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

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
4 August 2016 (04.08.2016)

WIPO | PCT

(10) International Publication Number
WO 2016/122835 A1

(51) International Patent Classification:
H01L 21/324 (2006.01) *H01L 21/67* (2006.01)

(21) International Application Number:
PCT/US2016/012066

(22) International Filing Date:
4 January 2016 (04.01.2016)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
62/110,440 30 January 2015 (30.01.2015) US
62/141,133 31 March 2015 (31.03.2015) US

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

(72) Inventors: **SAMIR, Mehmet Tugrul**; 1019 Asbury Way, Mountain View, California 94043 (US). **CHU, Schubert S.**; 38 Sequoia Way, San Francisco, California 94127 (US).

(74) Agents: **PATTERSON, B. Todd** et al.; Patterson & Sheridan, L.L.P., 24 Greenway Plaza, Suite 1600, Houston, Texas 77046 (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: LAMP HEATING FOR PROCESS CHAMBER

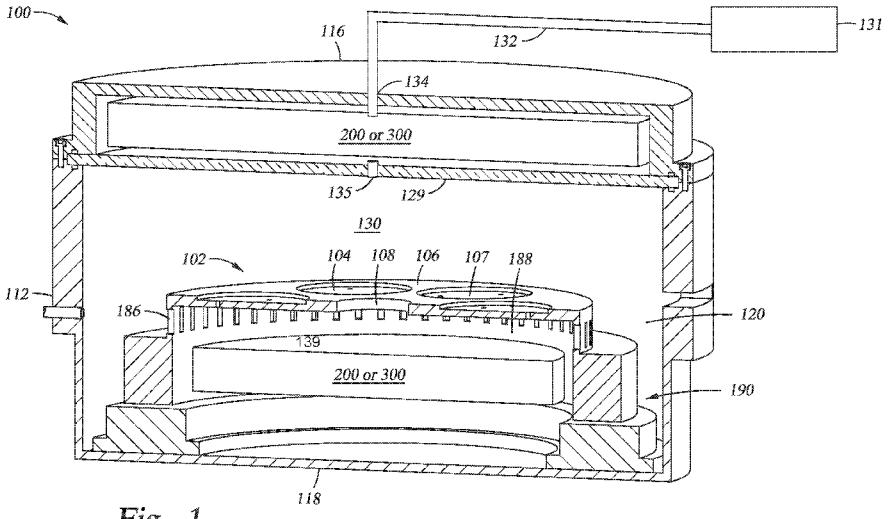


Fig. 1

(57) Abstract: A process chamber is provided including a top, a bottom, and a sidewall coupled together to define a volume. A substrate support is disposed in the volume. The process chamber further includes one or more lampheads facing the substrate support, each lamphead comprising an arrangement of lamps disposed along a plane. The arrangement of lamps is defined by a center and a plurality of concentric ring-shaped zones. Each ring-shaped zone is defined by an inner edge and an outer edge and each ring-shaped zone includes three or more alignments of one or more lamps. Each alignment of one or more lamps has a first end extending linearly to a second end that are separated by at least 10 degrees around the center. The first end and the second end are both located within one ring-shaped zone. Each alignment located within a same ring-shaped zone is equidistant to the center.

WO 2016/122835 A1

LAMP HEATING FOR PROCESS CHAMBER

BACKGROUND

Field

[0001] Embodiments disclosed herein generally relate to lamp heating of process chambers used to process semiconductor substrates. More specifically, embodiments disclosed herein are related to arrangements of linear lamps for heating of semiconductor substrates.

Description of the Related Art

[0002] Various processes are used to form electronic devices on semiconductor substrates. Such processes include chemical vapor depositions, plasma enhanced chemical vapor depositions, atomic layer depositions, and epitaxy. These processes are performed in process chambers, and temperature control across the surface of the semiconductor substrate disposed within the process chambers facilitates uniform and consistent results during processing.

[0003] Lamps are often used to heat the semiconductor substrates during processing. The lamps are often arranged radially relative to the center of the lamp. For example, a plurality of vertical lamps having a bulb extending towards the substrate can be arranged along various radii from a center of the lamphead. While these arrangements can provide adequate temperature control of radial locations on the substrates being processed, the temperature control around the different angular locations of the substrate still suffers from non-uniformities. Other arrangements, such as a honeycomb arrangement having hundreds or even thousands of lamps can provide improved temperature control, but having hundreds or thousands of lamps is not a cost-effective solution.

[0004] Therefore, there is a need for an improved and more efficient design for lamp heating in semiconductor process chambers.

SUMMARY

[0005] Embodiments of the disclosure are generally related to lamp heating of process chambers used to process semiconductor substrates. In one embodiment, a process chamber is provided. The process chamber includes a top, a bottom, and a sidewall coupled together to define a volume. A substrate support disposed in the volume. The process chamber further includes one or more lampheads facing the substrate support, each lamphead comprising an arrangement of lamps disposed along a plane. The arrangement of lamps is defined by a center and a plurality of concentric ring-shaped zones about the center. Each ring-shaped zone is defined by an inner edge and an outer edge and each ring-shaped zone includes three or more alignments of one or more lamps. Each alignment of one or more lamps has a first end extending linearly to a second end that are separated by at least 10 degrees around the center. The first end and the second end of each alignment are both located within one ring-shaped zone. Each alignment located within a same ring-shaped zone is equidistant to the center.

[0006] In another embodiment, a process chamber is provided. The process chamber includes a top, a bottom, and a sidewall coupled together to define a volume. A substrate support is disposed in the volume. The process chamber further includes a lamphead facing the substrate support, the lamphead including an arrangement of lamps disposed along a plane. The arrangement of lamps is defined by a center and three or more sectors. Each sector defined by a first leg extending from the center to a first outer point, a second leg extending from the center to a second outer point, and a connecting portion between the first outer point and the second outer point. Each sector includes a plurality of linear lamps. Each linear lamp has a first end and a second end that are separated by at least 10 degrees around the center. The first end and the second of each linear lamp are both located within one sector. Each linear lamp of a sector is located at a different distance from the center.

[0007] In another embodiment a process chamber is provided. The process chamber includes a top, a bottom, and a sidewall coupled together to define a volume. The process chamber further includes a substrate support disposed in the volume. The substrate support has a plurality of substrate locations distributed around a central location of the substrate support, and each substrate location has a substrate supporting surface. The process chamber further includes a lamphead facing the substrate support. The lamphead includes an arrangement of lamps disposed along a plane that is substantially parallel to the substrate supporting surfaces of the substrate locations. The arrangement of lamps is defined by a center, from three to seven ring-shaped zones, and from three to seven sectors overlapping the from three to seven ring-shaped zones. Each ring-shaped zone is concentric with the center of the plane and each ring-shaped zone is defined by an inner edge and an outer edge. Each sector is defined by a first leg extending from the center to a first outer point, a second leg extending from the center to a second outer point, and a connecting portion between the first outer point and the second outer point. Each linear lamp includes a first end and a second end that are both located within one ring-shaped zone and one sector. Each linear lamp extends at least 30 degrees around the center of the plane.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the disclosure, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

[0009] Figure 1 is a side sectional view of a process chamber, according to one embodiment.

[0010] Figures 2A and 2B are top sectional plan views of an arrangement of lamps, according to one embodiment.

[0011] Figure 2C is a side sectional view of a lamp to be used in the arrangement of lamps in Figures 2A and 2B, according to one embodiment.

[0012] Figures 3A and 3B are top sectional plan views of an arrangement of lamps, according to a second embodiment.

[0013] Figure 3C is a side sectional view of lamps to be used in the arrangement of lamps in Figures 3A and 3B, according to the second embodiment.

[0014] To facilitate understanding, common words have been used, where possible, to designate identical elements that are common to the figures. It is contemplated that elements disclosed in one embodiment may be beneficially utilized on other embodiments without specific recitation.

DETAILED DESCRIPTION

[0015] The present disclosure relates generally to lamp heating of process chambers used to process semiconductor substrates. More specifically, embodiments disclosed herein are related to arrangements of linear lamps for heating of semiconductor substrates.

[0016] In this disclosure, the terms “top”, “bottom”, “side”, “above”, “below”, “up”, “down”, “upward”, “downward”, “horizontal”, “vertical”, and the like do not refer to absolute directions. Instead, these terms refer to directions relative to a basis plane of the chamber, for example a plane parallel to a substrate processing surface of the chamber. Furthermore, because this application discloses lampheads 200 and 300 that may be provided above or below a substrate support, any specific example given for a lamphead or lamp arrangement above the substrate support should be understood by the reader to also include a similar or mirror image lamphead or lamp arrangement below

the substrate support without specific recitation of that lamphead or lamp arrangement below the substrate support.

[0017] Figure 1 is a perspective cross-sectional view of a process chamber 100 according to one embodiment. The process chamber 100 generally features a substrate support 102 having multiple substrate locations 104 on a processing surface 106 thereof, the substrate support 102 having a central opening 108 that provides uniform gas flow and exposure across the processing surface 106.

[0018] The chamber 100 has a top 116 and a bottom 118 that, together with the sidewall 112, define a volume 120 of the process chamber 100. The substrate support 102 is disposed within the volume 120.

[0019] Coupled at the top 116 of the process chamber 100 is a lamphead 200 including an arrangement 207 of lamps (see Figures 2A-2C) or a lamphead 300 including an arrangement 307 of lamps (see Figures 3A-3C) that project heat into the volume 120 toward the substrate support 102. The lampheads 200, 300 each include one or more types of heat sources, such as linear lamps and vertically oriented lamps that are described in fuller detail below. The lamphead 200 or the lamphead 300, may also be coupled to the chamber 100 at the bottom 118. Furthermore, in some embodiments, there may be a lamphead, such as lamphead 200 and/or a lamphead 300, at the top 116 and at the bottom 118. The lampheads 200, 300 may have reflective internal surfaces to increase the efficiency of power delivery to the processing surface 106 of the substrate support 102. Furthermore, in some embodiments each lamp in the lampheads 200, 300 may be disposed in a reflective tube to maximize power delivery from each lamp. Additionally, power delivery may be attenuated in a central region of the lamphead 200, 300 to avoid radiating excessive power through the central opening 108 of the substrate support 102.

[0020] A divider 129 may separate the lamphead 200, 300 at the top 116 of the chamber 100 from the volume 120 adjacent to the processing surface

106. The divider 129 and the processing surface 106 together define a processing region 130. The divider 129 may be a thermally resistant material, such as quartz, and may be transparent to energy emitted from the lamphead 200 to transmit the energy into the processing region 130. The divider 129 may also be a barrier to gas flow between the lamphead 200 and the processing region 130.

[0021] Interior surfaces of the lamphead 200 or 300 at the top 116 of the chamber 100, with the exception of the surface of the divider 129, may be lined or coated with a reflective material if desired. The reflective material may be any reflective material capable of withstanding the environment of the lampheads 200, 300. A cooling gas source 131 may be connected to the lamphead 200 through a gas conduit 132 and a portal 134 to maintain a temperature of the interior surfaces of the lamphead 200 at a desired level to avoid damage to the interior surfaces. The cooling gas may be an inert gas. A cooling gas source (not shown) may also be coupled to a lamphead 200, 300 disposed below the substrate support 102. Reflective materials that may be used include gold, silver, or other metals, and dielectric reflectors. The surface of the divider 129 facing the lamphead 200, 300 may be coated with an anti-reflective material, if desired. A divider similar to the divider 129 may be placed between a lamphead 200, 300 placed below the substrate support 102.

[0022] The substrate support 102 is rotatable, and may be rotated by a rotation assembly (not shown), such as a magnetic rotation assembly. If the substrate support 102 is rotated from the center of the substrate support 102, such as by a central shaft, then a lamphead 200, 300 disposed below the substrate support 102 may be configured to accommodate such a design. For example, in one embodiment, the lamphead 200, 300 may have an opening to allow connection of the central shaft to the substrate support 102. In another embodiment, the lamphead 200, 300 disposed below the substrate support 102 can include separate pieces mounted around the central shaft, such as three to six separate pieces mounted around the central shaft. Using

a lamphead design with separate pieces mounted around a central shaft can allow for easier maintenance of the lamphead as well as the substrate support and the rotation mechanism for the substrate support.

[0023] In an embodiment in which a lamphead 200, 300 is not disposed below the substrate support 102, a reflector (not shown) may be disposed in the interior 188 of the substrate support 102 to reflect any radiation that propagates through the opening 108, or is transmitted or radiated by the substrates or the substrate support 102, back toward the substrate supporting surface 107 of the substrate support 102. The reflector may have a reflective member and a support member. The support member may be coupled to the bottom 118 of the chamber 100, or may extend through the bottom to an optional actuator, which may extend or retract the reflective member.

[0024] Temperature sensors, such as pyrometers, may be disposed in various locations in the chamber 100 to monitor various temperatures that may be significant for particular processes. A first temperature sensor 139 may be disposed in and/or through one or more of the substrate locations 104 to allow the temperature sensor 139 unlimited access to the substrate for monitoring a temperature of the substrate. If the substrate support 102 is rotated, the first temperature sensor 139 may have wireless power and data transmission. A second temperature sensor 135 may be disposed in, on, or through the divider 129 to view substrates disposed in the substrate locations 104 and/or the substrate supporting surface 107 to monitor temperatures of those components. The second temperature sensor 135 may be wired or wireless.

[0025] Figures 2A and 2B are top sectional plan views of a lamphead 200 including an arrangement 207 of lamps, according to one embodiment. Figures 2A and 2B are essentially the same view of the arrangement 207 of lamps in the lamphead 200 taken from a different perspective. Both Figure 2A and 2B illustrate the arrangement 207 of lamps having a center 206 and including a plurality of linear lamps 210 disposed along a plane 205. Figure

2A is a view of the arrangement 207 of lamps in a radial perspective, showing the arrangement 207 of lamps divided into concentric ring-shaped zones 201-203. Figure 2B is a view of the arrangement 207 of lamps using an angular perspective, showing the arrangement 207 of lamps divided into sectors 208 extending from the center 206 of the arrangement 207 of lamps.

[0026] Although in Figures 2A and 2B the plane 205 is circular, and other references to circular geometry, such as a radial perspective, may be used herein, this disclosure is not limited to circular geometries. For example, a "ring-shaped zone" used herein can refer to any structure in which an inner edge surrounds an interior area and an outer edge surrounds the inner edge. Although this interior area is shown as open area without lamps or other heating sources in some embodiments, this interior area may include lamps or other heating sources. Furthermore, a "sector" used herein refers to an area formed by a first leg extending from a center point to a first outer point and a second leg extending from the center point to a second outer point and a connecting portion between the first outer point and the second outer point. The connecting portion can include one or more segments that can be straight or curved.

[0027] The arrangement 207 of lamps includes the center 206 that can also be a center of the lamphead 200. The plane 205 over which the arrangement 207 of lamps is disposed can be substantially parallel to the substrate supporting surfaces 107 (see Figure 1) of the substrate locations 104. The linear lamps 210 can direct radiation towards substrates located on the substrate supporting surfaces 107 of the substrate locations 104. Examples of suitable lamps to be used as the linear lamps 210 can include tungsten-halogen lamps, mercury vapor lamps, and carbon filament infrared emitters.

[0028] Referring to Figure 2A, the arrangement 207 can be divided into the plurality of ring-shaped zones 201-203. Each ring-shaped zone 201-203 may include at least three linear lamps 210. Each linear lamp 210 can also be

referred to as an alignment of one lamp due to the linear extension of the linear lamp 210 from a first end 211 to a second end 212 as described below. Each ring-shaped zone 201-203 can be defined by an inner edge (e.g., 201_{IE}, 202_{IE}, 203_{IE}) and an outer edge (e.g., 201_{OE}, 202_{OE}, 203_{OE}). The ring-shaped zones 201-203 may be non-overlapping, where each ring-shaped zone either surrounds another ring-shaped zone and/or is surrounded by another ring-shaped zone. Furthermore, each ring-shaped zone 201-203 may contact one of the other ring-shaped zones. For example, the outer edge 201_{OE} of a first ring-shaped zone 201 may be the same as the inner edge 202_{IE} of a second ring-shaped zone 202.

[0029] Each ring-shaped zone 201-203 includes a plurality of linear lamps 210. Each linear lamp 210 includes a first end 211 and a second end 212. The first end 211 and the second end 212 for each linear lamp 210 can both be located within one ring-shaped zone, such as the first ring-shaped zone 201. Each linear lamp 210 located within a ring-shaped zone, such as the first ring-shaped zone 201, can be located at a different angular location relative to the center 206 of the arrangement 207. Furthermore, each linear lamp 210 located within a ring-shaped zone, such as the first ring-shaped zone 201, may be equidistant from the center 206 of the arrangement 207. For, example a center point 210C of each linear lamp 210 located within a ring-shaped zone 201-203, such as the first ring-shaped zone 201, may be equidistant from the center 206. Furthermore, in some embodiments, for each given linear lamp 210 located within a ring-shaped zone, such as the first ring-shaped zone 201, there may be an opposing linear lamp 210 positioned 180 degrees away from that given linear lamp 210 and aligned parallel to the given linear lamp 210. In other embodiments, no two linear lamps located within a ring-shaped zone are aligned parallel with each other.

[0030] Although Figure 2A shows that the arrangement 207 of lamps includes three ring-shaped zones 201-203, in some embodiments the plurality of ring-shaped zones can include from two to eleven ring-shaped zones, such as from three to seven ring-shaped zones. In some embodiments, the width

of each ring-shaped zone (i.e., the distance between the outer edge and the inner edge of the ring-shaped zone) can be the same, so that uniform spacing between linear lamps 210 in directions away from the center 206 can aid in temperature control of the process chambers that are symmetrical about the center of the process chamber. Furthermore, the distance between an outer edge (e.g., outer edge 201_{OE}) and an inner edge (e.g., inner edge 201_{IE}) of each ring-shaped zone (e.g., first ring-shaped zone 201) can be less than one third of the distance between the center 206 of the arrangement 207 and the outer edge (e.g., outer edge 203_{OE}) of an outermost ring-shaped zone (e.g., ring-shaped zone 203).

[0031] In some embodiments, each linear lamp 210 can extend at least 10 or at least 15 degrees around the center 206 of the arrangement 207 from the first end 211 to the second end 212 of that linear lamp 210. In other embodiments, each linear lamp 210 can extend at least 30 degrees around the center 206 of the arrangement 207 from the first end 211 to the second end 212 of the linear lamp 210.

[0032] A first end 211 of a first linear lamp 210_1 in the first ring-shaped zone 201 can be positioned at a same angular location 221 relative to the center 206 of the arrangement 207 as a first end 211 of a second linear lamp 210_2 in the second ring-shaped zone 202. In some embodiments, this pattern of having a linear lamp with a first end located at a same angular location can be repeated for every ring-shaped zone, or other patterns may be used, such as every other ring-shaped zone.

[0033] The arrangement 207 of lamps can further include a plurality of additional heat sources 250, such as a plurality of vertically oriented lamps 260 and/or a plurality of coherent radiation sources 270. Used herein, coherent radiation refers to a radiation source that emits radiation having a coherence length greater than a distance between the coherent radiation source 270 and the substrate support 102. The vertically oriented lamps 260 and the coherent radiation sources 270 can be used to finely tune the

temperature control (e.g., hot spots and cold spots) inside the process chamber 100. Each heat source 250, such as a vertically oriented lamp 260 and/or a coherent radiation source 270, may have asurface to emit radiation (e.g., a bulb for the vertically oriented lamp 260) that only extends a few degrees around the center 206, such as less than 10 degrees around the center 206, or less than 5 degrees around the center 206 as shown by the angular area 250A in Figure 2B. The vertically oriented lamp 260 and the coherent radiation source 270 are only two examples of additional heat sources 250 that can be added to the lamphead 200 to provide fine tuning of the temperature control in the process chamber 100, and other heat sources known in the field may be used as well.

[0034] A vertically oriented lamp 260 can be positioned at an angular location between each linear lamp 210 located within some or all of the ring-shaped zones 201-203, such as the first ring-shaped zone 201. Similarly, a coherent radiation source 270 can be positioned at an angular location between each linear lamp 210 located within some or all of the ring-shaped zones, such as the first ring-shaped zone 201. Although Figure 2A shows a vertically oriented lamp 260 and/or a coherent radiation source 270 between each linear lamp 210 in an angular direction, other arrangements are possible. For example, some arrangements may include two or more linear lamps, such as linear lamps 210, in a row in an angular direction or two or more vertically oriented lamps, such as vertically oriented lamps 260, in a row in an angular direction. Furthermore, in some embodiments, only vertically oriented lamps 260 or only coherent radiation sources 270 may be used. Additionally, in some embodiments only linear lamps 210 may be used.

[0035] The vertically oriented lamps 260 may have power connections at a first end pointed toward the top 116 of the chamber 100 (see Figure 1) and emitters extending to a second end pointed toward the processing surface 106 of the substrate support 102. Examples of suitable lamps to be used as the vertically oriented lamps 260 can include tungsten-halogen lamps, mercury vapor lamps, and carbon filament infrared emitters. Each vertically

oriented lamp 260 may be disposed in a reflective tube to maximize power delivery from each lamp. The coherent radiation sources 270 can be, for example, a laser source, such as laser diode arrays having power connections pointed towards the top 116 of the chamber 100 and emitters pointed toward the processing surface 106 of the substrate support 102. The power supplied to the vertically oriented lamps 260 and/or the coherent radiation sources 270 may be adjusted to finely tune temperatures in the chamber during processing. In some embodiments, different types or sizes of vertically oriented lamps and/or coherent radiation sources may be used at different locations in the lamphead 200. For example, longer or more powerful vertically oriented lamps may be used in the outer regions of the lamphead to account for increased heat loss that may occur in the outer areas of the process chamber.

[0036] Figure 2A shows the linear lamps 210 arranged in sets of three, where the first end 211 of each linear lamp 210 in the set is positioned at a same angular location (see e.g., angular location 221) at different distances from the center 206 of the arrangement 207. Similarly, Figure 2A shows the vertically oriented lamps 260 and the coherent radiation sources 270 arranged in sets of five, where each vertically oriented lamp 260 and each coherent radiation source 270 is centered along a same angular location. Other embodiments may be contemplated as well, such as embodiments in which the linear lamps 210 as well as the vertically oriented lamps 260 and the coherent radiation sources 270 in the different ring-shaped zones are staggered in an angular direction. For example, every linear lamp 210, vertically oriented lamp 260, and coherent radiation source 270 in the second ring-shaped zone 202 may be offset by 5 degrees from the corresponding linear lamp 210, vertically oriented lamp 260, and coherent radiation source 270 in the first ring-shaped zone 201. Furthermore, different numbers of lamps may be used in the sets, for example more or less than 3 linear lamps 210, and more or less than 5 members in the sets of vertically oriented lamps 260 and coherent radiation sources 270 may be used.

[0037] Referring to Figure 2B, the arrangement 207 can be divided into the plurality of sectors 208. Each sector 208 can be defined by a first leg extending from the center 206 of the arrangement 207 to a first outer point, a second leg extending from the center 206 of the arrangement 207 to a second outer point, and a connecting portion between the first outer point and the second outer point. For example, a first sector 208_1 can be defined by a first leg 208_{L1} extending from the center 206 to a first outer point 208_{P1}, a second leg 208_{L2} extending from the center 206 to a second outer point 208_{P2}, and a connecting portion 208_{C1} between the first outer point 208_{P1} and the second outer point 208_{P2}. Each sector 208 can cover a different angular area of the plane 205. For example, the first sector 208_1 covers an angular defined by the angle 208A. In some embodiments, each sector can span the same angular area, such as the area defined by angle 208_A. The first leg and the second leg of each sector 208 can contact or coincide with a first leg and second leg of other sectors 208, so that the total area of the plane 205 can be filled by the sectors 208. Furthermore, the vertically oriented lamps 260 and the coherent radiation sources 270 can be described as being positioned along a shared leg (e.g., first leg 208_{L1}) extending from the center 206 of the arrangement 207 between a first sector 208_1 and a second sector 208_2. Although Figure 2B shows that the arrangement 207 of lamps includes six sectors 208, in some embodiments the plurality of sectors can include from two to eleven sectors, such as from three to seven sectors.

[0038] As discussed above, each linear lamp 210 can extend at least 10 or at least 15 degrees around the center 206 of the arrangement 207 from the first end 211 to the second end 212 of that linear lamp 210. In other embodiments, each linear lamp 210 can extend at least 30 degrees around the center 206 of the arrangement 207 from the first end 211 to the second end 212 of the linear lamp 210. For example, in Figure 2A six linear lamps 210 are shown extending around the center 206 in each ring-shaped zone, so these linear lamps 210 would extend somewhat less than 60 degrees around

the center 206, such as at least 50 degrees due to the spaces between the linear lamps 210.

[0039] Each sector 208 can include a plurality of the linear lamps 210. The first end 211 and the second end 212 of each linear lamp 210 can both be located within one sector 208. Each linear lamp 210 located within a sector 208 can be disposed at a different distance from the center 206 of the arrangement 207. Furthermore, the first end 211 of each linear lamp 210 located within a sector 208 can be disposed at a same angular location as the first end 211 of the other linear lamps 210 located within the same sector 208.

[0040] In some embodiments, each sector 208 can overly a separate substrate location 104. Such a design may be useful when a substrate support does not rotate, so that the temperature of each substrate may be largely controlled by the linear lamps of a given sector. Although Figure 2B is shown with the sectors overlying different substrate support locations, this is only one potential design to be used with the lamp arrangements disclosed herein. For example, in some embodiments two or more sectors may overly one substrate location, or one sector may overly more than one substrate location. Furthermore, this arrangement of lamps also provides benefits for heating single-substrate process chambers. For single-substrate process chambers, the substrate may be placed in a central area of the substrate support and the linear lamps may overly this central area as well as the outer areas. In some embodiments to be used with single-substrate process chambers, the center of the lamphead may include an arrangement of closely packed vertically oriented lamps or closely packed coherent radiation sources. In other embodiments, an array of linear lamps may overly the central area of the substrate support.

[0041] Figure 2C is a side sectional view of one embodiment of the linear lamp 210 to be used in the arrangement 207 of lamps in Figures 2A and 2B. Each linear lamp 210 can include two or more filaments 213 between the first end 211 and the second end 212 of the linear lamp 210. A bulb 219 can

surround the two or more filaments 213. Each linear lamp 210 can also include two or more power supply terminals 216. Each filament 213 in the linear lamp 210 can be electrically connected to a different power supply terminal 216 of that linear lamp 210. Each filament 213 in the linear lamp 210 can further be connected to another terminal 217, such as a common ground or neutral terminal. Conversely, in some embodiments each filament may be connected to a common power supply terminal and a separate power terminal on the neutral or ground side of the electrical connection. Thus, each filament is connected to at least one separate power terminal (i.e., either a separate power supply terminal 216 or a separate ground or neutral side terminal 217). Referring to Figure 2A, each filament 213 in a linear lamp 210 can be located at a different angular location relative to the center 206 of the plane than the other filaments 213 in that linear lamp 210. Furthermore, each filament 213 in every linear lamp 210 located within a ring-shaped zone, such as the first ring-shaped zone 201, can be located at a different angular location relative to the center 206 than the one or more other filaments 213 of the linear lamps 210 located within the first ring-shaped zone. Connecting the filaments 213 to different power supply terminals allows individual control of the power supplied to the different filaments, which in turn allows separate temperature control of the different angular locations of the process volume 120 in the process chamber 100. In embodiments in which the substrate support does not rotate, the linear lamps 210 can allow separate temperature control over different angular locations of the substrates.

[0042] Figure 2C shows one example of a linear lamp 210 that may be used in the lamphead 200. Figure 2A shows that the linear lamps 210 in the different ring-shaped zones 201-203 have different lengths from the first end 211 to the second end 212 of these linear lamps 210. In some embodiments, the linear lamps 210 in the ring-shaped zones further from the center 206 of the arrangement 207 than the linear lamps 210 in the other ring-shaped zones closer to the center 206 include additional filaments. In other embodiments, the linear lamps in the ring-shaped zones further from the center 206 of the

arrangement 207 include the same number of filaments as the linear lamps in the ring-shaped zones closer to the center 206 of the arrangement 207. In such embodiments, the filaments in the linear lamps in the zones further from the center 206 of the arrangement 207 may be longer than the filaments in the linear lamps 210 closer to the center 206 of the arrangement 207. In still other embodiments, the lamps in each ring-shaped zone may have a same length from the first end 211 to the second end 212 of the linear lamp 210. In such embodiments, the ring-shaped zones further from the center 206 of the arrangement 207 may include more linear lamps 210 than the ring-shaped zones closer to the center 206 of the arrangement 207. Using one type and size of a linear lamp 210 for all of the ring-shaped zones can help reduce spare parts costs.

[0043] Figures 3A and 3B are top sectional plan views of a lamphead 300 including an arrangement 307 of lamps, according to a second embodiment. Figures 3A and 3B are essentially the same view of the arrangement 307 of lamps in the lamphead 300 taken from a different perspective. Both Figure 3A and 3B illustrate the arrangement 307 of lamps having a center 306 and including a plurality of vertically oriented lamps 360 disposed along a plane 305. Figure 3A is a view of the arrangement 307 of lamps in a radial perspective, showing the arrangement 307 of lamps divided into concentric ring-shaped zones 301-303. Figure 3B is a view of the arrangement 307 of lamps using an angular perspective, showing the arrangement 307 of lamps divided into sectors 308 extending from the center 306 of the arrangement 307 of lamps.

[0044] Although in Figures 3A and 3B the plane 305 is circular, and other references to circular geometry, such as a radial perspective, may be used herein, this disclosure is not limited to circular geometries. For example, a "ring-shaped zone" used herein can refer to any structure in which an inner edge surrounds an interior area and an outer edge surrounds the inner edge. Although this interior area is shown as open area without lamps or other

heating sources in some embodiments, this interior area may include lamps or other heating sources.

[0045] The arrangement 307 of lamps includes the center 306 that can also be a center of the lamphead 300. The plane 305 over which the arrangement 307 of lamps is disposed can be substantially parallel to the substrate supporting surfaces 107 (see Figure 1) of the substrate locations 104. The vertically oriented lamps 360 can direct radiation towards substrates located on the substrate supporting surfaces 107 of the substrate locations 104. Examples of suitable lamps to be used as the vertically oriented lamps 360 can include tungsten-halogen lamps, mercury vapor lamps, and carbon filament infrared emitters.

[0046] Referring to Figure 3A, the arrangement 307 can be divided into the plurality of ring-shaped zones 301-303. Each ring-shaped zone 301-303 may include at least three linear sets 340 of heat sources, such as vertically oriented lamps 360. Each linear set 340 including the three or more vertically oriented lamps 360 may be disposed along a line 343 extending from the first end 341 to the second end 342 of the linear set 340. Each linear set 340 may also be referred to as an alignment of lamps due to the linear extension of the linear set 340 from a first end 341 to a second end 342. The linear sets 340 are described as including vertically oriented lamps 360, but other heat sources may be used. Figure 3C provides additional detail of an example of vertically oriented lamps 360 that may be used in a linear set 340 of the lamphead 300. Each ring-shaped zone 301-303 can be defined by an inner edge (e.g., 301_{IE}, 302_{IE}, 303_{IE}) and an outer edge (e.g., 301_{OE}, 302_{OE}, 303_{OE}). The ring-shaped zones 301-303 may be non-overlapping, where each ring-shaped zone either surrounds another ring-shaped zone and/or is surrounded by another ring-shaped zone. Furthermore, each ring-shaped zone 301-303 may contact one of the other ring-shaped zones. For example, the outer edge 301_{OE} of a first ring-shaped zone 301 may be the same as the inner edge 302_{IE} of a second ring-shaped zone 302.

[0047] Each ring-shaped zone 301-303 includes a plurality of linear sets 340 of heat sources, such as vertically oriented lamps 360. Each linear set 340 may include, for example, from three to fifteen vertically oriented lamps 360, such as from five to eleven vertically oriented lamps 360. Each vertically oriented lamp 360 in a given linear set 340 is disposed linearly with respect to the other vertically oriented lamps 360 in that linear set 340. Each linear set 340 includes a first vertically oriented lamp 360_1 at a first end 341 of the linear set 340 and a last vertically oriented lamp 360_n at a second end 342 of the linear set 340. The first end 341 and the second end 342 for each linear set 340 can both be located within one ring-shaped zone, such as the first ring-shaped zone 301. Each linear set 340 located within a ring-shaped zone, such as the first ring-shaped zone 301, can be located at a different angular location relative to the center 306 of the arrangement 307. Furthermore, each linear set 340 located within a ring-shaped zone, such as the first ring-shaped zone 301, may be equidistant from the center 306 of the arrangement 307. For, example a center point 340C of each linear set 340 located within a ring-shaped zone 301-303, such as the first ring-shaped zone 301, may be equidistant from the center 306. Furthermore, in some embodiments, for each given linear set 340 located within a ring-shaped zone, such as the first ring-shaped zone 301, there may be an opposing linear set 340 positioned 180 degrees away from that given linear set 340 and aligned parallel to the given linear set 340. In other embodiments, no two linear sets located within a ring-shaped zone are aligned parallel with each other.

[0048] Although Figure 3A shows that the arrangement 307 of lamps includes three ring-shaped zones 301-303, in some embodiments the plurality of ring-shaped zones can include from two to eleven ring-shaped zones, such as from three to seven ring-shaped zones. In some embodiments, the width of each ring-shaped zone (i.e., the distance between the outer edge and the inner edge of the ring-shaped zone) can be the same, so that uniform spacing between linear sets 340 in directions away from the center 306 can aid in temperature control of the process chambers that are symmetrical about the

center of the process chamber. Furthermore, the distance between an outer edge (e.g., outer edge 301_{OE}) and an inner edge (e.g., inner edge 301_{IE}) of each ring-shaped zone (e.g., first ring-shaped zone 301) can be less than one third of the distance between the center 306 of the arrangement 307 and the outer edge (e.g., outer edge 303_{OE}) of an outermost ring-shaped zone (e.g., ring-shaped zone 303).

[0049] In some embodiments, each linear set 340 can extend at least 10 degrees or at least 15 degrees around the center 306 of the arrangement 307 from the first end 341 to the second end 342 of that linear set 340. In other embodiments, each linear set 340 can extend at least 30 degrees around the center 306 of the arrangement 307 from the first end 341 to the second end 342 of the linear set 340. For example, in Figure 3A six linear sets 340 are shown extending around the center 306 in each ring-shaped zone, so these linear sets 340 would extend somewhat less than 60 degrees around the center 306, such as at least 50 degrees due to the spaces between the linear sets 340.

[0050] A first end 341 of a first linear set 340_1 in the first ring-shaped zone 301 can be positioned at a same angular location 321 relative to the center 306 of the arrangement 307 as a first end 341 of a second linear set 340_2 in the second ring-shaped zone 302. In some embodiments, this pattern of having a linear set with a first end located at a same angular location can be repeated for every ring-shaped zone, or other patterns may be used, such as every other ring-shaped zone.

[0051] The arrangement 307 of lamps can further include a plurality of additional heat sources 350, such as different types or differently sized vertically oriented lamps 375 and/or a plurality of coherent radiation sources 370. The vertically oriented lamps 375 and the coherent radiation sources 370 can be used to finely tune the temperature control (e.g., hot spots and cold spots) inside the process chamber 100. Each heat source 350, such as a vertically oriented lamp 375 and/or a coherent radiation source 370, may

have a surface to emit radiation (e.g., a bulb for the vertically oriented lamp 375) that only extends a few degrees around the center 306, such as less than 10 degrees around the center 306, or less than 5 degrees around the center 306 as shown by the angular area 350A in Figure 3B. The vertically oriented lamp 375 and the coherent radiation source 370 are only two examples of additional heat sources 350 that can be added to the lamphead 300 to provide fine tuning of the temperature control in the process chamber 100, and other heat sources known in the field may be used as well.

[0052] An additional heat source 350, such as a vertically oriented lamp 375 can be positioned at an angular location between each linear set 340 located within some or all of the ring-shaped zones 301-303, such as the first ring-shaped zone 301. Similarly, a coherent radiation source 370 can be positioned at an angular location between each linear set 340 located within some or all of the ring-shaped zones, such as the first ring-shaped zone 301. Although Figure 3A shows a vertically oriented lamp 375 and/or a coherent radiation source 370 between each linear set 340 in an angular direction, other arrangements are possible. For example, some arrangements may include two or more linear sets 340, in a row in an angular direction or two or more additional heat sources 350, such as coherent radiation sources 370, in a row in an angular direction. Furthermore, in some embodiments, only vertically oriented lamps 375 or only coherent radiation sources 370 may be used as the additional heat sources. Additionally, in some embodiments only linear sets 340 may be used without any additional heat sources 350. The coherent radiation sources 370 and the vertically oriented lamps 375 may be the same as the coherent radiation sources 270 and the vertically oriented lamps 260, respectively, described above and further detail on these additional heat sources 350 is not repeated here.

[0053] Figure 3A shows the linear sets 340 arranged in groups of three, where the first end 341 of each linear set 340 in the group is positioned at a same angular location (see e.g., angular location 321) at different distances from the center 306 of the arrangement 307. Similarly, Figure 3A shows the

vertically oriented lamps 375 and the coherent radiation sources 370 arranged in sets of five, where each vertically oriented lamp 375 and each coherent radiation source 370 is centered along a same angular location. Other embodiments may be contemplated as well, such as embodiments in which the linear sets 340 as well as the vertically oriented lamps 375 and the coherent radiation sources 370 in the different ring-shaped zones are staggered in an angular direction. For example, every linear set 340, vertically oriented lamp 375, and coherent radiation source 370 in the second ring-shaped zone 302 may be offset by 5 degrees from the corresponding linear set 340, vertically oriented lamp 375, and coherent radiation source 370 in the first ring-shaped zone 301. Furthermore, different numbers of lamps may be used in the groups, for example more or less than 3 linear sets 340, and more or less than 5 members in the sets of vertically oriented lamps 375 and coherent radiation sources 370 may be used.

[0054] Referring to Figure 3B, the arrangement 307 can be divided into the plurality of sectors 308. Each sector 308 can be defined by a first leg extending from the center 306 of the arrangement 307 to a first outer point, a second leg extending from the center 306 of the arrangement 307 to a second outer point, and a connecting portion between the first outer point and the second outer point. For example, a first sector 308_1 can be defined by a first leg 308_{L1} extending from the center 306 to a first outer point 308_{P1}, a second leg 308_{L2} extending from the center 306 to a second outer point 308_{P2}, and a connecting portion 308_{C1} between the first outer point 308_{P1} and the second outer point 308_{P2}. Each sector 308 can cover a different angular area of the plane 305. For example, the first sector 308_1 covers an angular defined by the angle 308A. In some embodiments, each sector can span the same angular area, such as the area defined by angle 308_A. The first leg and the second leg of each sector 308 can contact or coincide with a first leg and second leg of other sectors 308, so that the total area of the plane 305 can be filled by the sectors 308. Furthermore, the vertically oriented lamps 375 and the coherent radiation sources 370 can be described as being positioned

along a shared leg (e.g., first leg 308_{L1}) extending from the center 306 of the arrangement 307 between a first sector 308_1 and a second sector 308_2. Although Figure 3B shows that the arrangement 307 of lamps includes six sectors 308, in some embodiments the plurality of sectors can include from two to eleven sectors, such as from three to seven sectors.

[0055] As discussed above, each linear set 340 can extend at least 10 or at least 15 degrees around the center 306 of the arrangement 307 from the first end 341 to the second end 342 of that linear lamp 210. In other embodiments, each linear set 340 can extend at least 30 degrees around the center 306 of the arrangement 307 from the first end 341 to the second end 342 of the linear set 340.

[0056] Each sector 308 can include a plurality of the linear sets 340 of heat sources, such as vertically oriented lamps 360. The first end 341 and the second end 342 of each linear set 340 can both be located within one sector 308. Each linear set 340 located within a sector 308 can be disposed at a different distance from the center 306 of the arrangement 307. Furthermore, the first end 341 of each linear set 340 located within a sector 308 can be disposed at a same angular location as the first end 341 of the other linear sets 340 located within the same sector 308.

[0057] In some embodiments, each sector 308 can overlay a separate substrate location 104. Such a design may be useful when a substrate support does not rotate, so that the temperature of each substrate may be largely controlled by the linear sets of a given sector. Although Figure 3B is shown with the sectors overlying different substrate support locations, the embodiment of Figure 3B is only one potential design to be used with the lamp arrangements disclosed herein. For example, in some embodiments two or more sectors may overly one substrate location, or one sector may overly more than one substrate location. Furthermore, this arrangement of lamps also provides benefits for heating single-substrate process chambers. For single-substrate process chambers, the substrate may be placed in a

central area of the substrate support and the linear sets may overly this central area as well as the outer areas. In some embodiments to be used with single-substrate process chambers, the center of the lamphead may include an arrangement of closely packed vertically oriented lamps or closely packed coherent radiation sources. In other embodiments, an array of linear sets of heat sources, such as vertically oriented lamps, may overly the central area of the substrate support.

[0058] Figure 3C is a side sectional view of one embodiment of a vertically oriented lamp 360 to be used in the linear sets 340 in the arrangement 307 of lamps in Figures 3A and 3B. Each vertically oriented lamp 360 can include one or more filaments 363 located in a bulb 369. Each vertically oriented lamp can include a base 364. Each vertically oriented lamp can also include a bulb 369 extending from a first end located at the base 364 to a second end 362 located at an edge of the bulb 369 opposing the base 364. The base 364 may be mounted to a housing 309 of the lamphead 300. Each vertically oriented lamp 360 can also include a power supply terminal 366 and another terminal 367, such as a common ground or neutral terminal. Terminals 366, 367 may be located in the base 364, and may connect to an electrical circuit to power the vertically oriented lamps 360. Each vertically oriented lamp 360 may be connected to a different circuit. In some embodiments, each vertically oriented lamp 360 may be connected a common electrical circuit. Other electrical configurations are also possible, such as every two or three vertically oriented lamps being connected to a common electrical circuit.

[0059] Each vertically oriented lamp 360 may be disposed in a reflective tube 380. Each reflective tube 380 may include one or more side walls 382. A base 383 of each reflective tube 380 may also be formed of a reflective material. Reflective materials that may be used for the one or more side walls 382 and the base 383 include gold, silver, or other metals, and dielectric reflectors. The reflective tubes 380 can be used to prevent the vertically oriented lamps 360 from interfering with each other and enhance the ability of

each vertically oriented lamp 360 to control a temperature of a particular region of the process chamber 100 shown in Figure 1.

[0060] Referring to Figure 3A, each vertically oriented lamp 360 in a linear set 340 can be located at a different angular location relative to the center 306 of the arrangement 307 than the other vertically oriented lamps 360 in that linear set 340. Furthermore, each vertically oriented lamp 360 in every linear set 340 located within a ring-shaped zone, such as the first ring-shaped zone 301, can be located at a different angular location relative to the center 306 than the one or more other vertically oriented lamp 360 of the linear sets 340 located within the first ring-shaped zone 301. Each vertically oriented lamp 360 in a linear set 340 may be connected to a different power supply circuit to allow individual control of the power supplied each vertically oriented lamp 360, which in turn allows separate temperature control of the different angular locations of the process volume 120 in the process chamber 100. In embodiments in which the substrate support does not rotate, the vertically oriented lamps 360 having separate power supply circuits can allow separate temperature control over different angular locations of the substrates.

[0061] Figure 3C shows one example of a vertically oriented lamp 360 that may be used in the lamphead 300. Figure 3A shows that the linear sets 340 in the different ring-shaped zones 301-303 have different lengths from the first end 341 to the second end 342 due to the linear sets 340 in outer zones, such as ring-shaped zone 303, including more vertically oriented lamps 360, than linear sets 340 in inner zones, such as ring-shaped zone 301. However, in other embodiments, the linear sets in the ring-shaped zones further from the center 306 of the arrangement 307 may include the same number of vertically oriented lamps 360 as the linear sets in the ring-shaped zones closer to the center 306 of the arrangement 307. In such embodiments, the ring-shaped zones further from the center 306 of the arrangement 307 may include more linear sets 340 than the ring-shaped zones closer to the center 306 of the arrangement 307.

[0062] The embodiments described herein illustrate lamp arrangements for use in process chambers that can substantially reduce manufacturing costs as well as maintenance costs for the lamphead. The cost savings is achieved by reducing the number of lamps needed in the lamphead. Less lamps require less wiring and less time to mount in the lamphead. Furthermore, less lamps will result in less frequent replacement of lamps resulting in less downtime and maintenance. For example, some lampheads for process chambers include over 400 lamps or even greater than 1,000 lamps. Lamps eventually fail, so operating a process chamber with over 400 lamps will likely require replacing thousands of lamps over the useful life of the lamphead. In many of the embodiments described above, the number of lamps can be maintained below 100 lamps.

[0063] Despite the cost savings, the lamp arrangements disclosed here can provide precise temperature control of different areas of the process chamber during processing. Previously used lampheads that included less than 100 lamps generally only provided radial temperature control while azimuthal temperature control was lacking. Conversely, the embodiments disclosed herein provide radial temperature control as well as azimuthal temperature control. For example, the linear lamps described above in reference to Figures 2A-2C or the linear sets of lamps described above in reference to Figures 3A-3C can be arranged in ring-shaped zones to provide radial temperature control. Furthermore, the linear lamps and the linear sets of lamps can be arranged in sectors to provide azimuthal temperature control. Additionally, some embodiments of the linear lamps described above can include multiple filaments, where each filament is individually powered and positioned at a different angular location in the lamphead, further improving the ability to azimuthally control the temperature in the process chamber. For the embodiment shown in Figures 3A-3C, each vertically oriented lamp 360 can be individually powered and positioned at a different angular location in the lamphead to improve the ability to azimuthally control the temperature in the process chamber. Furthermore, using other heat sources, such as

vertically oriented lamps and/or coherent radiation sources, between the linear lamps or the linear sets of lamps can further improve the temperature control in the process chamber. Moreover, as shown in Figure 1, some embodiments can include one of the lampheads 200 or 300 above the substrate support as well as one of the lampheads 200 or 300 below the substrate support to have temperature control ability from either side of the substrate support.

[0064] 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, and the scope thereof is determined by the claims that follow.

Claims:

1. A process chamber, comprising:

a top, a bottom, and a sidewall coupled together to define a volume;

a substrate support disposed in the volume; and

one or more lampheads facing the substrate support, each lamphead comprising an arrangement of lamps disposed along a plane, wherein the arrangement of lamps is defined by a center and a plurality of concentric ring-shaped zones about the center, each ring-shaped zone defined by an inner edge and an outer edge and each ring-shaped zone comprising three or more alignments of one or more lamps, wherein:

each alignment of one or more lamps comprises a first end extending linearly to a second end

the first end and the second end are separated by at least 10 degrees around the center;

the first end and the second end are both located within one ring-shaped zone; and

each alignment located within a same ring-shaped zone is equidistant to the center.

2. The process chamber of claim 1, wherein each alignment includes a linear lamp extending from the first end to the second end, each linear lamp having two or more filaments between the first end and the second end.

3. The process chamber of claim 2, wherein each filament in every linear lamp located within a first ring-shaped zone is located at a different angular location relative to the center than the one or more other filaments of the linear lamps located within the first ring-shaped zone.

4. The process chamber of claim 3, wherein each linear lamp includes three or more power terminals and each filament in each linear lamp is electrically connected to at least one different power terminal than the other filaments in that linear lamp.

5. The process chamber of claim 2, wherein each linear lamp extends at least 15 degrees around the center from the first end to the second end.

6. The process chamber of claim 2, wherein each linear lamp extends at least 30 degrees around the center from the first end to the second end.

7. The process chamber of claim 2, wherein the plurality of ring-shaped zones comprises from three to seven ring-shaped zones.

8. The process chamber of claim 2, wherein a first end of a first linear lamp in a first ring-shaped zone is positioned at a same angular location relative to the center as a first end of a second linear lamp in a second ring-shaped zone.

9. The process chamber of claim 2, further comprising:

a heat source positioned at an angular location between each linear lamp of a first ring-shaped zone, wherein a surface to emit radiation of each heat source extends less than 5 degrees around the center; and

a coherent radiation source positioned at an angular location between each linear lamp of a first ring-shaped zone.

10. The process chamber of claim 1, wherein each alignment includes three or more vertically oriented lamps disposed along a line extending from the first end to the second end, wherein each vertically oriented lamp includes a base and a bulb extending from the base towards the substrate support.

11. A process chamber, comprising:

a top, a bottom, and a sidewall coupled together to define a volume;

a substrate support disposed in the volume; and

a lamphead facing the substrate support, the lamphead comprising an arrangement of lamps disposed along a plane, wherein the arrangement of lamps is defined by a center and three or more sectors, each sector defined by a first leg

extending from the center to a first outer point, a second leg extending from the center to a second outer point, and a connecting portion between the first outer point and the second outer point, each sector comprising a plurality of linear lamps, wherein:

each linear lamp comprises a first end and a second end that are separated by at least 10 degrees around the center,

the first end and the second of each linear lamp are both located within one sector; and

each linear lamp of a sector is located at a different distance from the center.

12. The process chamber of claim 11, wherein each linear lamp further comprises two or more filaments between the first end and second end.

13. The process chamber of claim 12, wherein each filament in a first linear lamp is located at a different angular location relative to the center than the one or more other filaments in the first linear lamp.

14. The process chamber of claim 11, further comprising a plurality of coherent radiation sources positioned along a shared leg between a first sector and a second sector.

15. A process chamber, comprising:

a top, a bottom, and a sidewall coupled together to define a volume;

a substrate support disposed in the volume, the substrate support having a plurality of substrate locations distributed around a central location of the substrate support, each substrate location having a substrate supporting surface; and

a lamphead facing the substrate support, the lamphead comprising an arrangement of lamps disposed along a plane that is substantially parallel to the substrate supporting surfaces of the substrate locations, wherein the arrangement is defined by a center, from three to seven ring-shaped zones, and from three to seven sectors overlapping the from three to seven ring-shaped zones, wherein:

each ring-shaped zone is concentric with the center and each ring-shaped zone is defined by an inner edge and an outer edge;

each sector is defined by a first leg extending from the center to a first outer point, a second leg extending from the center to a second outer point, and a connecting portion between the first outer point and the second outer point;

each linear lamp comprises a first end and a second end that are both located within one ring-shaped zone and one sector; and

each linear lamp extends at least 30 degrees around the center of the plane.

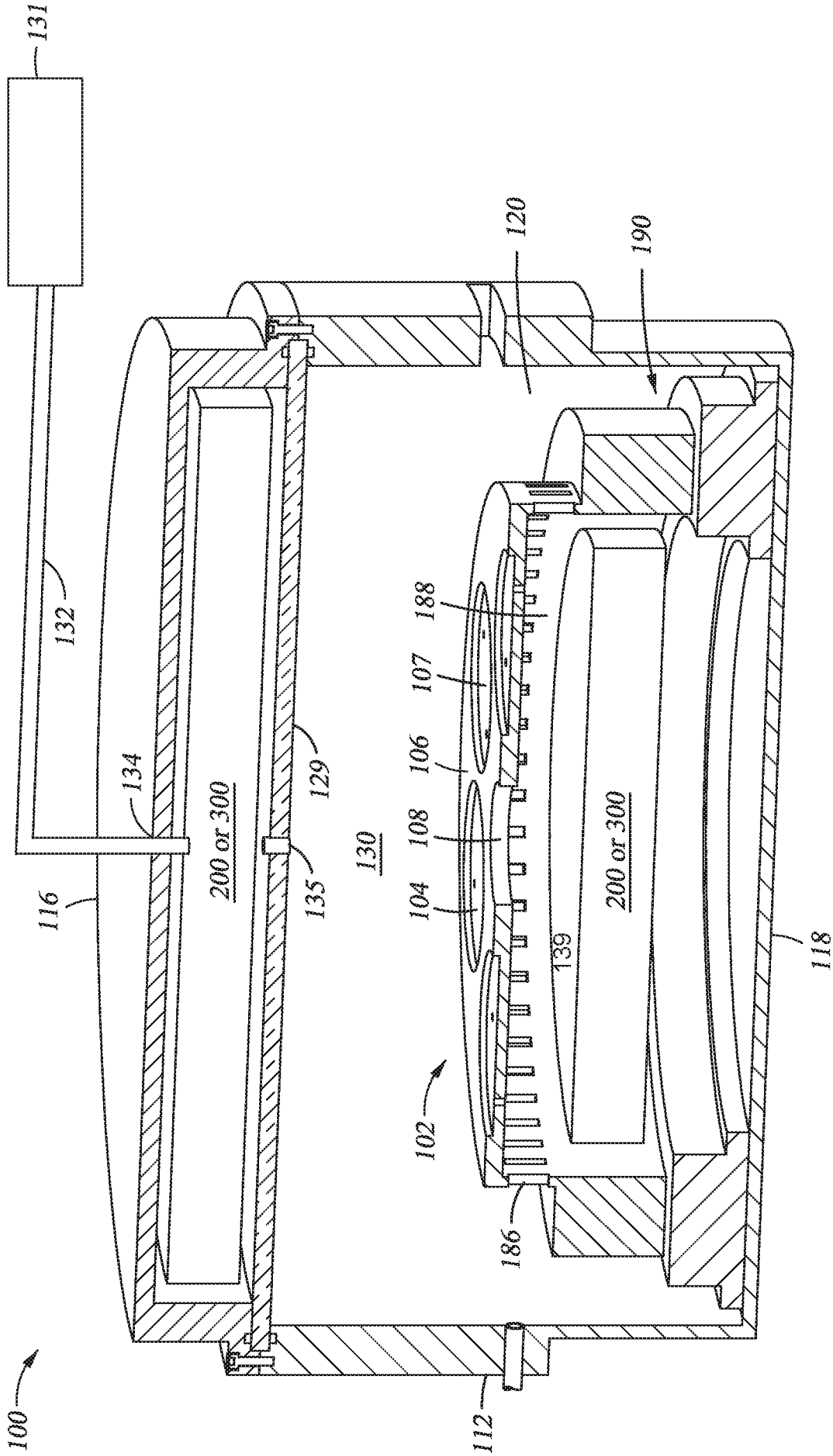

131
120
190
132
188
107
106
134
129
108
200 or 300
130
135
104
116
200 or 300
139
118
102
186
100
112

Fig. 1

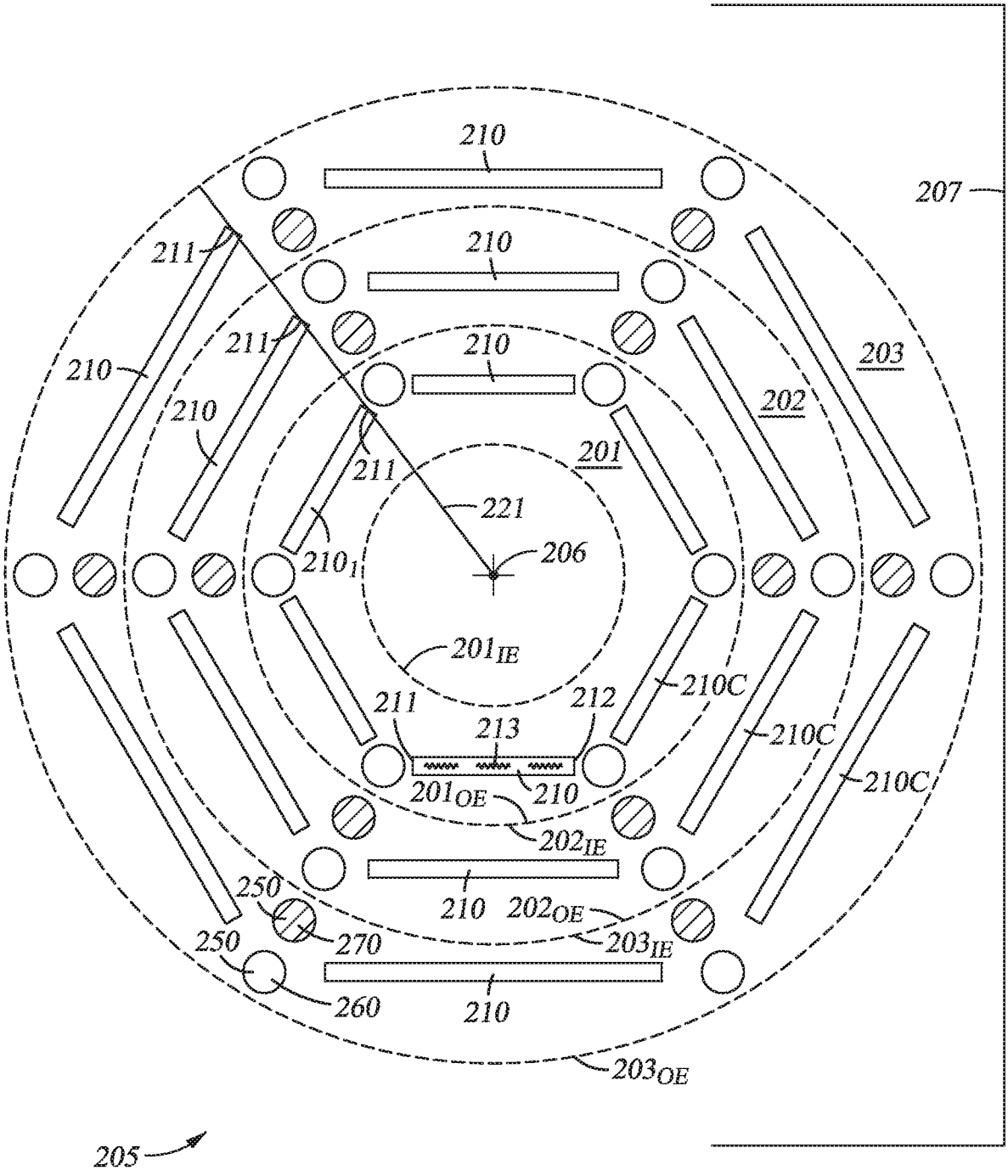

210
207
211
210
211
210
203
210
202
210
201
211
221
206
210I
201IE
211
212
210C
213
210C
201OE
210
210C
202IE
250
210
202OE
270
203IE
250
260
210
203OE
205

Fig. 2A

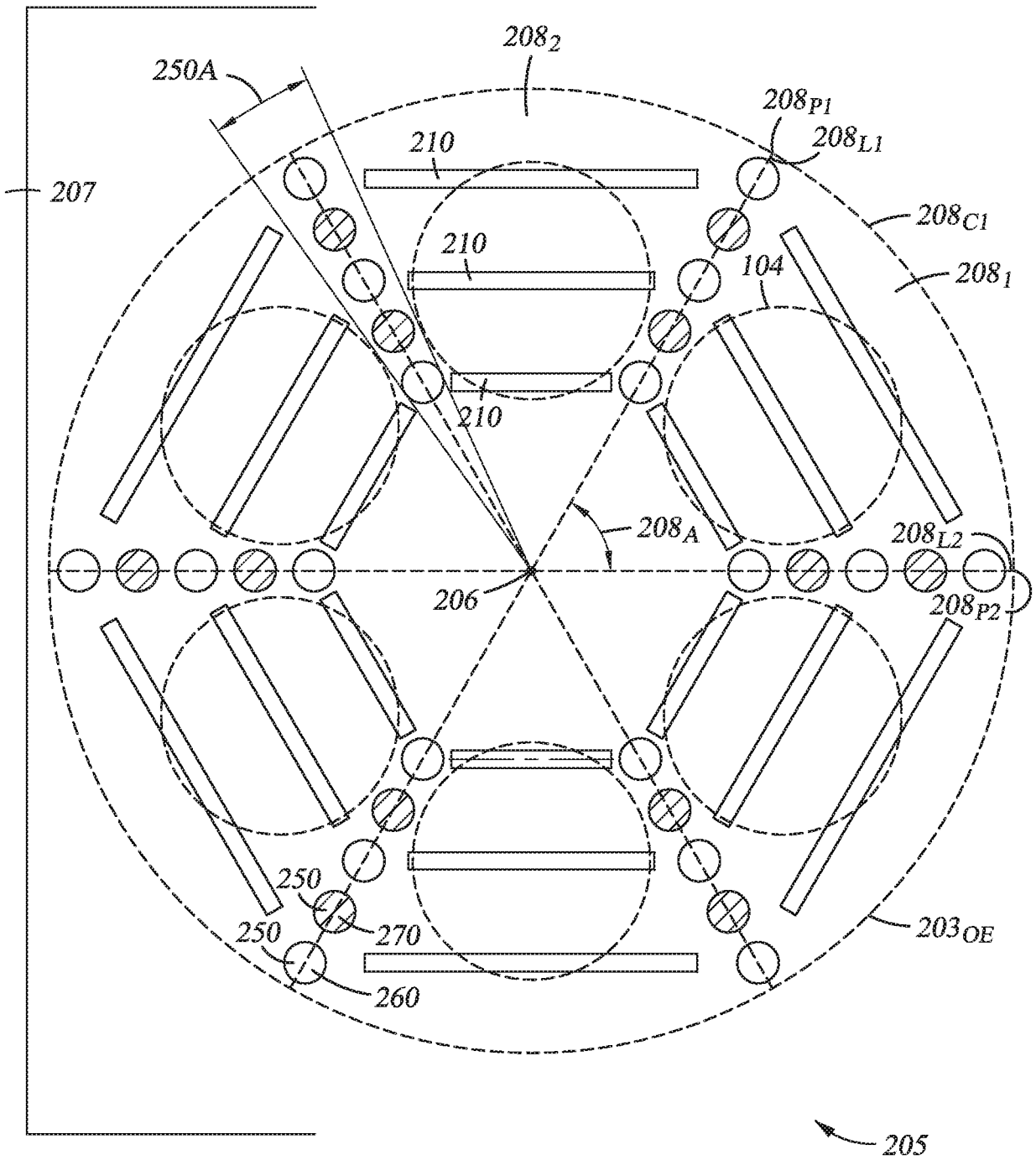

208_2
250A
208_{P1}
208_{L1}
210
207
208_{C1}
210
104
208_1
210
208_A
208_{L2}
206
208_{P2}
250
250
270
260
203_{OE}
205

Fig. 2B

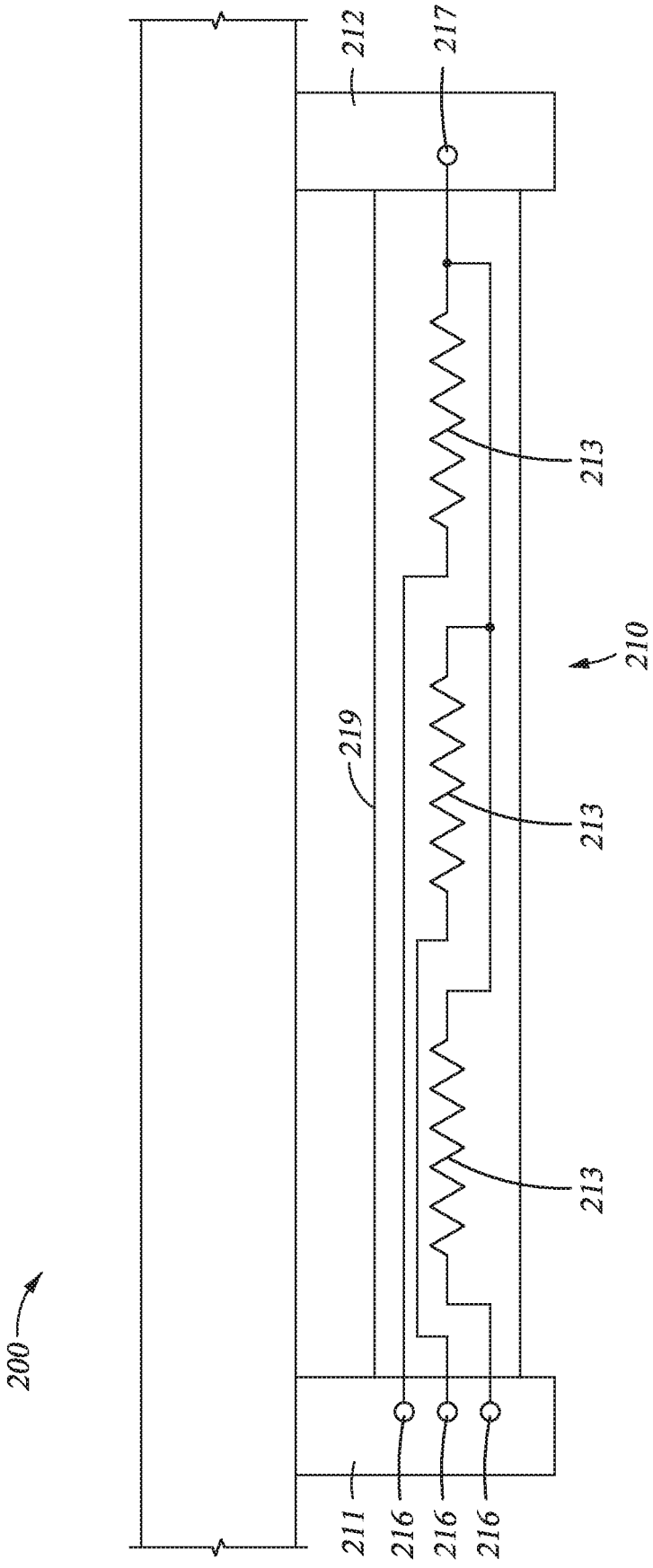


Fig. 2C

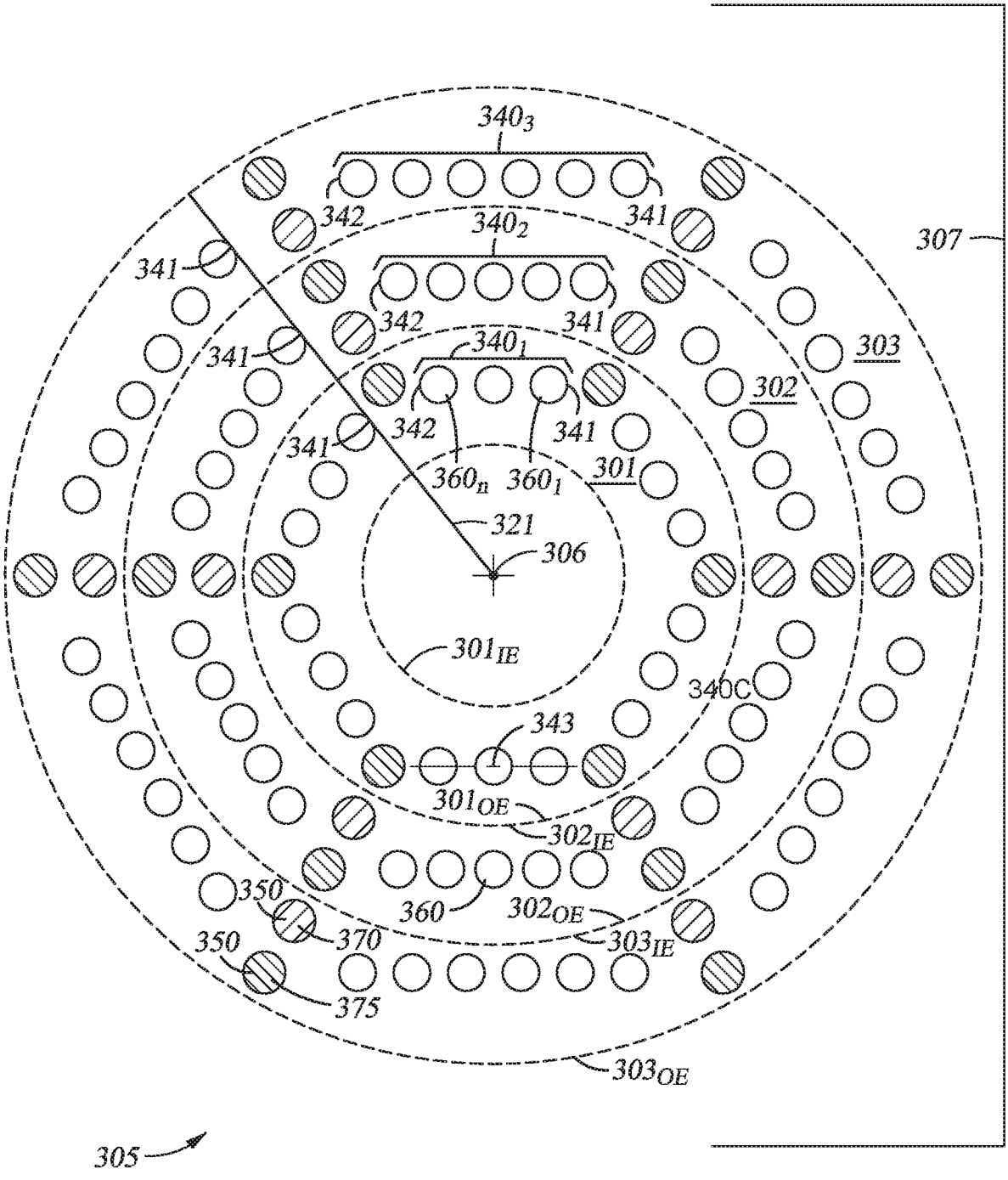

340$_3$
342
341
340$_2$
307
341
342
341
303
341
340$_1$
302
342
341
341
360$_n$
360$_1$
301
321
306
301$_{IE}$
340C
343
301$_{OE}$
302$_{IE}$
350
360
302$_{OE}$
370
303$_{IE}$
350
375
303$_{OE}$
305

Fig. 3A

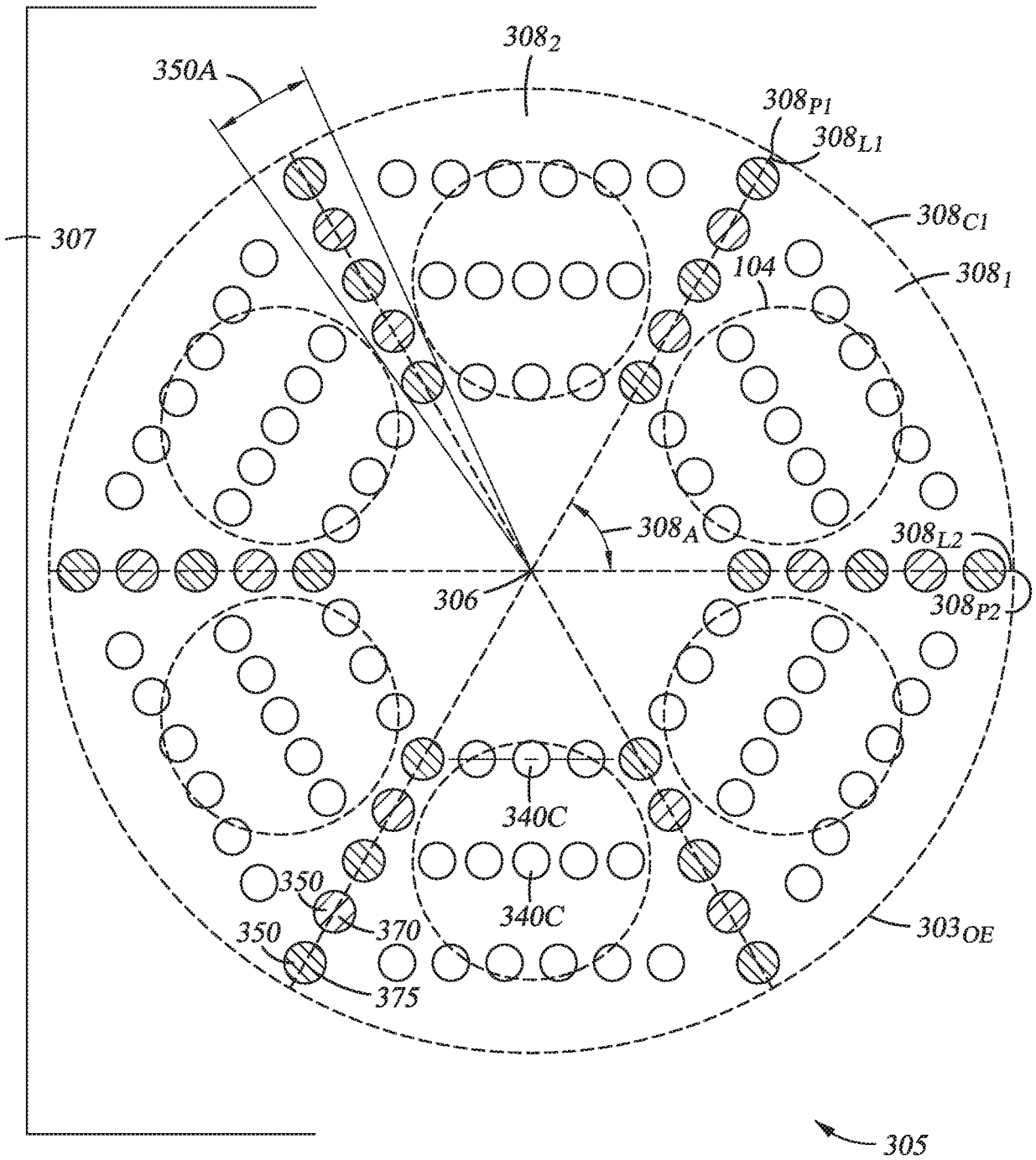

308_2
350A
308_{P1}
308_{L1}
308_{C1}
307
104
308_1
308_A
308_{L2}
306
308_{P2}
340C
340C
350
350
370
375
303_{OE}
305

Fig. 3B

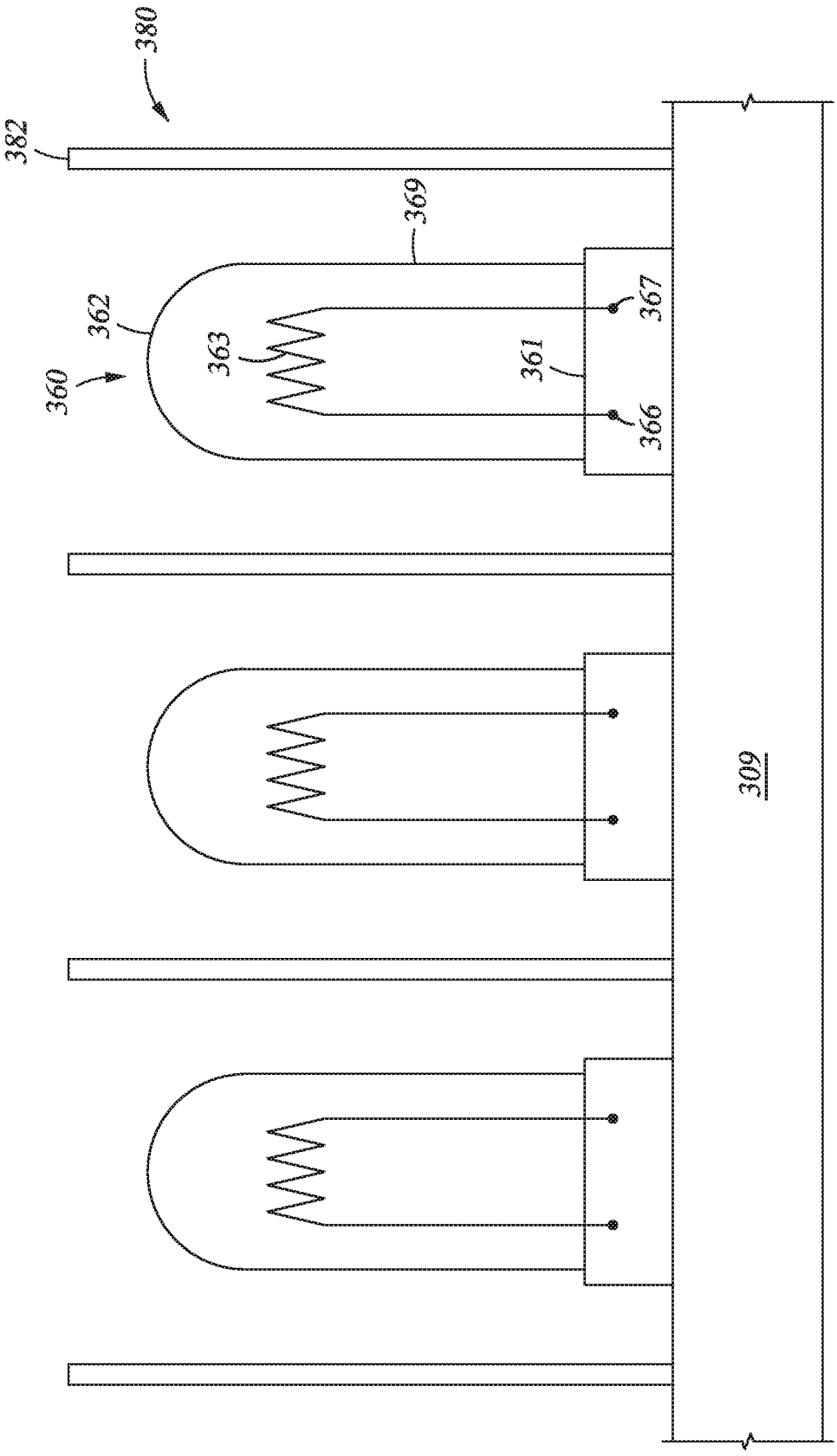


Fig. 3C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/012066

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/324(2006.01)i, H01L 21/67(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 21/324; F27D 11/00; G01R 31/26; H01L 21/205; H01L 21/26; F27B 5/14; H01L 21/66; H01L 21/683; H01L 21/67

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: chamber, linear lamp, heat, substrate

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2014-172174 A1 (APPLIED MATERIALS INC.) 23 October 2014 See paragraphs [0029]-[0057] and figures 1, 9.	1,10
Y		2-9,11-15
Y	JP 2003-059853 A (TOKYO ELECTRON LTD.) 28 February 2003 See paragraph [0052] and figure 4.	2-9,12-13
Y	US 2010-0018960 A1 (ARNON GAT et al.) 28 January 2010 See paragraph [0065] and figure 2.	9,14
Y	KR 10-1458963 B1 (JUNG EUN MIN) 12 November 2014 See paragraphs [0103]-[0104] and figures 10a-10b.	11-15
A	US 2007-0238202 A1 (JOSEPH MICHAEL RANISH et al.) 11 October 2007 See paragraphs [0039]-[0044] and figures 3-10.	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 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
27 April 2016 (27.04.2016)	**27 April 2016 (27.04.2016)**

Name and mailing address of the ISA/KR
International Application Division
Korean Intellectual Property Office
189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea
Facsimile No. +82-42-481-8578

Authorized officer
LEE, Myung Jin
Telephone No. +82-42-481-8474

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2016/012066

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2014-172174 A1	23/10/2014	KR 10-2015-0143700 A	23/12/2015
		TW 201502314 A	16/01/2015
JP 2003-059853 A	28/02/2003	None	
US 2010-0018960 A1	28/01/2010	AU 2000-22246 A1	24/07/2000
		EP 1141999 A1	10/10/2001
		JP 2002-534803 A	15/10/2002
		TW 504728 A	01/10/2002
		US 2002-0017618 A1	14/02/2002
		US 2005-0008351 A1	13/01/2005
		US 2006-0201927 A1	14/09/2006
		US 6717158 B1	06/04/2004
		US 6771895 B2	03/08/2004
		US 7038174 B2	02/05/2006
		US 7608802 B2	27/10/2009
		US 8138451 B2	20/03/2012
		WO 00-041223 A1	13/07/2000
KR 10-1458963 B1	12/11/2014	None	
US 2007-0238202 A1	11/10/2007	CN 101495847 A	29/07/2009
		EP 2005134 A2	24/12/2008
		JP 2009-532877 A	10/09/2009
		KR 10-1019932 B1	08/03/2011
		KR 10-2008-0113086 A	26/12/2008
		TW I387007 B	21/02/2013
		US 7398693 B2	15/07/2008
		WO 2007-114987 A2	11/10/2007
		WO 2007-114987 A3	23/10/2008