or support 276, while the inner cylindrical conductor 298 is connected to the chiller plate 270 and/or showerhead 214 via a conductive cylinder 217. In some embodiments, a dielectric ring 219, is disposed between and separates the conductive cylinder 217 and the chiller plate 270.

[0036] The exhaust system 220 generally includes a pumping plenum 224 and one or more conduits that couple the pumping plenum 224 to the inner volume 205 (and generally, the processing volume 204) of the chamber body 202, for example via one or more inlets 222. A vacuum pump 228 may be coupled to the pumping plenum 224 via a pumping port 226 for pumping out the exhaust gases from the chamber body 202. The vacuum pump 228 may be fluidly coupled to an exhaust outlet 232 for routing the exhaust to appropriate exhaust handling equipment. A valve 230 (such as a gate valve, or the like) may be disposed in the pumping plenum 224 to facilitate control of the flow rate of the exhaust gases in combination with the operation of the vacuum pump 228. Although a z-motion gate valve is shown, any suitable, process compatible valve for controlling the flow of the exhaust may be utilized.

[0037] To facilitate control of the process chamber 200 as described above, the controller 250 may be one of any form of general-purpose computer processor that can be used in an industrial setting for controlling various chambers and sub-processors. The memory, or computer-readable medium, 256 of the CPU 252 may be one or more of readily available memory such as random access memory (RAM), read only memory (ROM), floppy disk, hard disk, or any other form of digital storage, local or remote. The support circuits 254 are coupled to the CPU 252 for supporting the processor in a conventional manner. These circuits include cache, power supplies, clock circuits, input/output circuitry and subsystems, and the like.

[0038] One or more methods and/or processes may generally be stored in the memory 256 as a software routine 258 that, when executed by the CPU 252, causes the process chamber 200 to perform the processes methods and/or processes. The software routine 258 may also be stored and/or executed by a second CPU (not shown) that is remotely located from the hardware being controlled by the CPU 252. Some or all of the method of the present disclosure may also be performed in hardware. As such, the methods and/or processes may be implemented in software and executed using a computer system, in hardware as, *e.g.*, an application specific integrated circuit or other type of hardware implementation, or as a combination of software and hardware. The software routine 258 may be executed after the substrate 210 is positioned on the substrate support pedestal 208. The software routine 258, when executed by the CPU 252, transforms the general purpose computer into a specific purpose computer (controller) 250 that controls the chamber operation such that the methods disclosed herein are performed.

[0039] Thus, embodiments of a showerhead having a detachable gas distribution plate have been provided herein. Embodiments of the inventive showerhead may advantageously provide a longer useful life and a more cost efficient manner of replacing the gas distribution plate as compared to conventional showerheads.

[0040] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof.

Claims:

1. A showerhead for use in a semiconductor processing chamber, comprising:

a base having a first side and a second side opposing the first side;

a gas distribution plate disposed proximate the second side of the base, wherein the gas distribution plate is formed from a material having an electrical resistivity between about 60 ohm-cm to about 90 ohm-cm;

a clamp disposed about a peripheral edge of the gas distribution plate to removably couple the gas distribution plate to the base; and

a thermal gasket disposed in a gap between the base and gas distribution plate.

2. The showerhead of claim 1, wherein the thermal gasket comprises a plurality of concentric rings disposed between the base and the gas distribution plate.

3. The showerhead of claim 1, further comprising:

an yttrium fluoride coating on the second side of the base.

4. The showerhead of claim 1, wherein the gas distribution plate is fabricated from single crystalline silicon (Si).

5. The showerhead of any of claims 1 to 4, wherein the gas distribution plate is fabricated from single crystalline silicon (Si) that is doped or coated with a high resistivity material.

6. The showerhead of any of claims 1 to 4, wherein the gas distribution plate is fabricated from single crystalline silicon (Si) that is doped or coated with boron.

7. The showerhead of any of claims 1 to 4, wherein the base comprises a plurality of through holes extending from the first side to the second side of the base.

8. The showerhead of claim 7, wherein the base comprises a plenum formed in the first side of the base, the plenum fluidly coupled to the plurality of through holes.

9. The showerhead of any of claims 1 to 4, further comprising:

a plurality of pins pressed into the second side of the base and disposed in the gap to maintain a thickness of the gap when the gas distribution plate deflects toward the base.

10. The showerhead of claim 9, wherein each of the plurality of pins includes a through-hole to allow a volume behind each pin to be evacuated.

11. The showerhead of any of claims 1 to 4, wherein the thermal gasket comprises a plurality of concentric rings disposed between the base and the gas distribution plate.

12. A process chamber, comprising:

a chamber body having a substrate support disposed within an inner volume of the chamber body; and

a showerhead disposed within the inner volume of the chamber body opposite the substrate support, the showerhead as described in any of the preceding claims, wherein the first side of the base is coupled to a component of the process chamber.

13. The process chamber of claim 12, wherein the component of the process chamber is a chiller plate, and wherein the chiller plate is coupled to a ceiling of the chamber body.

14. The process chamber of claim 12, further comprising a radio frequency (RF) power source coupled to the showerhead, wherein the RF power source operates at a power greater than or equal to about 2000 watts and a frequency of about 162 MHz.

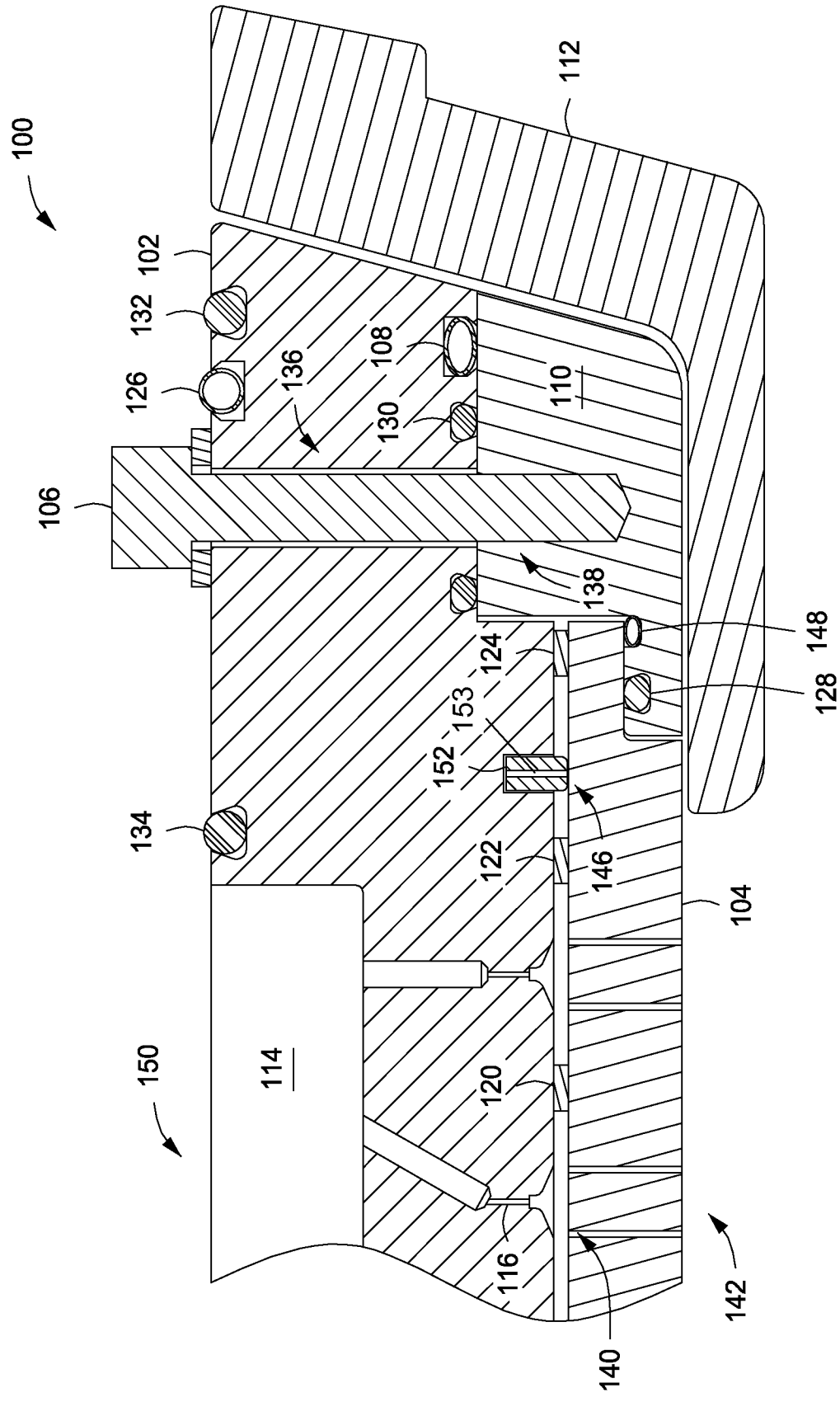

100
102
132
126
106
134
150
114
112
136
108
110
130
138
148
128
124
153
152
122
146
104
120
116
140
142

FIG. 1

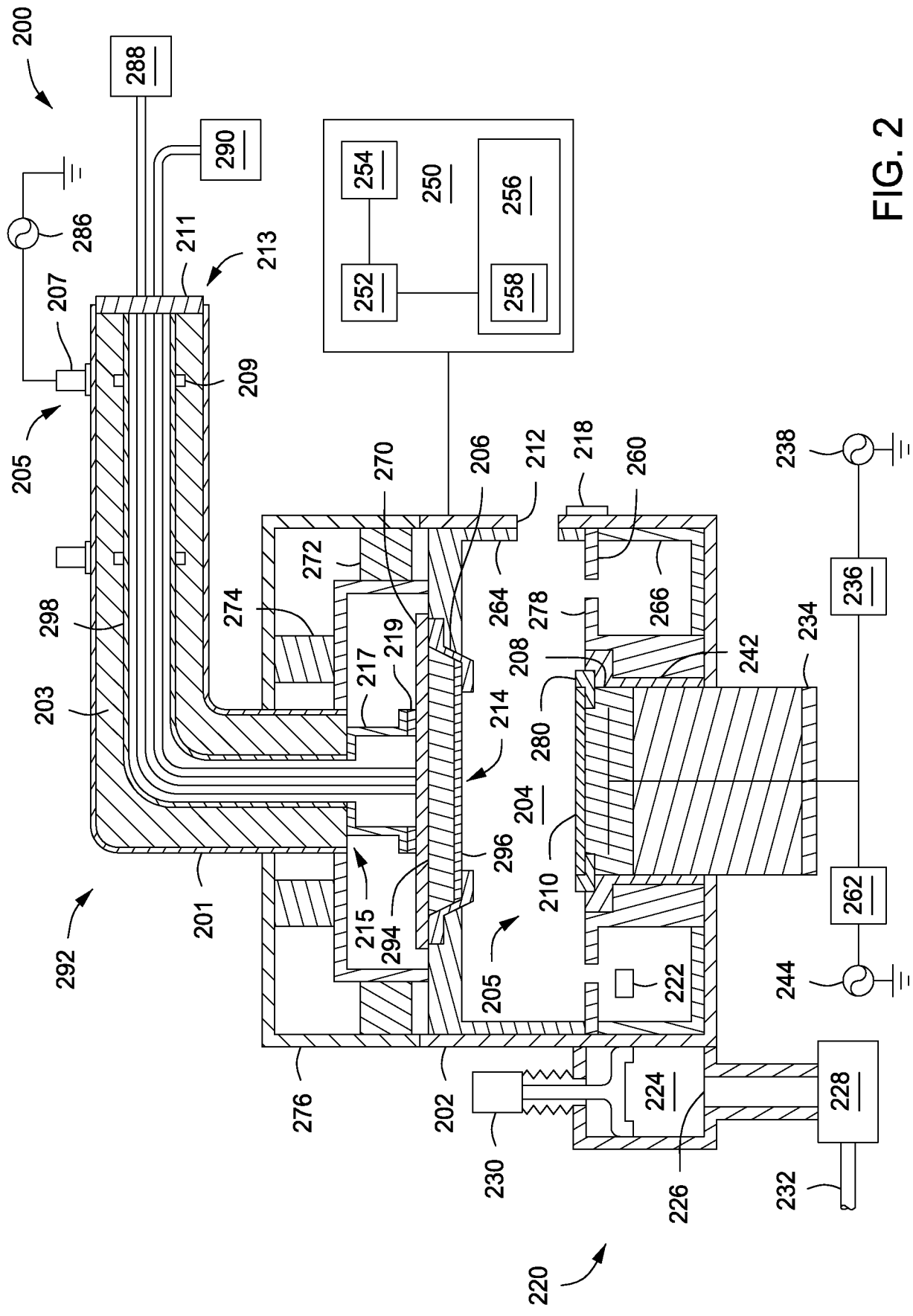

200
288
290
286
211
213
207
209
205
254
250
256
252
258
270
206
212
218
260
238
272
274
264
278
266
236
298
208
242
234
203
219
217
214
280
204
296
210
262
215
294
205
222
244
292
201
276
202
224
228
230
226
232
220

FIG. 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2015/035501

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/205(2006.01)i, H01L 21/02(2006.01)i

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)
H01L 21/205; H01L 21/3065; C23F 1/00; C23F 1/02; B32B 37/12; H01L 21/465; C23C 16/00; H01L 21/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: showerhead, chamber, resistivity, gas

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2010-0184298 A1 (RAJINDER DHINDSA) 22 July 2010 See abstract, paragraphs [0021]-[0038], and figure 1A.	1-14
Y	US 2002-0127853 A1 (JEROME S. HUBACEK et al.) 12 September 2002 See abstract, paragraphs [0016]-[0029], [0047], and figures 1-2.	1-14
Y	US 2007-0034337 A1 (SHINYA NISHIMOTO et al.) 15 February 2007 See abstract, paragraphs [0048]-[0059], and figure 3.	3,8
A	US 2010-0003824 A1 (BABAK KADKHODAYAN et al.) 07 January 2010 See abstract, paragraphs [0021]-[0037], and figure 1.	1-14

☐ 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	Date of mailing of the international search report
23 September 2015 (23.09.2015)	**23 September 2015 (23.09.2015)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 35208, Republic of Korea
Facsimile No. +82-42-472-7140

Authorized officer
CHOI, Sang Won
Telephone No. +82-42-481-8291

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2015/035501

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2010-0184298 A1	22/07/2010	CN 102124819 A	13/07/2011
		CN 102124819 B	26/02/2014
		EP 2316253 A2	04/05/2011
		EP 2316253 A4	07/08/2013
		JP 2012-500471 A	05/01/2012
		JP 5490119 B2	14/05/2014
		KR 10-2011-0049800 A	12/05/2011
		SG 192552 A1	30/08/2013
		TW 201012309 A	16/03/2010
		US 2012-0171871 A1	05/07/2012
		US 2013-0280914 A1	24/10/2013
		US 8147648 B2	03/04/2012
		US 8484846 B2	16/07/2013
		WO 2010-019197 A2	18/02/2010
		WO 2010-019197 A3	14/05/2010
US 2002-0127853 A1	12/09/2002	CN 100466152 C	04/03/2009
		CN 1488161 A	07/04/2004
		EP 1346394 A1	24/09/2003
		JP 2004-524677 A	12/08/2004
		KR 10-2003-0066770 A	09/08/2003
		TW 548741 A	21/08/2003
		US 2008-0026589 A1	31/01/2008
		US 8845855 B2	30/09/2014
		WO 02-054444 A1	11/07/2002
US 2007-0034337 A1	15/02/2007	AU 2003-274566 A1	19/04/2004
		AU 2003-274566 A8	19/04/2004
		CN 100424811 C	08/10/2008
		CN 1682342 A	12/10/2005
		JP 2006-501609 A	12/01/2006
		JP 4589115 B2	01/12/2010
		KR 10-0739247 B1	12/07/2007
		KR 10-2005-0053710 A	08/06/2005
		US 2004-0060661 A1	01/04/2004
		US 7147749 B2	12/12/2006
		US 7566379 B2	28/07/2009
		WO 2004-030020 A2	08/04/2004
		WO 2004-030020 A3	16/09/2004
US 2010-0003824 A1	07/01/2010	CN 102084726 A	01/06/2011
		CN 102084726 B	08/10/2014
		EP 2301309 A2	30/03/2011
		EP 2301309 A4	31/07/2013
		EP 2301309 B1	06/05/2015
		JP 2011-527520 A	27/10/2011
		JP 5615813 B2	29/10/2014
		KR 10-1168847 B1	30/07/2012
		KR 10-2011-0016489A	17/02/2011

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2015/035501

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		TW 201018321 A	01/05/2010
		US 2012-0171872 A1	05/07/2012
		US 8161906 B2	24/04/2012
		US 8313805 B2	20/11/2012
		WO 2010-005541 A2	14/01/2010
		WO 2010-005541 A3	22/04/2010