



(51) International Patent Classification:

H01L 21/683 (2006.01) *C04B 35/58* (2006.01)
H05B 3/20 (2006.01)

(21) International Application Number:

PCT/US2013/048060

(22) International Filing Date:

27 June 2013 (27.06.2013)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

13/540,710 3 July 2012 (03.07.2012) US

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

(72) Inventors: **TZU, Gwo-Chuan**; 848 Sweetbay Drive,
Sunnyvale, California 94086 (US). **CUVALCI, Olkan**;
455 Brahms Way, Apt. 205, Sunnyvale, California 94087
(US). **CHANG, Yu**; 1493 Fields Drive, San Jose, California
95129 (US). **YUAN, Xiaoxiong**; 2162 Capitol Park
Court, San Jose, California 95132 (US).

(74) Agent: **TABOADA, Alan**; 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, IS, JP, KE, KG, 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, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, 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, 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: SUBSTRATE SUPPORT FOR SUBSTRATE BACKSIDE CONTAMINATION CONTROL

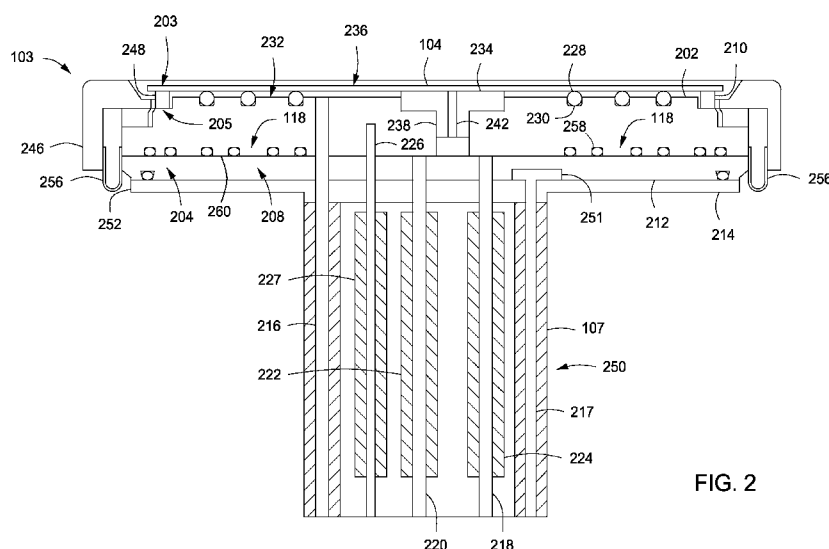


FIG. 2

(57) Abstract: Embodiments of substrate supports are provided herein. In some embodiments, a substrate support may include a first aluminum plate for supporting a substrate, the first aluminum plate having a plurality of heating elements embedded therein to provide a plurality of heating zones; a second aluminum plate disposed beneath and supporting the first aluminum plate; a third aluminum plate disposed beneath and supporting the second aluminum plate; a non-metallic seal ring disposed atop the first aluminum plate; and a plurality of spacers having an upper portion disposed above a surface of the first aluminum plate, wherein the non-metallic seal ring and the plurality of spacers support the substrate above the first aluminum plate.

SUBSTRATE SUPPORT FOR SUBSTRATE BACKSIDE CONTAMINATION CONTROL

FIELD

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

BACKGROUND

[0002] Conventional substrate supports utilized in deposition process chambers may include a heater plate fabricated from a steel alloy, for example, such as stainless steel. However, the inventors have observed that the low heat conductivity of stainless steel may create a temperature gradient across the heating plate (e.g., a temperature variation from the center to edge of the heater plate), causing uneven heating of the substrate, thereby leading to process non-uniformities. In addition, the high (radio frequency) RF resistivity of the stainless steel causes non-uniform plasma distribution, thereby further leading to non-uniform deposition of materials atop the substrate in plasma-assisted substrate processes.

[0001] The inventors have also observed that when using a substrate support having a metal heater plate during a substrate process (e.g., a deposition process), contamination of the substrate may occur as a result of metal to substrate contact. For example, when utilizing a conventional heater plate fabricated from stainless steel, iron (Fe) from the heater plate may diffuse into a back surface of the substrate, thereby contaminating the substrate.

[0002] Therefore, the inventors have provided embodiments of improved substrate supports.

SUMMARY

[0003] Embodiments of substrate supports are provided herein. In some embodiments, a substrate support may include a first aluminum plate to support a substrate, the first aluminum plate having a plurality of heating elements embedded therein to provide a plurality of heating zones; a second aluminum plate disposed beneath and supporting the first aluminum plate; a third aluminum plate disposed

beneath and supporting the second aluminum plate; a non-metallic seal ring disposed atop the first aluminum plate; and a plurality of spacers having an upper portion disposed above a surface of the first aluminum plate, wherein the non-metallic seal ring and the plurality of spacers support the substrate above the first aluminum plate.

[0004] Other and further embodiments of the present invention are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0005] Embodiments of the present invention, briefly summarized above and discussed in greater detail below, can be understood by reference to the illustrative embodiments of the invention depicted in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0006] Figure 1 depicts a process chamber suitable for use with a substrate support in accordance with some embodiments of the present invention.

[0007] Figure 2 depicts a substrate support in accordance with some embodiments of the present invention.

[0008] Figures 3-5 depict portions of the substrate support of Figure 2 in accordance with some embodiments of the present invention.

[0009] Figure 6 depicts a heating element configuration suitable for use with a substrate support in accordance with some embodiments of the present invention.

[0010] 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. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0011] Substrate supports that may provide one or more of improved backside contamination control, heat distribution, or improved plasma uniformity are provided herein. Embodiments of the inventive substrate support may advantageously support a substrate above a heater plate during processing, thereby eliminating any direct substrate to metal contact, thus reducing or eliminating contamination of the substrate. Embodiments of the inventive substrate support may further advantageously provide a heater plate fabricated from aluminum, thereby providing an improved heat distribution over conventionally utilized stainless steel heater plates, due to the higher heat conductivity of aluminum as compared to stainless steel. In addition, the lower RF resistivity of aluminum (as compared to stainless steel), facilitates providing an improved RF grounding path, thereby providing improved plasma uniformity in plasma-assisted processes. While not intended to be limiting of the scope of the invention, the inventive substrate support disclosed herein may be particularly advantageous in process chambers configured for chemical vapor deposition (CVD) having radio frequency (RF) capability, for example such as CVD process chambers suitable to process 200, 300, or 450 mm substrates, or the like.

[0012] Figure 1 depicts a process chamber 100 suitable for use with a substrate support having a heater in accordance with some embodiments of the present invention. The process chamber 100 may be any process chamber suitable for performing one or more substrate processes, for example, deposition process such as chemical vapor deposition (CVD), physical vapor deposition (PVD), atomic layer deposition (ALD) or the like. In embodiments where the process chamber is a CVD chamber, the CVD chamber may be any suitable CVD chamber known in the art. For example, the CVD chamber may be a standalone process chamber or a part of a cluster tool, such as one of the CENTURA®, PRODUCER®, or ENDURA® cluster tools available from Applied Materials, Inc. of Santa Clara, California.

[0013] In some embodiments, the process chamber 100 may generally include a chamber body 102, a substrate support 103 for supporting a substrate 104 and one

or more gas inlets (e.g., showerhead 108) for providing one or more process gases to an inner volume 105 of the chamber body 102.

[0014] In some embodiments, the chamber body 102 may comprise one or more openings (one opening 109 shown) to allow for the substrate 104 to be provided to, and removed from, the process chamber 100. The opening 109 may be selectively sealed via a slit valve 110, or other mechanism for selectively providing access to the inner volume 105 of the chamber body 102 through the opening 109. In some embodiments, the substrate support 103 may be coupled to a lift mechanism 112 that may control the position of the substrate support 103 between a lower position (as shown) suitable for transferring substrates into and out of the chamber via the opening 109 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 103 may be disposed above the opening 109 to provide a symmetrical processing region.

[0015] The one or more gas inlets (e.g., showerhead 108) may be coupled to a gas source 128 for providing one or more process gases for carrying out processes in the process chamber 100. Although a showerhead 108 is shown, additional or alternative gas inlets may be provided such as nozzles or inlets disposed in the ceiling or on the sidewalls of the process chamber 100 or at other locations suitable for providing gases as desired to the process chamber 100, such as the base of the chamber body 102, the periphery of the substrate support 103, or the like.

[0016] In some embodiments, the process chamber 100 further includes an exhaust 130 coupled to a pump 126 for removing process gases, purge gases, processing byproducts, and the like from the process chamber 100, for example, via one or more openings 138 fluidly coupling the inner volume 105 of the chamber body 102 with the exhaust 130. In some embodiments, the exhaust 130 may be disposed about the walls of the chamber body 102 and may further be split into an upper exhaust 132 and a lower exhaust 134 with one or more openings 136 disposed between the upper exhaust 132 and lower exhaust 134 to control the flow of the process gases, etc., through the exhaust 130 and to the pump 126 (e.g., to

provide more azimuthally uniform flow from the processing region of the process chamber above the substrate to the exhaust 130 due to the asymmetric pump configuration).

[0017] The substrate support 103 generally comprises a plate (heater plate) 106 configured to support the substrate 104 and a substrate support shaft 107 to support the heater plate 106. In some embodiments, one or more heating elements 118 may be embedded within or recessed within the heater plate 106, thereby allowing the heater plate 106 to function as a heater. A power source may provide power to the heating element 118 via a conduit 113 disposed within the substrate support shaft 107. In some embodiments, a sheath may be provided to surround heating elements 118. The sheath may be fabricated from a conductive metal, for example, such as aluminum. The inventors have observed that fabricating sheaths of the heating elements 118 from aluminum may provide an improved heat distribution over conventionally utilized stainless steel sheathed heating elements due to the high heat conductivity of aluminum as compared to stainless steel. In addition, the aluminum sheaths have the same thermal expansion as the heater plate 106, thereby reducing or eliminating thermal stresses that may occur due to thermal expansion/contraction mismatch between components.

[0018] In some embodiments, a gas, for example a purge gas (*e.g.*, an inert gas, such as argon), may be provided by a gas source 114 to a backside 122 of the substrate 104 via a conduit 116. One or more second conduits (not shown) may be provided to deliver the purge gas proximate the edge of the substrate 104.

[0019] The inventors have observed that conventional substrate supports utilized in deposition process chambers typically include a heater plate (*e.g.*, heater plate 106) fabricated from a steel alloy, for example, such as stainless steel. However, the inventors have observed that the low heat conductivity of stainless steel creates a temperature gradient across the heating plate (*e.g.*, a temperature range from the center to edge of the heater plate), causing uneven heating of the substrate, thereby leading to process non-uniformities. In addition, the high (radio frequency) RF resistivity of the stainless steel causes non-uniform plasma distribution, thereby further leading to non-uniform deposition of materials atop the substrate.

[0020] Accordingly, in some embodiments, the heater plate 106 may be fabricated from aluminum (Al). The inventors have discovered that a heater plate fabricated from aluminum may provide an improved heat distribution over conventionally utilized stainless steel heater plates due to the high heat conductivity of aluminum as compared to stainless steel. In addition, because of the lower RF resistivity of aluminum (as compared to stainless steel), an improved RF grounding path may be provided, thereby providing an improved plasma uniformity.

[0021] Details of the substrate support 103 in accordance with at least some embodiments of the invention are further described in Figure 2, which depicts a more detailed view of the substrate support 103 of Figure 1. In Figure 2, an embodiment of the heater plate 106 is shown as heater plate 202 (e.g., a first aluminum plate). In some embodiments, the heating elements 118 may be embedded or recessed within the heater plate 202, such as shown in Figure 2. In such embodiments, the heating elements 118 may be disposed within a plurality of channels 258 formed in a bottom surface 260 of the first aluminum plate 202. In some embodiments, the heating elements 118 may be configured such that multiple heating zones (e.g., outer heating zone 204 and inner heating zone 208 as shown) are present across the heater plate 202. Greater or fewer zones may also be provided.

[0022] In some embodiments, the substrate support 103 may comprise one or more additional plates (such as second aluminum plate 212 and third aluminum plate 214 shown in Figure 2) disposed beneath the heater plate 202 (e.g., the first aluminum plate). By fabricating all of the substrate support plates (i.e., the heater plate 202, second aluminum plate 212 and third aluminum plate 214) from aluminum, the inventors have observed that a heat transfer from the heating elements may be faster and more uniform, as compared to conventional substrate support plates fabricated from, for example, stainless steel. The substrate support plates may be coupled together via any process suitable to couple aluminum, for example, such as welding, brazing, or the like.

[0023] The inventors have observed that when using a substrate support having a metal heater plate (e.g., substrate support 103 and heater plate 202) during a

substrate process (e.g., a deposition process), contamination of the substrate may occur as a result of metal to substrate contact. For example, when utilizing a conventional heater plate fabricated from stainless steel, iron (Fe) from the heater plate may diffuse into a back surface of the substrate, thereby contaminating the substrate. Accordingly, in some embodiments, a plurality of non-metallic spacers (spacers) 228 may be disposed between the substrate 104 and the heater plate 202. The inventors have observed that by providing the plurality of non-metallic spacers 228, the substrate 104 is supported above the heater plate 202 during processing, thereby eliminating any direct substrate 104 to metal contact, thus reducing or eliminating contamination of the substrate 104. In addition, the inventors have observed that by supporting the substrate 104 above the heater plate 202, a gap 232 formed between the substrate 104 and the heater plate 202 provides an improved substrate backside pressure control that reduces vacuum pressure drop at the substrate edge, thereby retaining a desired clamping force on the substrate.

[0024] The plurality of non-metallic spacers 228 may be fabricated from any non-metallic material suitable to support the substrate 104 above the heater plate 202 while being resistant to the environment within the process chamber during processing. For example, in some embodiments, the non-metallic spacers 228 may be fabricated from a crystalline form of aluminum oxide (Al_2O_3) (e.g., sapphire), aluminum nitride (AlN), or the like. The non-metallic spacers 228 may have any shape suitable to support the substrate 104. For example, in some embodiments, each non-metallic spacer 228 may have a substantially spherical shape and may be held in place in corresponding recesses formed in an upper surface of the heater plate 202. The size of the non-metallic spacers 228 may be selected to provide the gap 232 with a size sufficient to prevent contamination of the substrate 104 from material of the heater plate 202. For example, in some embodiments, the gap 232 may be about 0.002 to about 0.010 inches, or in some embodiments, about 0.007 inches.

[0025] The non-metallic spacers 228 may be disposed between the substrate 104 and heater plate 202 in any manner suitable to support the substrate 104 in a static position during processing. For example, in some embodiments, the non-metallic spacers 228 may be partially recessed into openings 230 formed in the heater plate

202. In such embodiments, the non-metallic spacers 228 may be secured in place via any means suitable, for example, such as a swaging process (e.g., via a swage press).

[0026] In addition to the non-metallic spacers 228, in some embodiments, a non-metallic seal ring 210 may be disposed atop the heater plate 202 to further support the substrate 104 above the heater plate 202 and to provide a seal between the processing volume within the process chamber and the region between the substrate and the heater plate (e.g., the gap 232). When present, the non-metallic seal ring 210 supports the substrate 104 proximate a peripheral edge 203 of the substrate. The non-metallic seal ring 210 may be fabricated from any non-metallic material suitable to support the substrate 104 above the heater plate 202 while being resistant to the processing environment. For example, in some embodiments, the non-metallic seal ring 210 may be fabricated from aluminum nitride (AlN), aluminum oxide (Al₂O₃) or the like.

[0027] The non-metallic seal ring 210 may have any thickness suitable to support the substrate 104 such that a desired gap (e.g., the gap 232 discussed above) is formed between the substrate 104 and heater plate 202. However, the inventors have observed that as the thickness of the non-metallic seal ring 210 increases, the non-metallic seal ring 210 may be susceptible to breakage due to thermal stresses. Moreover, as the thickness of the non-metallic seal ring 210 increases, an impedance difference between a center of the substrate 104 and an edge of the substrate 104 during processing may increase, leading to process non-uniformities. Accordingly, in some embodiments, the non-metallic seal ring 210 may be about 0.10 to about 0.30 inches thick. The non-metallic seal ring 210 may be positioned atop the heater plate 202 in any manner suitable to support the substrate 104 above the 202. For example, in some embodiments, the non-metallic seal ring 210 may be disposed directly atop a top surface of a peripheral edge of the heater plate 202. In some embodiments, the non-metallic seal ring 210 may sit on a recess or cutout 205 of the heater plate 202, such as shown in Figure 2.

[0028] In some embodiments, a plurality of pins may be utilized to to maintain the non-metallic seal ring 210 in a desired position and/or to center the non-metallic seal

ring 210 with respect to the heater plate 202. For example, Figure 3 depicts a pin 312 extending from the heater plate 202 to center the non-metallic seal ring 210 with respect to the heater plate 202. Each pin of the plurality of pins (e.g., pin 312) may comprise any electrically insulating material, such a ceramic, for example, aluminum oxide (Al_2O_3), aluminum nitride (AlN), or the like. In some embodiments, each pin of the plurality of pins (e.g., pin 312) may comprise a top portion 304 configured to interface with a feature 306 formed in the non-metallic seal ring 210 and a bottom portion 314 configured to interface with a recess 302 formed in the heater plate 202. In some embodiments, each pin of the plurality of pins (e.g., pin 312) may comprise a flange 308 configured to interface with a top portion 310 of the recess 302. In some embodiments, three pins may be provided in an azimuthally symmetric arrangement.

[0029] Referring back to Figure 2, in addition to the non-metallic spacers 228, in some embodiments, a non-metallic disk 234 may be disposed proximate a center 236 of the heater plate 202 to further support the substrate 104 above the heater plate 202. The non-metallic disk 234 may comprise any electrically insulating material, such a ceramic, for example, aluminum oxide (Al_2O_3), aluminum nitride (AlN), or the like. In some embodiments, the non-metallic disk 234 may be at least partially recessed into an opening formed in the heater plate 202.

[0030] In some embodiments, the non-metallic disk 234 may include a shaft 238 coupled to and extending outwardly from a bottom portion of the non-metallic disk 234 and through a corresponding opening in the heater plate 202. In such embodiments, the shaft 238 and non-metallic disk 234 may include a through hole 242 to prevent gas from being trapped between the non-metallic disk 234 and the heater plate 202. The shaft 238 may be fabricated from a different, or in some embodiments, the same material used to fabricate the non-metallic disk 234. In some embodiments, the shaft 238 and non-metallic disk 234 may be fabricated from a single piece of material, thereby providing a single unitary part comprising the shaft 238 and non-metallic disk 234.

[0031] In some embodiments, the substrate support shaft 107 may generally comprise a body 250 having one or more conduits (two conduits 216, 217 shown)

formed therein. The body 250 may be fabricated from any material suitable to support the substrate support 103, for example, a metal, such as aluminum, or the like.

[0032] By utilizing conduits 216, 217 formed in the body 250 of the substrate support shaft 107, the inventors have discovered that the conduits 216, 217 are less susceptible to degradation or failure as compared to conventional substrate support shafts that utilized separate components to form conduits. In some embodiments, the conduits 216, 217 may be configured to provide gases (e.g., purge gases), a vacuum, or the like, to the heater plate 202 and/or to an area above the heater plate 202 (e.g., the inner volume 105 of the process chamber 100 shown in Figure 1). For example, in some embodiments a first conduit (e.g., conduit 217) may provide one or more gases to a purge channel 248 via a series of channels 251, 252 formed in the third aluminum plate 214. In some embodiments, a second conduit (e.g., conduit 216) may be coupled to a vacuum (not shown) to facilitate chucking the substrate 104 to the substrate support 103.

[0033] In some embodiments, one or more power supply lines (two power supply lines 220, 218 shown) may be disposed within the substrate support shaft 107 to provide power from a power supply (e.g., power source 111 described above) to the heating elements 118. In addition, in some embodiments, a thermocouple probe 226 may be disposed within the substrate support shaft 107 and extending into a portion of the heater plate 202 to facilitate monitoring a temperature of the heater plate 202. In some embodiments, at least a portion of the thermocouple probe 226 and/or the power supply lines 220, 218 may be enclosed within an aluminum tube (aluminum tube 227 shown for thermocouple probe 226). In some embodiments, the aluminum tube 227 may be coupled to the substrate support shaft 107 via any process suitable to provide a secure coupling, for example, via welding, brazing or the like. By enclosing the thermocouple probe within the aluminum tube 227, the inventors have observed that a noise coupling from the power supply lines 220, 218 and the thermocouple probe 226 may be reduced or eliminated, thereby facilitating a more accurate reading from the thermocouple probe 226.

[0034] In some embodiments, a purge ring 246 may be disposed on the heater plate 202 to define the purge channel 248 to provide a purge gas to a peripheral portion of the substrate 104 to prevent deposition thereon. In some embodiments, the purge ring 246 may be fabricated from a metal, such as aluminum (Al), stainless steel, or the like, or a non-metal material, such as aluminum oxide (Al₂O₃), aluminum nitride (AlN), or the like.

[0035] In such embodiments, the inventors have observed that conventionally utilized mechanisms (e.g., via multiple springs and/or metal skirting) to provide a grounding path for a purge ring (e.g., purge ring 246) fail to provide reliable grounding. Accordingly, in some embodiments, the purge ring 246 and the heater plate 202 may be coupled to one another via a plurality of metal clips (two metal clips 256 shown). The inventors have discovered that utilizing the metal clips 256 to couple each of the purge ring 246 and heater plate 202 provides a more secure and reliable coupling, and therefore a better grounding, as compared to, for example, a spring force contact typically used in conventional substrate supports. The inventors have further discovered that the improved coupling and grounding allows the heater (e.g., heating elements 118 and the heater plate 202 described above) to be reliably operated at broad range of RF frequencies for plasma processes, for example, such as 13.56 MHz, 40Mhz, or higher.

[0036] Referring to Figure 4, in some embodiments, each of the plurality of metal clips 256 may comprise a first end 404, a second end 410 and a u-shaped portion 428 disposed between and coupling the first end 404 to the second end 410. Each of the first end 404 and second end 410 include a through hole 406, 420 configured to accommodate a fastener 408, 412. In some embodiments, the first end 404 and second end 410 may extend outwardly from the u-shaped portion and may be offset from one another, such as shown in Figure 5. Configuring the first end 404 and second end 410 in such a manner allows for clear access to each through hole 406, 420, thereby allowing for a simple installation.

[0037] Referring back to Figure 4, the fastener 408, 412 can be any type of fastener suitable to couple the metal clips 256 to the purge ring 246 and heater plate 202 while providing an adequate connection to facilitate an electrical grounding of

the purge ring 246. For example, the fastener 408, 412 may be a rivet, screw, bolt, or the like. In embodiments where the fastener 408, 412 is a bolt, for example such as shown in Figure 4, the fastener 408, 412 may comprise a head 409, 413 configured to interface with a tool to allow tightening of the fastener 408, 412 and a threaded portion 418, 422 configured to interface with a hole 414, 426 disposed the purge ring 246 and heater plate 202. In some embodiments, the hole 414, 426 may comprise internal threads configured to mate with the threaded portion 418, 422 of the fastener 408, 412. Alternatively, an insert 416, 424 may be press fit within the hole 414, 426.

[0038] Referring to Figure 6, the heating elements 118 may be configured in any manner to provide a suitable temperature provide to the heater plate 202 for a particular process being performed. For example, in some embodiments, the heating elements may comprise a first heating element 610 configured to provide heat to the inner heating zone 208 (e.g., an inner portion of the first aluminum plate 202) and a second heating element 612 configured to provide heat to the outer heating zone 204 (e.g., an outer portion of the first aluminum plate, or heater plate 202). In such embodiments, each of the outer heating zone 204 and inner heating zone 208 heating elements 118 may be configured in a recursive pattern, for example, as shown in Figure 6. In some embodiments, the heating elements 118 for the inner heating zone 208 may comprise a recursive pattern 602 having one or more, or in some embodiments, two or more, curved sections or loops (two curved sections/loops 606, 608 shown) disposed in an area proximate a center 604 of the heater plate 202. By providing the heating elements 118 in such a manner, the inventors have discovered that a temperature proximate the center 604 of the heater plate 202 may increase, thereby providing a temperature profile having an improved uniformity across the heater plate, as compared to conventionally configured heating elements.

[0039] Thus, embodiments of substrate supports that may provide one or more of backside contamination control, improved heat distribution, and improved plasma uniformity have been provided herein. The inventive substrate support may advantageously support a substrate above a heater plate during processing, thereby eliminating any direct substrate to metal contact, thus reducing or eliminating

contamination of the substrate. The inventive substrate support may further advantageously provide a heater plate fabricated from aluminum, thereby providing an improved heat distribution over conventionally utilized stainless steel heater plates. In addition, the lower RF resistivity of aluminum (as compared to stainless steel) provides an improved RF grounding path, resulting in improved plasma uniformity.

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

Claims:

1. A substrate support, comprising:
 - a first aluminum plate for supporting a substrate, the first aluminum plate having a plurality of heating elements embedded therein to provide a plurality of heating zones;
 - a second aluminum plate disposed beneath and supporting the first aluminum plate;
 - a third aluminum plate disposed beneath and supporting the second aluminum plate;
 - a non-metallic seal ring disposed atop the first aluminum plate; and
 - a plurality of spacers having an upper portion disposed above a surface of the first aluminum plate, wherein the non-metallic seal ring and the plurality of spacers support the substrate above the first aluminum plate.
2. The substrate support of claim 1, wherein the plurality of spacers are at least partially recessed into a top surface of the first aluminum plate.
3. The substrate support of claim 1, wherein the plurality of spacers have a substantially spherical shape.
4. The substrate support of claim 1, wherein the non-metallic seal ring and the plurality of spacers support the substrate about 0.002 to about 0.010 inches above the first aluminum plate.
5. The substrate support of claim 1, wherein the plurality of spacers are fabricated from sapphire.
6. The substrate support of any of claims 1 to 5, wherein the first aluminum plate further comprises a plurality of channels formed in a bottom surface of the first aluminum plate, wherein the heating elements are disposed within the plurality of

channels, and wherein the heating elements are secured in the plurality of channels by the second plate.

7. The substrate support of any of claims 1 to 5, wherein the non-metallic seal ring is fabricated from at least one of aluminum nitride (AlN) or aluminum oxide (Al₂O₃).

8. The substrate support of any of claims 1 to 5, further comprising:
a plurality of pins, each having a first end disposed in a feature of the first aluminum plate and a second end extending beyond a top surface of the first aluminum plate and configured to interface with a feature formed in a bottom surface of the non-metallic seal ring to maintain the non-metallic seal ring in a desired position.

9. The substrate support of any of claims 1 to 5, further comprising a non-metallic disk disposed proximate a center of the plate, the non-metallic disk having an upper portion disposed above the surface of the first aluminum plate, wherein the non-metallic disk, non-metallic seal ring, and the plurality of spacers support the substrate above the first aluminum plate.

10. The substrate support of claim 9, wherein the non-metallic disk further comprises:

a shaft coupled to a bottom of the non-metallic disk and disposed within a through hole formed in the plate.

11. The substrate support of any of claims 1 to 5, wherein the plurality of heating elements comprise:

a first heating element configured to provide heat to an inner portion of the first aluminum plate; and

a second heating element configured to provide heat to an outer portion of the first aluminum plate.

12. The substrate support of claim 11, wherein a portion of the first heating element comprises two or more curved sections disposed proximate a center of the first aluminum plate to provide heat to an area proximate the center of the first aluminum plate.

13. The substrate support of any of claims 1 to 5, further comprising a support shaft disposed beneath the third aluminum plate to support the third aluminum plate, the support shaft comprising:

- a body having a hollow portion formed within the body; and
- one or more conduits formed in the body, wherein each of the one or more conduits are configured to provide a gas or apply a vacuum to an area above the first aluminum plate.

14. The substrate support of claim 13, wherein the support shaft further comprises:

- a thermocouple to provide a temperature of the first aluminum plate, the thermocouple disposed within the hollow portion of the support shaft; and
- an aluminum tube surrounding the thermocouple.

15. The substrate support of any of claims 1 to 5, further comprising:

- a purge ring disposed about a periphery of the plate; and
- a plurality of metal strips, each of the plurality of metal strips comprise a first end coupled to the purge ring, a second end coupled to the plate and a curved section coupling the first end to the second end, wherein the plurality of metal strips electrically couple the purge ring to the first aluminum plate.

1/5

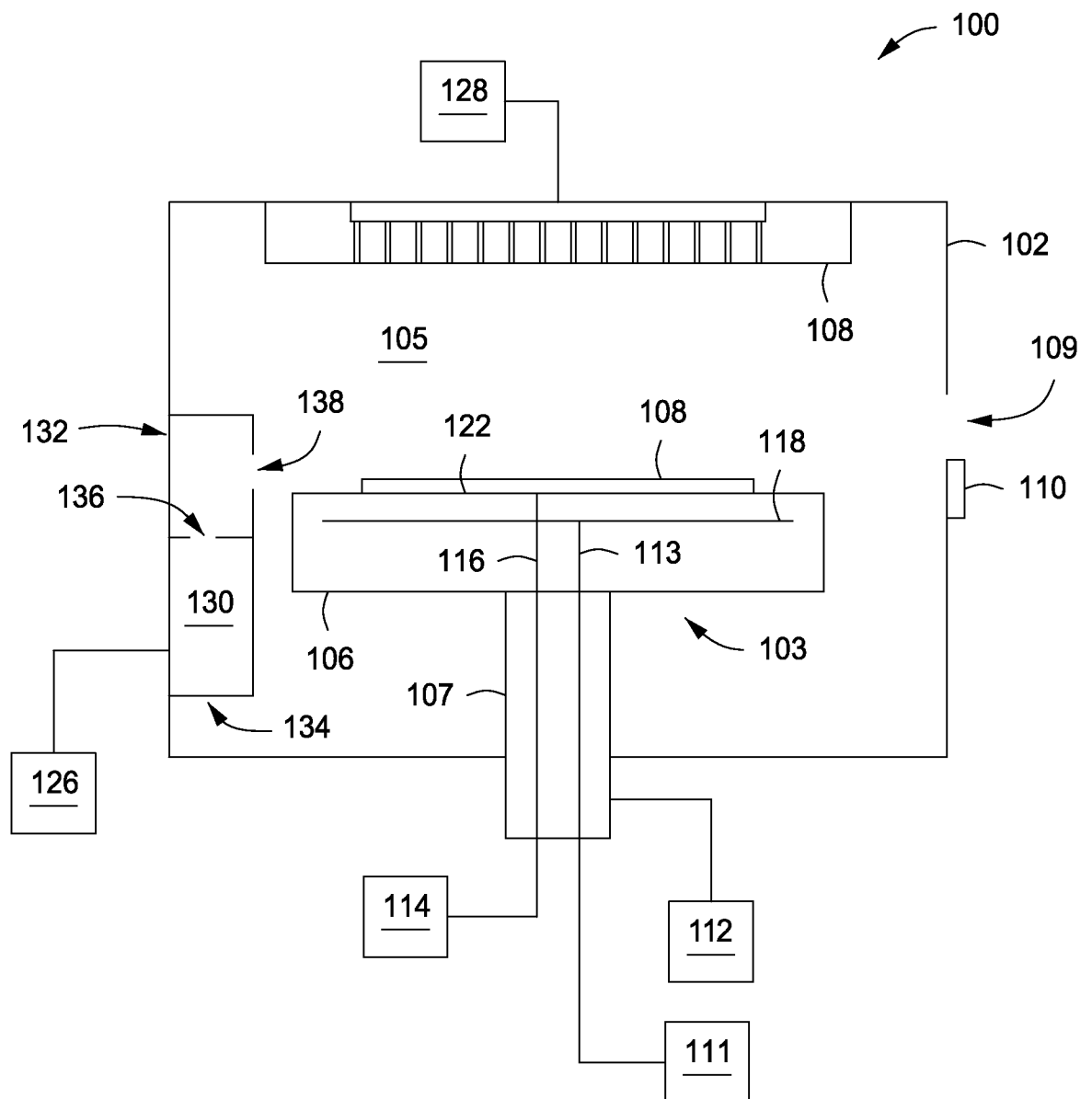


FIG. 1

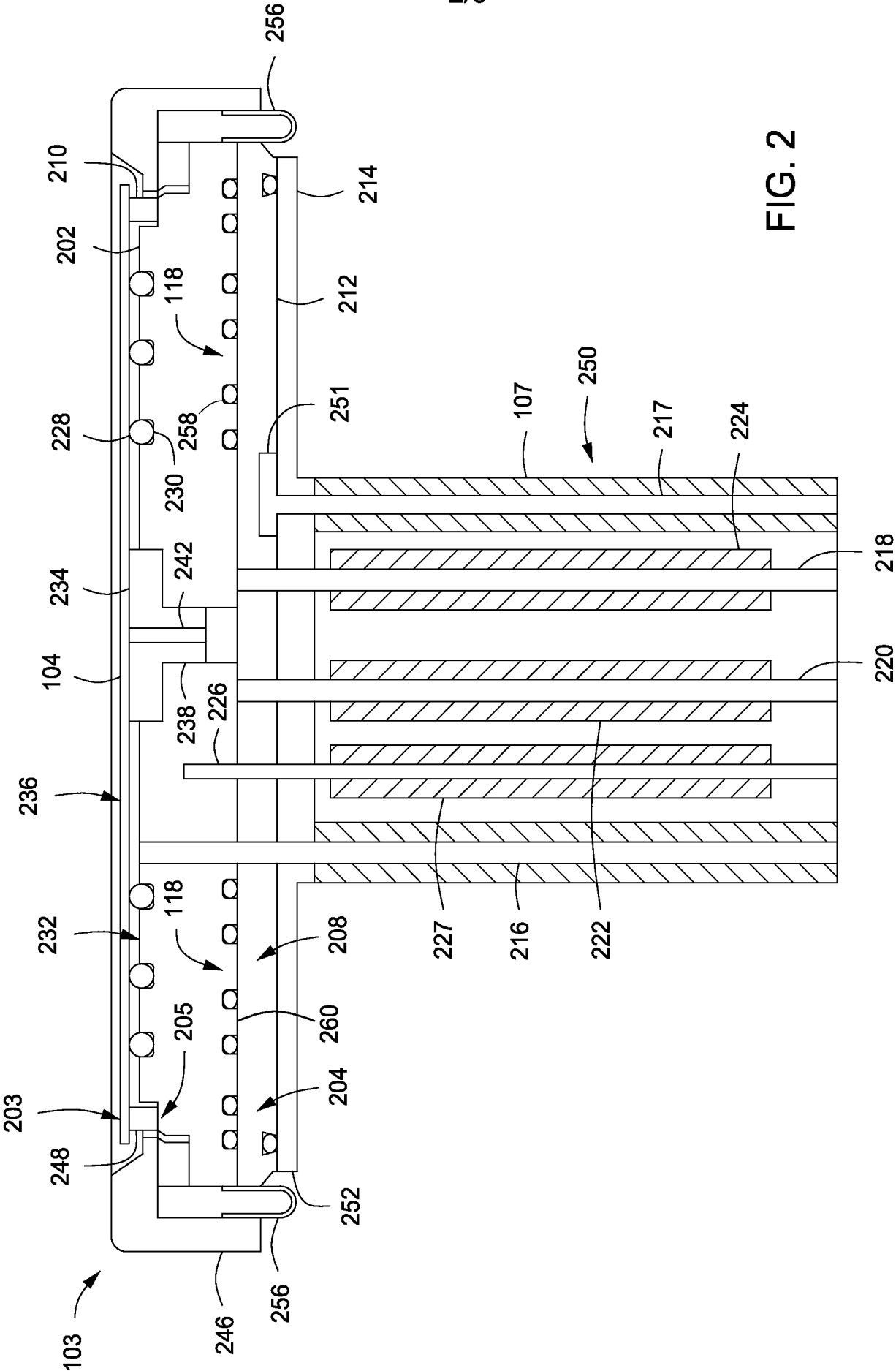


FIG. 2

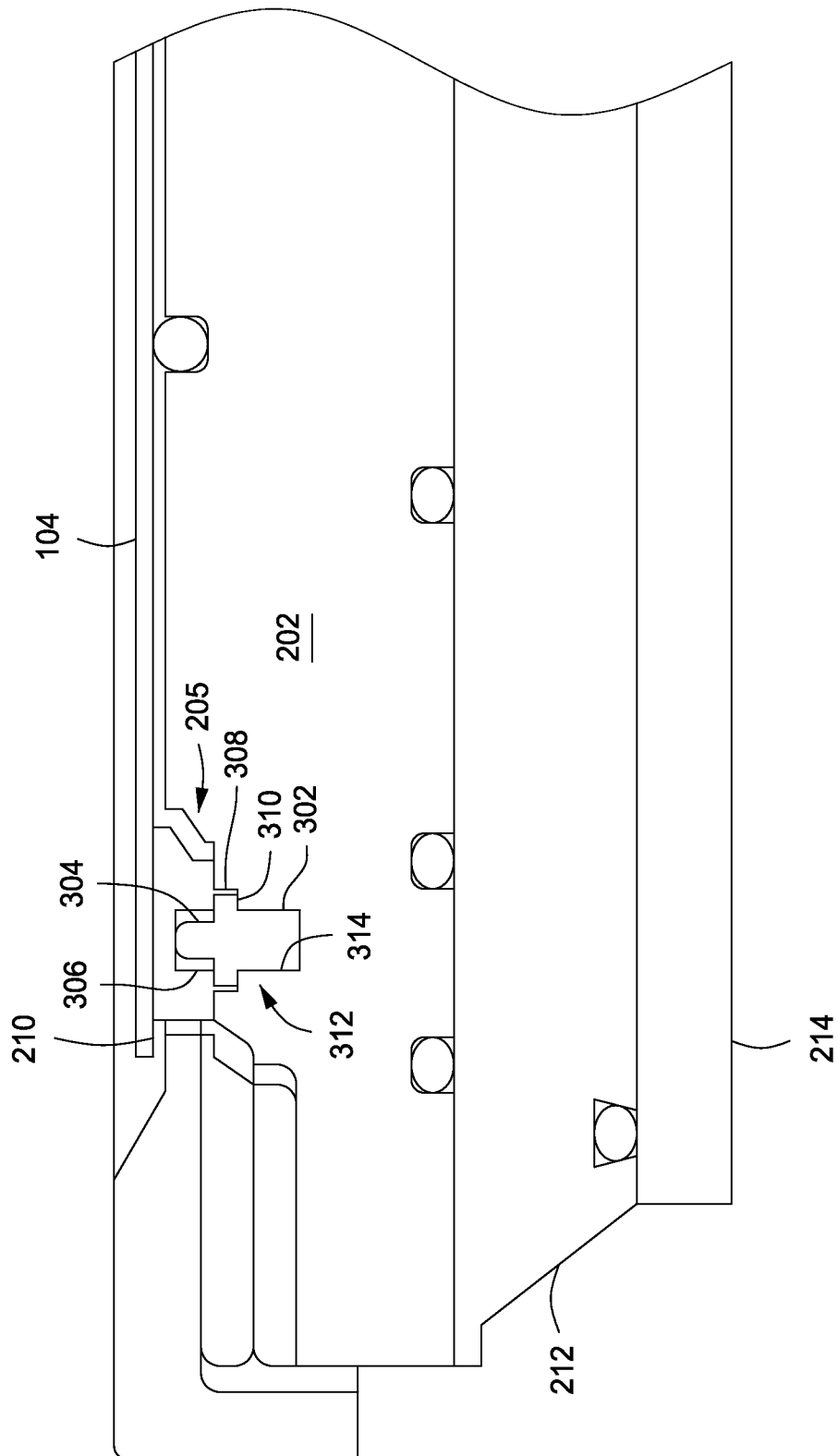


Fig. 3

4/5

FIG. 4

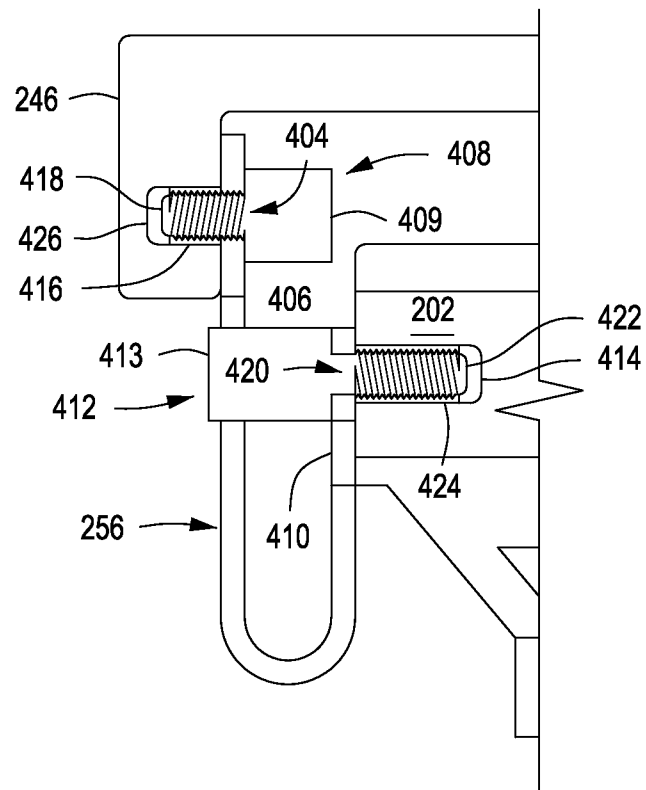
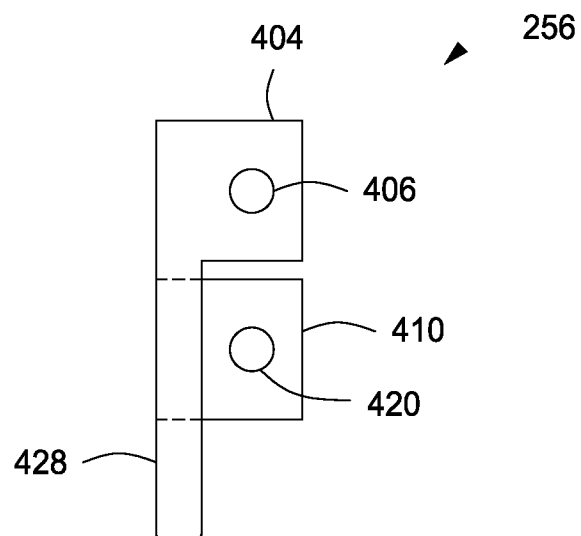


FIG. 5



5/5

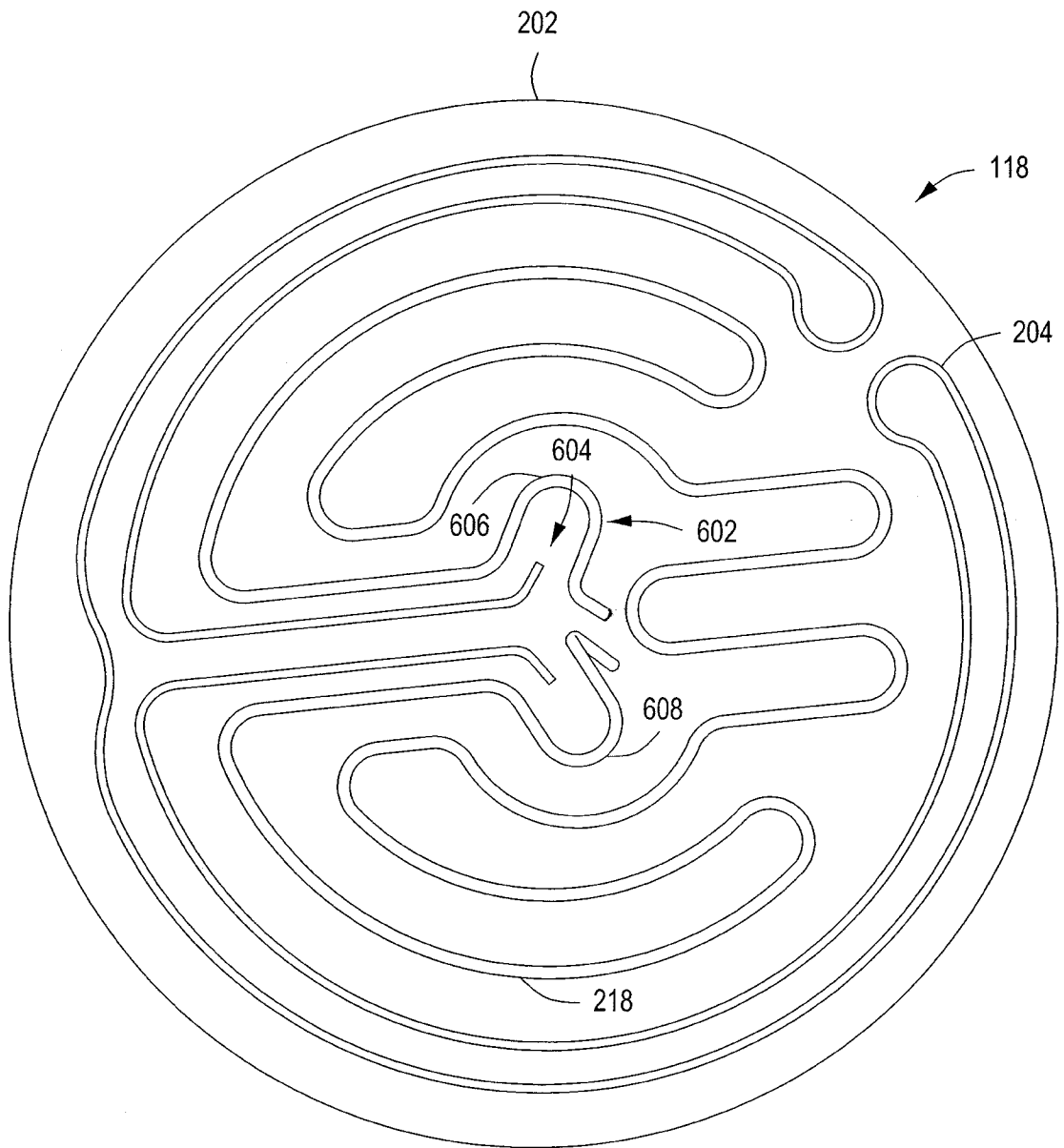


FIG. 6

A. CLASSIFICATION OF SUBJECT MATTER**H01L 21/683(2006.01)i, H05B 3/20(2006.01)i, C04B 35/58(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 21/683; H02N 13/00; H01L 21/205; H01L 21/687; B23Q 3/15; H01L 21/02; H05B 3/20; C04B 35/58

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: wafer, support, aluminum, heat, thermocouple, pin, and purge

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	KR 10-2011-0089692 A (POINT ENGINEERING CO., LTD.) 09 August 2011 See abstract, paragraphs [0025],[0035],[0039]-[0040],[0045], and figure 3.	1-7,9-13
A		8,14-15
Y	KR 10-2007-0001036 A (POINT ENGINEERING CO., LTD.) 03 January 2007 See page 4, lines 50-52, page 5, lines 19-23, 45-51, and figures 3,5.	1-7,9-13
Y	US 2010-0046134 A1 (MIZUNO, SHIGERU et al.) 25 February 2010 See abstract, paragraphs [0009],[0036],[0090],[0093],[0123], and figures 1,4.	10,13
A	JP 2010-272730 A (SHINKO ELECTRIC IND. CO., LTD.) 02 December 2010 See abstract, claim 1, and figure 1.	1-15
A	KR 10-2011-0025101 A (TOKYO ELECTRON LTD.) 09 March 2011 See abstract and claim 1.	1-15



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 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

17 September 2013 (17.09.2013)

Date of mailing of the international search report

17 September 2013 (17.09.2013)

Name and mailing address of the ISA/KR

Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City,
302-701, Republic of Korea

Facsimile No. +82-42-472-7140

Authorized officer

KIM Jin Ho

Telephone No. +82-42-481-8699



INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/048060

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
KR 10-2011-0089692 A	09/08/2011	KR 10-1115527 B1	06/02/2012
KR 10-2007-0001036 A	03/01/2007	KR 10-0875388 B1	16/12/2008
US 2010-0046134 A1	25/02/2010	JP 2004-022888 A	22/01/2004
		JP 2004-022889 A	22/01/2004
		JP 2004-253403 A	09/09/2004
		JP 4010541 B2	21/11/2007
		JP 4061131 B2	12/03/2008
		JP 4338376 B2	07/10/2009
		KR 10-0511854 B1	02/09/2005
		KR 10-2004-0002552 A	07/01/2004
		TW 233658 A	01/06/2005
		TW 233658 B	01/06/2005
		TW I233658 B	01/06/2005
		US 2004-0040665 A1	04/03/2004
		US 2006-0158823 A1	20/07/2006
		US 2009-0059462 A1	05/03/2009
		US 2009-0122459 A1	14/05/2009
		US 7623334 B2	24/11/2009
		US 7724493 B2	25/05/2010
		US 7791857 B2	07/09/2010
		US 7848077 B2	07/12/2010
JP 2010-272730 A	02/12/2010	None	
KR 10-2011-0025101 A	09/03/2011	CN 102013408 A	13/04/2011
		JP 2011-054838 A	17/03/2011