

(51) International Patent Classification:
H01L 21/205 (2006.01) *C23C 16/455* (2006.01)(21) International Application Number:
PCT/US2011/061596(22) International Filing Date:
21 November 2011 (21.11.2011)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
61/416,044 22 November 2010 (22.11.2010) US
61/511,820 26 July 2011 (26.07.2011) US
61/514,458 2 August 2011 (02.08.2011) US(71) Applicant (for all designated States except US): **APPLIED MATERIALS, INC.** [US/US]; 3050 Bowers Avenue, Santa Clara, California 95054 (US).

(72) Inventors; and

(75) Inventors/Applicants (for US only): **NGUYEN, Tuan, Anh** [CA/US]; 3559 Agate Drive, Santa Clara, California 94051 (US). **QUACH, David, H.** [US/US]; 1205 Swinging Gate Court, San Jose, California 95120 (US). **SHEN, Kuan-Chien** [US/US]; 4440 Bassett Street, # 5, Santa Clara, California 95005 (US). **DUBOUST, Alain** [US/US]; 803 Goldenrod Court, Sunnyvale, California 94086 (US). **KOJIRI, Hidehiro** [JP/US]; 730 E. Evelyn Avenue, # 231, Sunnyvale, California 94086 (US). **HSU, Wei-Yung** [US/US]; 5915 Friar Way, San Jose, California 95129 (US).(74) Agents: **PATTERSON, Todd, B.** et al.; Patterson & Sheridan, L.L.P., 3040 Post Oak Blvd., Suite 1500, Houston, Texas 77056-6582 (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, 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, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, 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, MD, 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, ML, MR, NE, SN, TD, TG).

Published:

— without international search report and to be republished upon receipt of that report (Rule 48.2(g))

(54) Title: INTERCHANGEABLE PUMPING RINGS TO CONTROL PATH OF PROCESS GAS FLOW

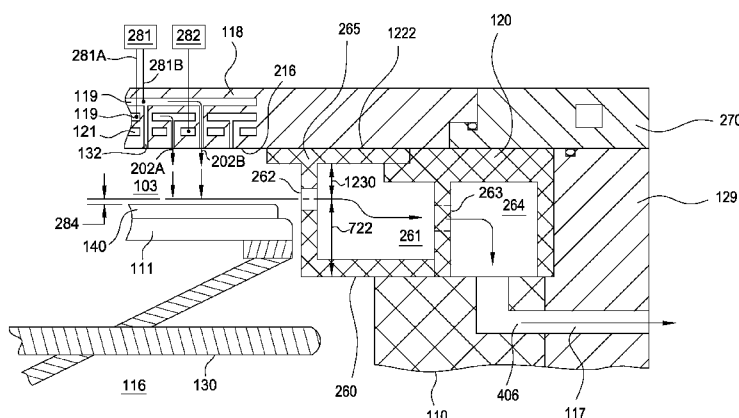


FIG. 2C

(57) Abstract: Apparatus and methods for forming metal nitride films using a processing chamber are provided. The method comprises loading multiple substrates onto a substrate support assembly of the processing chamber, wherein the substrate support is in a loading position during the loading multiple substrates and moving the substrate support from the loading position upwards to a processing position, wherein the multiple substrates are positioned above a first opening for exhausting process gases from the processing chamber, and flowing process gases comprising a metal containing precursor and a nitrogen containing precursor perpendicular to the surfaces of the multiple substrates to form a metal nitride film on the multiple substrates, wherein after contacting the surfaces of the multiple substrates, the process gases flow across the surfaces of the multiple substrates and down toward the first opening.



INTERCHANGEABLE PUMPING RINGS TO CONTROL PATH OF PROCESS GAS FLOW

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to methods and apparatus for uniformly heating substrates during high temperature deposition processing.

Description of the Related Art

[0002] Advancements in reliably and consistently forming compound semiconductor layers (e.g., gallium nitride or gallium arsenide layers) that have uniform properties holds much promise for a wide range of applications in the electronics field (e.g., high frequency, high power devices and circuits) and the optoelectronics field (e.g., lasers, light-emitting diodes and solid state lighting). Generally, compound semiconductors are formed by high temperature thermal processes, such as heteroepitaxial growth on a substrate material. The thermal uniformity across the substrate during processing is important, since the epitaxial layer composition, and thus LED emission wavelength and output intensity, are a strong function of the surface temperature of the substrate. Moreover, since the compound semiconductor deposition and thermal processing temperatures are often in excess of 800 degrees Celsius, the control of the temperature in the processing chamber becomes much more difficult due to the difference in temperature between the heated substrate(s) and the much cooler processing chamber boundaries or walls. The processing chamber boundaries, or walls, are often maintained at temperatures less than about 200 degrees Celsius to reliably provide a sealed processing region and for human safety reasons.

[0003] Due to the often long processing times (e.g., 1 - 24 hours) commonly required to form the compound semiconductor layers used in an LED devices, it is often desirable to process substrates in batches of two or more substrates at a time. During batch processing, the substrates are positioned on a supporting

structure that is used to support and retain the substrates. However, the ability to control the temperature and gas flow uniformity across a substrate from substrate to substrate, and within each substrate, becomes much more difficult in batch configurations. The center to edge temperature and gas flow variations commonly found in conventional processing chambers, due to the presence of the cooler processing chamber boundaries near the heated substrates, are generally too high to meet the current process yield goals. Variations in the substrate surface temperature will affect the formation rate of the formed compound semiconductor layer(s) causing them to be non-uniform across the substrate surface. In extreme cases, the substrate can bow enough to crack or break, thus damaging or ruining the compound semiconductor layers grown thereon.

[0004] Therefore, there is a need for apparatuses and methods that can provide a more uniform gas flow across all of the substrates disposed in a batch processing chamber.

SUMMARY OF THE INVENTION

[0005] Embodiments of the present invention generally relate to methods and apparatus for uniformly heating substrates during high temperature processing. In one embodiment, an apparatus for processing a substrate is provided. The apparatus comprises a processing chamber body that encloses a processing region, a support assembly defining a lower edge of the processing region, and having an outer edge and an inner region for supporting a substrate carrier, a showerhead assembly disposed over the support assembly and defining an upper edge of the processing region, and an exhaust port formed in the processing chamber body, wherein the support assembly is disposed between the showerhead assembly and the exhaust channel.

[0006] In another embodiment of the present invention a support shaft, comprising a shaft region having an upper region, a middle region and a lower region and three or more arms that are coupled to the upper region, wherein the three or more arms are in a spaced apart relationship to each other, wherein the

middle region has a diameter that is larger than a diameter of the upper or lower regions is provided.

[0007] In yet another embodiment of the present invention a substrate carrier, comprising a body configured to provide structure support to one or more substrates, wherein one or more recesses are formed in the body from a top surface, each recess is configured to retain one substrate by contacting only a portion of a back side of the substrate, each recess has a supporting surface, and a circular capturing surface surrounding the supporting surface, wherein the capturing surface defines an opening larger than a diameter of a substrate so that at least a flat portion of an outer edge of the substrate is not in contact with the circular capturing surface is provided.

[0008] In yet another embodiment of the present invention a baffle plate, comprising a body region having a plurality of holes formed therein, wherein the baffle plate comprises a material that is optically transparent is provided.

[0009] In yet another embodiment of the present invention, a method for forming metal nitride films using a processing chamber is provided. The method comprises loading multiple substrates onto a substrate support assembly of the processing chamber, wherein the substrate support is in a loading position during the loading multiple substrates and wherein the processing chamber comprises a chamber body that encloses a processing volume, the support assembly defining a lower edge of the processing volume and having an outer edge and an inner edge for supporting a substrate carrier, a showerhead assembly having multiple gas ports for supplying process gases to the processing volume disposed over the substrate support assembly and defining an upper edge of the processing region, a lower liner assembly coupled with an interior sidewall of the chamber body, an upper liner assembly positioned on the lower liner assembly, an exhaust ring disposed radially inward of the upper liner assembly, and a showerhead liner assembly disposed over the exhaust ring, wherein the exhaust ring and showerhead liner define a first opening for exhausting process gases from the processing volume, moving the substrate support from the loading position upwards to a processing position,

wherein the multiple substrates are positioned in a horizontal plane above a horizontal plane of the first opening, and flowing process gases comprising a metal containing precursor and a nitrogen containing precursor perpendicular to the surfaces of the multiple substrates to form a metal nitride film on the multiple substrates, wherein after contacting the surfaces of the multiple substrates, the process gases flow across the surfaces of the multiple substrates and down toward the first opening between the showerhead liner assembly and the exhaust ring.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, 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 invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0011] FIG. 1 is a schematic side cross-sectional view of a processing chamber having a process kit according to embodiments described herein;

[0012] FIG. 2A is an enlarged cross-sectional view of one embodiment of a process kit interfaced with the processing chamber of FIG. 1;

[0013] FIG. 2B is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1;

[0014] FIG. 2C is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1;

[0015] FIG. 2D is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1;

[0016] FIG. 2E is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1;

[0017] FIG. 2F is a top view of one embodiment of a process kit interfaced with the processing chamber of FIG. 1;

[0018] FIG. 3 is a top schematic view of a process kit interfaced with the processing chamber without the showerhead assembly of FIG. 1;

[0019] FIGS. 4A-4H are schematic views of a lower liner assembly according to embodiments described herein;

[0020] FIGS. 5A-5H are schematic views of an upper liner assembly according to embodiments described herein;

[0021] FIGS. 6A-6F are schematic views of an upper liner assembly cover ring according to embodiments described herein;

[0022] FIGS. 7A-7H are schematic views of an exhaust ring assembly according to embodiments described herein;

[0023] FIGS. 8A-8F are schematic views of a cover ring assembly according to embodiments described herein;

[0024] FIGS. 9A-9D are schematic views of a baffle plate according to embodiments described herein;

[0025] FIGS. 10A-10D are schematic views of a support shaft according to embodiments described herein;

[0026] FIGS. 11A-11D are schematic views of a substrate carrier according to embodiments described herein; and

[0027] FIGS. 12A-12B are schematic views of a showerhead liner assembly according to embodiments described herein;

[0028] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. It

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

DETAILED DESCRIPTION

[0029] Embodiments of the present invention generally relate to an apparatus and methods for uniformly depositing one or more layers on multiple substrates in a processing chamber. In one embodiment, an apparatus generally includes a substrate supporting structure, process kit and gas delivery structure that is configured to minimize the temperature variation across each of the substrates during thermal processing and prevent particle generation within the processing chamber during normal processing. In general, processing chambers that may benefit from one or more of the embodiments described herein include chambers that are able to perform high temperature thermal processes, such as metal oxide chemical vapor deposition (MOCVD), hydride vapor phase epitaxy (HVPE) deposition or other thermal processes used to form or process light emitting diode (LED) and laser diode (LD) devices.

[0030] The embodiments described herein may provide at least one of the following: 1) Enable different flow paths by changing different iterations of pumping/exhaust ring (e.g., side exhaust, top exhaust, and bottom exhaust with respect to the edge of the carrier), 2) decouple the effect of temperature from flow (Since before there is only one flow path) and 3.) improve thermal coupling between the various process kit components and the substrate heating components (e.g., lamps). So by keeping the position of the carrier the same, the dominant mode of heat transfer (radiation) is kept the same while the flow paths can change by varying the pumping/exhaust ring to understand effect of flow.

[0031] There is a need to decouple or minimize the interrelation of temperature and flow in the making of an LED stack on sapphire/silicon wafers within a processing chamber, such as an MOCVD chamber. The techniques and configurations described herein were used to better understand the effect of flow on the process. Processing of this LED stack is done at very high temperature (>1000

degrees Celsius), hence the primary mode of heat transfer is through radiation. So the purpose of this hardware is to enable the position of the carrier and wafer substrate at the same position relative to surrounding hardware (showerhead which is held at a temperature ~ 100 degrees Celsius, and other quartz liners isolating the carrier and wafers from a water cooled chamber) so that the radiation heat loss is minimally changed while the path of the process gas flow can be varied to adjust its effect on process uniformity (wavelength, PL intensity) independent of temperature.

[0032] An example of a thermal processing chamber that may benefit from one or more the embodiments described herein is a metal oxide chemical vapor deposition (MOCVD) deposition chamber, which is illustrated in FIG. 1 and is further described below. While the discussion below primarily describes one or more of the embodiments of the present invention being disposed in a MOCVD chamber, this processing chamber type is not intended to be limiting as to the scope of the invention described herein. For example, the processing chamber may be an HVPE deposition chamber that is available from Applied Materials Inc. of Santa Clara, California.

[0033] FIG. 1 is a schematic side cross-sectional view of a processing chamber 100 having a process kit according to one or more embodiments described herein. In one embodiment, the process kit comprises a lower liner assembly 110, an upper liner assembly 120, an exhaust ring 160, and an upper liner cover ring 170. In certain embodiments, the process kit further comprises a substrate carrier cover ring 180.

[0034] In one example, as illustrated in FIG. 1, the processing chamber 100 is a metal oxide chemical vapor deposition (MOCVD) chamber. The processing chamber 100 comprises a chamber body 102, a lid assembly 106, a dome structure 114, a chemical delivery module for delivering process gases, a substrate support assembly 104, an energy source 122, a controller 101 and a vacuum system.

[0035] The chamber body 102 encloses a processing volume 103 disposed between a showerhead assembly 118 and the substrate support assembly 104 that

is coupled to the chamber body 102. The chamber body 102 comprises a sidewall 129. The sidewall 129 may be a quartz material, a ceramic material or a metallic material. The sidewall 129 may include metallic materials, such as stainless steel or aluminum. The sidewall 129 may also include a coolant channel (not shown) to maintain the sidewall 129 at a temperature lower than the temperature of the processing volume 103.

[0036] In one embodiment of the processing chamber 100, the lid assembly 106 comprises a showerhead assembly 118. The showerhead assembly 118 may include multiple gas delivery channels that are each configured to uniformly deliver one or more processing gases to the substrates disposed in the processing volume 103. In one configuration, the showerhead assembly 118 includes multiple manifolds 119 coupled with the chemical delivery module for delivering multiple precursor gases discretely to the processing volume 103. The showerhead assembly 118 may be made of metallic materials, such as stainless steel or aluminum. A ceramic liner or a ceramic coating may be disposed over the metallic material. The showerhead assembly 118 also includes a temperature control channel 121 coupled with a cooling system to help regulate the temperature of the showerhead assembly 118.

[0037] The manifolds 119 are in fluid communication with gas conduits 145 and gas conduits 146 that deliver gases to the processing volume 103 separately from each of the manifolds 119. In some configurations, a remote plasma source is adapted to deliver gas ions or gas radicals to the processing volume 103 via a conduit 123 formed in the showerhead assembly 118. It should be noted that the precursors may comprise a process gas, process gas mixtures, or may comprise one or more precursor gases or process gases as well as carrier gases and dopant gases which may be mixed with the precursor gases.

[0038] The dome structure 114 contains a lower chamber volume 116 and the energy source 122 disposed adjacent to the dome structure 114. The dome structure 114 may be made of transparent material, such as high-purity quartz, to

allow energy (e.g., light) delivered from the energy source 122 to pass through for radiant heating of the substrates 140.

[0039] In one configuration, the chemical delivery module includes sources of process gases for deposition of various metal nitride films, including GaN, aluminum nitride (AlN), indium nitride (InN), and compound films, such as AlGaIn and InGaIn. The chemical delivery module may also comprise sources for dopant gases such as silane (SiH₄) or disilane (Si₂H₆) gases for silicon doping, and Bis(cyclopentadienyl) magnesium (Cp₂Mg or (C₅H₅)₂Mg) for magnesium doping. The chemical delivery module may also comprise sources for non-reactive gases, such as hydrogen (H₂), nitrogen (N₂), helium (He), argon (Ar) or other gases and combinations thereof.

[0040] A single lift mechanism 105 having the capability to lift, lower and rotate is disposed at least partially in the processing volume 103. The single lift mechanism 105 comprises a plurality of support features 134 coupled to a common drive device that is configured to provide rotational and vertical movement of the support features 134. In one embodiment, the single lift mechanism 105 comprises the substrate support assembly 104 having a plurality of support features 134 coupled thereto.

[0041] The substrate support assembly 104 is generally configured to support and retain the substrate carrier 111 during processing. However, during transfer, the substrate support assembly 104 is configured to support the substrate carrier 111 to facilitate transfer of the substrate carrier 111. The substrate support assembly 104 includes a support shaft 150 that has a plurality of support arms 133 on which the support features 134 are disposed. The substrate support assembly 104 generally includes an actuator assembly 107 that is configured to provide vertical movement and rotation of the support shaft 150 about a central axis A. During processing, the substrate support assembly 104 supports and rotates the substrate carrier 111 about the central axis A during processing.

[0042] The radiant heating provided from the energy source 122 may be provided by a plurality of inner lamps 127A and outer lamps 127B disposed below the dome structure 114. The inner lamps 127A and the outer lamps 127B may be positioned in a circular pattern or rings below the dome structure 114. Reflectors 128 may be used to help control the radiant energy provided by the inner lamps 127A and the outer lamps 127B. Additional rings of lamps may also be used for finer temperature control of the substrates 140.

[0043] The temperature of the substrates 140 is maintained at a desired processing temperature using a closed-loop control system. The closed-loop control system generally comprises a controller 101. The closed-loop control system may also include a temperature probe 124 such as a pyrometer. In one embodiment, the temperature probe 124 monitors the temperature of the substrates 140. The controller 101 may use the temperature information from the temperature probe 124 to vary power to the energy source 122, vary the spacing of the substrate carrier 111 relative to the energy source 122 and/or the showerhead assembly 118, and combinations thereof.

[0044] During processing a substrate carrier 111 is disposed on the substrate support assembly 104. The substrate carrier 111 is generally adapted to support and retain one or more substrates 140 thereon during processing. The substrate carrier 111 is also utilized to transfer the one or more substrates 140 into and out of the processing chamber 100. The substrate carrier 111 is shown in a processing position in FIG. 1, but the substrate carrier 111 may be moved by the substrate support assembly 104 to a lower position where, for example, the substrates 140 and/or substrate carrier 111 may be transferred into or out of the chamber body 102 by commands sent from a controller 101. The controller 101 is generally designed to facilitate the control and automation of the overall processing chamber 100 and typically may include a central processing unit (CPU) (not shown), memory (not shown), and support circuits (or I/O) (not shown).

[0045] During processing, the substrate carrier 111 is generally designed to damp the spatial variation in the amount of energy delivered from the energy

source 122 to the substrates 140. An optional baffle plate 130 may be disposed on the substrate support assembly 104. The baffle plate 130 (FIGS. 9A-9D) is utilized to dampen thermal variation created by any non-uniform distribution of radiant energy from lamps 127A-127B.

[0046] The substrate carrier 111 is also designed to provide a steady support surface for each substrate 140 during processing and transfer. In one configuration, each of the substrates 140 may be disposed in a recess 113 formed in the substrate carrier 111. The substrate carrier 111 generally comprises a material that is able to withstand the high processing temperatures (e.g., >800°C) used to process substrates in the processing volume 103 of the processing chamber 100. The substrate carrier 111 generally comprises a material that has good thermal properties, such as a good thermal conductivity. The substrate carrier 111 may also have physical properties similar to the substrates 140, such as a similar coefficient of thermal expansion, to avoid unnecessary relative motion between the surface of the substrate carrier 111 and the substrates 140 during heating and/or cooling. In one example, the substrate carrier 111 may comprise silicon carbide (SiC), or a graphite core that has a silicon carbide coating formed by a CVD process over the core.

[0047] The lower liner assembly 110 and the upper liner assembly 120 serve as heat insulators, contamination liners, and also form exhaust paths for process gases. The lower liner assembly 110 and the upper liner assembly 120 may be coupled to an interior sidewall 131 of the process chamber 100. The lower liner assembly 110 and the upper liner assembly 120 may individually be quartz, opaque quartz, a ceramic or include a ceramic coating.

[0048] The upper liner cover ring 170 is positioned adjacent to an inner portion of the upper liner assembly 120. The upper liner cover ring 170 is dimensioned to fit within and be supported by the upper liner assembly 120. The upper liner cover ring 170 may comprise a solid silicon carbide material, or a silicon carbide coated graphite material. The upper liner cover ring 170 prevents process gases from

interacting with the upper liner assembly 120 and creating particulates within the processing volume 103 of the process chamber 100.

[0049] The exhaust ring 160 may be disposed around the inside diameter of the chamber body 102. The exhaust ring 160 minimizes deposition from occurring in the lower chamber volume 116 below the substrate support assembly 104. The exhaust ring 160 also directs exhaust gases from the processing volume 103 to exhaust channel 117. The exhaust ring 160 may be formed from a solid silicon carbide material, or a silicon carbide coated graphite material.

[0050] In certain embodiments, the substrate carrier cover ring 180 circumscribes the substrate carrier 111. The upper liner cover ring 170 is dimensioned to fit within and be supported by the upper liner assembly 120. The substrate carrier cover ring 180 works in conjunction with the exhaust ring 160 and the upper liner cover ring 170 to direct process gases from the processing volume 103 toward the exhaust channel 117. The substrate carrier cover ring 180 may comprise a solid silicon carbide material, or a silicon carbide coated graphite material.

[0051] FIG. 2A is an enlarged cross-sectional view of one embodiment of a process kit interfaced with the processing chamber 100 of FIG. 1. The process kit depicted in FIG. 2A comprises the lower liner assembly 110, the upper liner assembly 120, the exhaust ring 160, the upper liner cover ring 170, and the substrate carrier cover ring 180. An opening 206 for exhausting process gases from the processing volume 103 is formed between the upper liner assembly 120 and the lower liner assembly 110. The lower liner assembly 110 and the upper liner assembly 120 interface to form an arcuate exhaust channel 210. The arcuate exhaust channel 210 is coupled with the exhaust channel 117 for exhausting process gases 202a, 202b and the inert gases 204 from the process chamber. A gap 214 is formed between a surface 216 of the showerhead assembly 118 and the surface of the substrate carrier 111. In certain embodiments, the gap 214 may be between about 5 mm and about 13 mm, for example, about 10 mm.

[0052] The showerhead assembly 118 receives processing gases from a gas distribution system 281 (shown schematically) via two or more gas supply lines 281A, 281B. The gas distribution system 281 may comprise sources for precursors, carrier gas, and purge gas. The gas distribution system 281 may also comprise one or more remote plasma sources.

[0053] In one configuration, the gas distribution system 281 includes sources of process gases 202a, 202b for deposition of various metal nitride films, including gallium nitride (GaN), aluminum nitride (AlN), indium nitride (InN), and compound films, such as AlGaN and InGaN. The gas distribution system 133 may also comprise sources for dopant gases such as silane (SiH_4) or disilane (Si_2H_6) gases for silicon doping, and Bis(cyclopentadienyl) magnesium (Cp_2Mg or $(\text{C}_5\text{H}_5)_2\text{Mg}$) for magnesium doping. The gas distribution system 133 may also comprise sources for non-reactive gases, such as hydrogen (H_2), nitrogen (N_2), helium (He), argon (Ar) or other gases and combinations thereof.

[0054] As depicted in FIG. 2A, the process gases 202a, 202b flow from the showerhead assembly 118 perpendicularly toward the substrate carrier 111 which may have substrates 140 positioned thereon. After flowing over the surfaces of the substrates 140 or substrate carrier 111, the process gases 202a, 202b flow toward the substrate carrier cover ring 108. The substrate carrier cover ring 180 directs the process gases between the exhaust ring 160 and the upper liner cover ring 170 preventing process gases 202a, 202b from entering the lower chamber volume 116. The upper liner cover ring 170 and the exhaust ring 160 prevent the process gases 202a, 202b from contacting the surfaces of the lower liner assembly 110 and the upper liner assembly 120 positioned within the process volume 103 and the lower chamber volume 116. The process gases 202a, 202b then flow through the opening 206 into the arcuate exhaust channel 210 and then through the exhaust channel 117.

[0055] FIG. 2B is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1. The process kit of FIG. 2B is similar to the process kit depicted in FIG. 2A. The process kit of FIG. 2B

does not contain a carrier cover ring and the exhaust ring 160 is replaced with the exhaust ring 260. The exhaust ring 260 has a smaller inner diameter than the exhaust ring 160. The smaller inner diameter of the exhaust ring 260 positions the exhaust ring 260 closer to the substrate carrier 111. As depicted in FIG. 2B, a gap 228 is formed between the bottom surface 216 of the showerhead assembly 118 and the substrate carrier. The gap 228 is larger than the gap 214 of FIG. 2B. The larger gap 228 positions the substrate carrier 111 closer to the exhaust ring 260.

[0056] As depicted in FIG. 2B, the process gases 202a, 202b flow perpendicularly toward the substrate carrier 111 which may have substrates 140 positioned thereon. After flowing over the surfaces of the substrates 140 or substrate carrier 111, the process gases 202a, 202b flow toward the exhaust ring 260. The process gases 202a, 202b flow between the exhaust ring 260 and the upper liner cover ring 170 toward the opening 206. The exhaust ring 260 prevents process gases 202a, 202b from entering the lower chamber volume 116. The process gases 202a, 202b then flow through the opening 206, the arcuate exhaust channel 210 and through the exhaust channel 117.

[0057] The embodiments depicted in FIG. 2A and FIG. 2B lead to more uniform flow of the process gases over the surface of the substrate carrier 111 and the substrates 140 positioned in the substrate carrier 111. It is believed that positioning the substrate carrier 111 slightly above the arcuate exhaust channel 210 and the exhaust channel 117 as shown in FIG. 2A and FIG. 2B forces the process gas to flow to the edge of the substrate carrier 111 before exiting the chamber through the exhaust channel 210 and the exhaust channel 117 leading to more uniform flow of the process gases over the surface of the substrate carrier 111 and the substrates 140 positioned on the substrate carrier 111. In configurations where the substrate carrier 111 is positioned below the exhaust channel 210 and exhaust channel 117 during processing, the process gas is typically exhausted from the process chamber prior to reaching the edge of the substrate carrier leading to non-uniform flow of the process gas over the substrate carrier 111 and the substrates positioned thereon.

[0058] FIG. 2C is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1. The process kit in FIG. 2C is similar to the process kits depicted in FIG. 2A and FIG. 2B. The process kit of FIG. 2C does not contain a carrier cover ring 180 and the upper liner cover ring 170 is replaced with a showerhead liner assembly 265. A first opening or recess 262 is formed between the showerhead liner assembly 265 and the exhaust ring 260 for exhausting gases from the processing volume 103. A second opening 263 is formed in the upper liner assembly 120. An inner circular channel 261 is formed between the showerhead liner assembly 265, the exhaust ring 260 and the upper liner assembly 120. An outer circular channel 264 is formed between the upper liner assembly 120 and lower liner 110.

[0059] As depicted in FIG. 2C, the substrate carrier 111 and the substrate 140 are positioned at substantially the same level as the first opening 262. A distance between a top surface of the substrate 140 and a center of the first opening 262 is depicted by arrows 284. The process gases 202a, 202b flow from the showerhead assembly 118 perpendicularly toward the substrate carrier 111 and substrates 140. After contacting the substrate, the process gases 202a, 202b flow across the surface of the substrates 140 toward the first opening 262 formed between the showerhead liner assembly 265 and the exhaust ring 260. The process gases 202a, 202b flow through the first opening 262 between the exhaust ring 260 and the showerhead liner assembly 265 into the inner circular channel 261. The process gases 202a, 202b then flow through the inner annular channel 261 through the second opening 263 into the outer annular channel 264 before being exhausted from the chamber via exhaust port 406.

[0060] FIG. 2C also depicts another embodiment of the showerhead assembly 118. The showerhead assembly 118 may comprise two or more plates stacked together to form independent pathways 119a, 119b for two or more processing gases and cooling channels (such as temperature control channel 121). Each independent pathway 119a, 119b has a plurality of apertures opening to the processing volume 103 on a showerhead surface 216. The plurality of apertures

132 for each independent path may be evenly distributed across the showerhead surface 216. The showerhead assembly 118 may be formed from a metal, such as 316L stainless steel, INCONEL[®], HASTELLOY[®], electroless nickel plated aluminum, pure nickel, and other metals and alloys resistant to chemical attack, or even quartz.

[0061] The showerhead assembly 118 includes a heat exchanging channel 270 through which gas conduits (not shown) in the showerhead assembly 118 extend to control the temperature of the gases or vapor delivered therethrough and into the processing volume 103 of the processing chamber 100. The heat exchanging channel 270 may be connected to a heat exchanger 282 (shown schematically).

[0062] Suitable heat exchanging fluids include water, water-based ethylene glycol mixtures, a perfluoropolyether (*e.g.*, Galden[®] fluid), oil-based thermal transfer fluids, liquid metals (such as gallium or gallium alloy) or similar fluids. The heat exchanging fluid may be circulated through the heat exchanging channel 270 to raise or lower the temperature of the heat exchanging fluid as required to maintain the temperature of the showerhead assembly 118 within a desired temperature range.

[0063] In one embodiment, the heat exchanging fluid is maintained within a temperature range of about 20°C to about 120°C for a MOCVD process. In another embodiment, the heat exchanging fluid may be maintained within a temperature range of about 100°C to about 350°C. In yet another embodiment, the heat exchanging fluid may be maintained at a temperature of greater than 350°C. The heat exchanging fluid may also be heated above its boiling point so that the showerhead assembly 118 may be maintained at higher temperatures using readily available heat exchanging fluids.

[0064] FIG. 2D is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1. The process kit in FIG. 2C is similar to the process kit depicted in FIG. 2C. However, the first opening 262 formed between the showerhead liner assembly 265 and the exhaust ring 260

is positioned above the carrier 111 and the substrate 140 when the carrier 111 and the substrate 140 are positioned in a processing position.

[0065] A distance between a top surface of the substrate 140 and a center of the first opening 262 is depicted by arrows 286. The process gases 202a, 202b flow from the showerhead assembly 118 perpendicularly toward the substrate carrier 111 and substrates 140. After contacting the substrate, the process gases 202a, 202b flow across the surface of the substrates 140 and up toward the first opening 262 formed between the showerhead liner assembly 265 and the exhaust ring 260. The process gases 202a, 202b flow through the first opening 262 between the exhaust ring 260 and the showerhead liner assembly 265 into the inner circular channel 261. The process gases 202a, 202b then flow through the inner annular channel 261 through the second opening 263 into the outer annular channel 264 before being exhausted from the chamber via exhaust port 406.

[0066] FIG. 2E is an enlarged cross-sectional view of another embodiment of a process kit interfaced with the processing chamber of FIG. 1. The process kit in FIG. 2E is similar to the process kits depicted in FIG. 2C and FIG. 2D. However, the first opening 262 formed between the showerhead liner assembly 265 and the exhaust ring 260 is positioned below the carrier 111 and the substrate 140 when the carrier 111 and the substrate 140 are positioned in a processing position.

[0067] A distance between a top surface of the substrate 140 and a center of the first opening 262 is depicted by arrows 288. The process gases 202a, 202b flow from the showerhead assembly 118 perpendicularly toward the substrate carrier 111 and substrates 140. After contacting the substrate, the process gases 202a, 202b flow across the surface of the substrates 140 and down toward the first opening 262 formed between the showerhead liner assembly 265 and the exhaust ring 260. The process gases 202a, 202b flow through the first opening 262 between the exhaust ring 260 and the showerhead liner assembly 265 into the inner circular channel 261. The process gases 202a, 202b then flow through the inner annular channel 261 through the second opening 263 into the outer annular channel 264 before being exhausted from the chamber via exhaust port 406.

[0068] FIG. 2F is a top view of one embodiment of a process kit interfaced with the processing chamber of FIG. 1 with the showerhead 118 removed. FIG. 2F schematically illustrates the gas flow path in the processing chamber 100 during processing wherein the exhaust ring 260, upper liner assembly 120, and showerhead liner assembly 265 are shown in section. The processing gases exit the processing volume 103 from the plurality of recesses 262 and enter the inner circular channel 261. The processing gases then enter the outer circular channel 264 through the second opening 263, and eventually exit the processing chamber 100 through the exhaust channel 117. In certain embodiments, there are fewer openings 263 than the recesses 262 so that the process gases flow in tangential directions to extend the length of the exhaust path.

[0069] FIG. 3 is a top schematic view of a process kit interfaced with the substrate carrier 111 of the processing chamber 100 with the showerhead assembly 118 removed.

[0070] FIGS. 4A-4G are schematic views of the lower liner assembly 110 according to embodiments described herein. The lower liner assembly 110 may comprise quartz, a ceramic, or include a ceramic coating. The lower liner assembly 110 comprises an annular body 400 having a slit valve 402 for the ingress and egress of a substrate carrier, for example, substrate carrier 111, an exhaust channel 404, and an exhaust port 406 for exhausting gases from the processing chamber 100.

[0071] The exhaust channel 404 is configured to mate with an exhaust channel 502 of the upper liner assembly 120 to form the arcuate exhaust channel 210. The annular body 400 has a top surface 408, a bottom surface 410, an inner wall 412, and an outer wall 414. The exhaust channel 404 is formed in the top surface 408 of the annular body 400. One end of the exhaust channel 404 has an opening 416 of greater width than the exhaust channel 404. The exhaust channel 404 extends around a portion of the circumference of the annular body 400.

[0072] The exhaust channel 404 has an outer diameter 418. The outer diameter 418 of the exhaust channel 404 may be between about 480 mm and about 500 mm. The exhaust channel 404 has an inner diameter 420. The inner diameter 420 of the exhaust channel 404 may be between about 430 mm and about 450 mm. The opening 416 and the exhaust channel 404 share the same outer diameter 418. The opening 416 has an inner diameter 422. The inner diameter 422 of the opening 416 may be between 420 mm and 430 mm.

[0073] The lower liner assembly 110 has an outer diameter 424. The outer diameter 424 of the lower liner assembly 110 may be between about 500 mm and about 510 mm. The lower liner assembly 110 has an inner diameter 426. The inner diameter 426 of the lower liner assembly 110 may be between about 400 mm and about 420 mm.

[0074] The top surface 408 has an inner diameter as shown by arrows 428. The inner diameter of the top surface 408 may be between about 425 mm and about 430 mm. The bottom surface 410 has an outer diameter as shown by arrows 430. The outer diameter of the bottom surface 410 may be between about 450 mm and about 460 mm. The bottom surface 410 has an inner diameter as shown by arrows 432. The inner diameter of the bottom surface 410 may be between about 440 mm and about 450 mm.

[0075] As shown in FIG. 4G, the inner wall 412 of the annular body 400 may be angled outward. The inner wall 412 has a top diameter as shown by arrows 434. The top diameter of the inner wall 412 may be from about 405 mm and about 420 mm. The inner wall 412 may have a run from the top diameter shown by arrows 434 to the inner diameter of the bottom surface 410.

[0076] The outer wall 414 of the annular body 400 may have a slanted portion 436. The slanted portion 436 has an outer diameter as shown by arrows 438. The outer diameter of the slanted portion may be from about 480 mm and about 495 mm. The slanted portion shares the outer diameter of the bottom surface 410 as shown by arrows 430. The slanted portion 436 may have a run from the outer

diameter as shown by arrows 438 to the outer diameter of the bottom surface 410 as shown by arrows 430. The lower liner assembly 110 may have a thickness between about 90 mm and about 110 mm as shown by arrows 440.

[0077] A recessed portion 442 may be formed between the inner diameter of the top surface as shown by arrows 428 and the top diameter of the inner wall 412 as shown by arrows 434.

[0078] FIGS. 5A-5H are schematic views of the upper liner assembly 120 according to embodiments described herein. The upper liner assembly 120 may comprise quartz, a ceramic, or include a ceramic coating. The upper liner assembly 110 comprises an annular body 500 having an exhaust channel 502 formed in the annular body 500. The exhaust channel 502 mates with the exhaust channel 404 of the lower liner assembly 110 to form the arcuate exhaust channel 210. The annular body 500 has a top surface 504, a bottom surface 506, an outer wall 508, and an inner wall 510.

[0079] The exhaust channel 502 is formed in the bottom surface 506 of the annular body 500. Each end of the exhaust channel 502 has an opening 512a, 512b of greater width than the channel 502. The exhaust channel 502 extends around a portion of the circumference of the annular body 500. The exhaust channel 504 has an outer diameter as shown by arrows 526. The outer diameter of the channel 502 as shown by arrows 526 may be between about 480 mm and about 500 mm. The exhaust channel 502 has an inner diameter as shown by arrows 528. The inner diameter of the exhaust channel 502 as shown by arrows 528 may be between about 430 mm and about 450 mm. The openings 512a, 512b and the exhaust channel 502 share the same outer diameter as shown by arrow 526. The openings 512a, 512b have an inner diameter as shown by arrow 536. The inner diameter of the openings 512a, 512b as shown by arrow 536 may be between 420 mm and 430 mm.

[0080] The upper liner assembly 120 has an outer diameter as shown by arrows 514. The outer diameter of the upper lid assembly 120 may be between about 505

mm and about 510 mm. The upper liner assembly 120 has an inner diameter as shown by arrows 516. The inner diameter of the upper lid assembly 120 may be between about 400 mm and about 405 mm. The top surface 504 has an outer diameter as shown by arrows 518. The outer diameter of the top surface 504 may be between about 490 mm and about 500 mm. The top surface 504 has an inner diameter as shown by arrows 520. The inner diameter of the top surface 504 may be between about 405 mm and about 415 mm. The bottom surface 506 has an outer diameter as shown by arrows 514. The bottom surface 506 has an inner diameter as shown by arrows 522. The inner diameter of the bottom surface 506 may be between about 420 mm and about 430 mm. The upper liner assembly may have a thickness between about 15 mm and about 25 mm as shown by arrows 524.

[0081] A first stepped portion 530 is defined between the outer diameter of the upper liner assembly 120 as shown by arrows 514 and the outer diameter of the top surface 504 as shown by arrows 518. A second stepped portion 532 is formed between the inner diameter of the upper liner assembly 120 as shown by arrows 516 and the inner diameter of the bottom surface as shown by arrows 522. An inner lip 534 is formed between the inner diameter of the upper liner assembly as shown by arrows 516 and the inner diameter of the top surface 504 as shown by arrows 520.

[0082] FIGS. 6A-6F are schematic views of the upper liner assembly cover ring 170 according to embodiments described herein. In one embodiment, the upper liner assembly cover ring assembly 170 may comprise a solid silicon carbide material, or a silicon carbide coated graphite material. The upper liner cover ring assembly 170 may be L-shaped. The upper liner cover ring assembly 170 comprises an annular band 602. The annular band 602 has a horizontal portion 604 and a vertical portion 606 extending from the horizontal portion 604. An outer diameter of the horizontal portion 604 is shown by arrows 608. The outer diameter of the horizontal portion 604 may be between about 406 mm and about 432 mm as shown by arrows 608. An outer diameter of the vertical portion is shown by arrows

610. The outer diameter of the vertical portion 606 may be between about 394 mm and about 406 mm as shown by arrows 610. Both the horizontal portion 604 and the vertical portion 606 share the same inner diameter as shown by arrows 612. The inner diameter of the horizontal portion 604 and the vertical portion 606 may be between about 381 mm and about 395 mm.

[0083] The horizontal portion 604 has an inner periphery 614, an outer periphery 616, a top surface 618, and a bottom surface 620. The vertical portion 606 has an inner periphery 622, an outer periphery 624, and a bottom surface 626. The inner periphery 614 of the horizontal portion 604 and the inner periphery 622 of the vertical portion 606 form a unitary surface. The outer periphery 624 of the vertical portion 606 and the bottom surface 620 of the horizontal portion 604 intersect to form a stepped portion 628. The stepped portion 628 may be configured to rest on the upper liner assembly 120.

[0084] The upper liner cover ring assembly 170 may not be a completely joined circle such that a gap may be present between the two ends of the cover ring assembly 170 as shown by arrows 630. The gap may have a width of between about 0.76 mm and about 1.27 mm.

[0085] FIGS. 7A-7H are schematic views of the exhaust ring assembly 160 according to embodiments described herein. The exhaust ring 160 may have a plurality of teeth 702 that extend from the exhaust ring 160. The teeth 702 may be disposed at a diameter of between about 355 mm and about 381 mm as shown by arrows 704. The outer diameter of the exhaust ring 160 may be between about 404 mm and about 432 mm as shown by arrows 706. The exhaust ring 160 may not be a completely joined circle such that a gap may be present between the two ends of the exhaust ring 160. The gap may have a width of between about 0.76 mm and about 1.27 mm as shown by arrows 710 and a half width of between about 0.25 mm to about 0.76 mm as shown by arrows 712.

[0086] The teeth 702 may be spaced apart by a distance of between about 7.6 mm and about 10 mm as shown by arrows 718. The teeth 702 rise above a gully

714 in the exhaust ring 160 by a distance of between about 1.27 mm to about 3.81 mm as shown by arrows 720. The total height of the exhaust ring 160 may be between about 12.7 mm to about 15.2 mm as shown by arrows 722.

[0087] The exhaust ring 160 has several corners 738, 740, 744. The corners 738, 740 mark the location of a raised portion of the exhaust ring 160. The raised portion is raised between about 0.76 mm and about 1.27 mm as shown by arrows 736. The flange portion of the exhaust ring 160 has a height of between about 3.81 mm and about 5.08 mm as shown by arrows 742. The flange has a slanted surface having a run of between about 4.57 mm and about 5.3 mm inches as shown by arrows 748.

[0088] FIGS. 8A-8F are schematic views of the cover ring assembly 180 according to embodiments described herein. In one embodiment, the cover ring assembly 180 may comprise a solid silicon carbide material, or a silicon carbide coated graphite material. The cover ring 180 may have numerous corners 818, 820, 822, 826, and 828. The cover ring 180 may have an outside diameter of between about 381 mm and about 406 mm as shown by arrows 808. The cover ring assembly 180 may have an inner diameter 802 of between about 305 mm to about 330 mm. A top surface 824 of the cover ring 180 extends from the inner diameter 802 to the outer diameter as shown by arrows 808.

[0089] A cylindrical band 830 extends downward from the top surface 824. An outer diameter of the cylindrical band 830 may be between 355 mm and about 381 mm as shown by arrows 810. An inner diameter of the cylindrical band 830 may be between about 357 mm and about 368 mm as shown by arrows 804. An inner surface 832 extending from corner 826 to 828 of the cylindrical band 830 may be sloped toward the outer diameter of the cover ring. The inner surface 832 may be sloped between 10 degrees and 20 degrees relative to the outer diameter of the cylindrical band 830. A bottom surface 834 of the cylindrical band 830 extends from corner 822 to corner 828. An inner diameter of the bottom surface is shown by arrows 806.

[0090] The cover ring 180 may also have an inner flange 840. The inner flange 840 may extend from corner 826 to curved corner 812. The thickness of the inner flange 840 is shown by arrows 816. The cover ring may also have an outer flange 850. The outer flange may extend from corner 820 to corner 818. The edge of the cover ring 180 may have a curved corner 812 on the flange. The cover ring 180 may have a plurality of slots 860a-c to prevent it from making a complete circle. The thickness of the slots 860 is shown by arrows 838.

[0091] FIGS. 9A-9D are schematic views of a baffle plate 130 according to one or more of the embodiments described herein. The baffle plate 130 may comprise quartz, sapphire or other similar material that is at least semi-transparent to the radiation delivered from lamps 127A-127B. The baffle plate 130 may have a thickness 902 that is about 2-10 mm thick. As illustrated in the isometric view shown in FIG. 9A, the baffle plate 130 may comprise a circular body 901 that has three rectangular cutouts 905 that extend through the circular body 901 and are even distributed across the face 911 of the baffle plate 130 at an angle 912. The three rectangular cutouts 905, which are shown in FIG. 9D, have a horizontal dimension 913 and a vertical dimension 914. The three rectangular cutouts 905 in the baffle plate 130 are typically configured to mate with the support arms 133 (FIGS. 10A-10D) formed on the support shaft 150. The baffle plate can be used in conjunction with the lower liner assembly 110 and exhaust ring 160 to help minimize the gas flow into the lower chamber volume 116 from the processing volume 103.

[0092] FIGS. 10A-10D are schematic views of a support shaft 150 according to one or more of the embodiments described herein. FIG. 10A is an isometric view of one embodiment of the support shaft 150 that has three support arms 133 and a shaft region 1018. The three support arms 133 may be separated by an angle 1006. The support shaft 150 generally comprises a low thermal conductivity material, such as quartz, aluminum oxide, sapphire or other ceramic material, and is sized such that it will not interfere with the radiant heat delivered from the lamps 127A-127B to a carrier 111 disposed on the support arms 133. A length of the

support shaft 150 is shown by arrows 1015. In one configuration, the shaft region 1018 comprises an upper shaft region 1020, a middle shaft region 1030 and lower shaft region 1040. The upper shaft region 1020 has three support arms 133a-c that are disposed at a length 1022 from the middle shaft region 1030. The length 1022 (e.g., 40-400 mm) and diameter 1021 (e.g., 10-40 mm) of the support shaft 150, along with the width 1007 (e.g., 4-15 mm) and diameter 1008 (e.g., 100-400 mm) of the support arms 133a-c, are generally configured to reduce the amount of heat transferred from a carrier 111 disposed on the support features 134a-b to the actuator assembly 107, while also assuring that the support shaft 150 is strong enough to support and rotate a carrier 111 during processing.

[0093] The middle shaft region 1030 of the support shaft 150 generally has a length 1032 and a diameter 1031. The diameter 1031 is greater in size than the diameter 1021 of the upper shaft region 1020 and the diameter 1041 of the lower shaft region 1040. The middle shaft region 1030 may be useful as a bearing surface or a registration surface that interfaces with a portion of the actuator assembly 107.

[0094] The lower shaft region 1040 of the support shaft 150 generally has a length 1042 and a diameter 1041. The lower shaft region 1040 may also comprise an interface region 1046 that comprises a protrusion 1045 that has a diameter 1044 and a shoulder surface 1047. The shoulder surface 1047 and protrusion 1045 of the interface region 1046 may be adapted to be received within or align to a bearing assembly, such as an air bearing or conventional roller bearing assembly that is found in the actuator assembly 107. The lower shaft region 1040 may be useful as a bearing surface or registration surface that interfaces with a portion of the actuator assembly 107.

[0095] FIGS. 11A-11D are schematic views of a substrate carrier 111 according to one or more of the embodiments described herein. FIG. 11A is top-view of a substrate carrier 111 that has an outer diameter 1101, thickness 1102 (FIG. 11B (i.e., side view)) and has eight recesses 113 formed therein to hold or retain eight substrates 140 (FIG. 1). In one embodiment, the diameter 1101 is between about

300 mm and about 500 mm in diameter and the thickness 1102 is between about 2 and about 5 mm. In one configuration, the recesses 113 are formed in an array that includes seven recesses 113 disposed around the edge of the carrier 111 and one recess 113 in the middle, as shown in FIG. 11A. The recesses 113 each generally comprise a capturing surface 1114 (FIG. 11D) and a supporting surface 1115 that are configured to retain and support a substrate 140 (not shown). The capturing surface 1114 generally has a diameter 1118 that is larger than the outer diameter of a substrate 140 and a height 1121 that is larger than at least half the thickness of a substrate 140, and is thus configured to retain and/or capture the substrate 140 during processing. In one configuration, as shown in FIGS. 11A and 11C, the supporting surface 1115 is adapted to support a substrate 140 (not shown in FIGS. 11A or 11C) that has a major flat, such as a 4 inch (100mm) or a 6 inch (150mm) diameter substrate. To support the flat region of a substrate 140, each recess 113 may have a flat region 1131, which comprises a portion of the supporting surface 1115 that has an inner dimension 1132, which is smaller than the distance between the flat region of a substrate 140 to the center of the substrate 140, and a flat width 1133, which is generally smaller than the width of the flat formed on the substrate 140, to assure that the flat of the substrate 140 is always supported by the flat region 1131 during processing. The substrate 140 is generally positioned and aligned to the flat region 1131 when it is loaded into the substrate carrier 111.

[0096] In one embodiment, the recess 113 also contains a relief region 1116 that is disposed below the supporting surface 1115 to allow the substrate 140 to bow or deform into this region without coming into contact with a surface of the carrier 111 during processing. The relief region 1116 may have a depth 1122, which can be between about 0.5 and about 2 mm. The relief region 1116 generally has an inner radius 1119 and inner dimension 1132 that is sized to prevent the smallest possible substrate that is disposed on the supporting surface 1115 from becoming unsupported during processing.

[0097] In one embodiment of the substrate carrier 111, as shown in FIGS. 11A and 11C, the capturing surface 1114 is circular while the supporting surface 1115 has a flat region 1131. It is believed that this configuration of the capturing surface 1114 and supporting surface 1115 in the formed recesses 113 are useful, since it prevents the edges of the flat region of a substrate from unnecessarily contacting a capture surface of a conventionally design recess, which typically has a non-circular shape (*i.e.*, conventional capturing surfaces in conventional recesses follow the contours of the edge of the substrate.). The unwanted contact between the edge of a flat region of a substrate with a capture surface can cause substrate damage, such as chipping or breakage, due to the difference in expansion and/or contraction of the substrate 140 relative to the carrier 111 as the substrates and carrier are rapidly heated and cooled to the high processing temperatures used in a metal oxide chemical vapor deposition (MOCVD) or a hydride vapor phase epitaxy (HVPE) deposition process.

[0098] FIGS. 12A-12B are schematic views of a showerhead liner assembly 265 according to embodiments described herein. The showerhead liner assembly 265 may comprise a solid silicon carbide material, or a silicon carbide coated graphite material. The showerhead liner assembly 265 has an annular body 1202 and a cylindrical band 1204 extending downward from the annular body 1202. The showerhead liner may have numerous corners 1206, 1208, 1210, 1212, 1214, 1216, 1218, and 1220. The length of the cylindrical band 1204 is shown by arrows 1230.

[0099] The annular body 1202 has a planar upper surface 1222 extending from corner 1206 to corner 1216. The cylindrical band 1204 extends downward from the annular body 1202. An inner surface 1224 of the cylindrical band 1204 extends from corner 1210 to corner 1212 of the cylindrical band 120. The length of the cylindrical band 1204 is shown by arrows 1230. In certain embodiments, the cylindrical band may comprise at least one hole or one or more teeth 1234. The hole or teeth 1234 may form a portion of the first opening 262.

[00100] The annular body 1202 may also have an inner flange 1226. The inner flange 1226 may extend from corner 1210 to corner 1208. The annular body 1202 may also have an outer flange 1228. The outer flange may extend from corner 1218 to curved corner 1220. The thickness of the inner flange 1226 is shown by arrows 1232.

[00101] Embodiments of the present invention provide several advantages over traditional processing chamber configuration. First, processing uniformity is improved by forcing the process gases to flow to the edge of the substrate carrier prior to exhausting the gases from the chamber. Flowing process gases to the edge of the substrate carrier before exhausting the gases from the chamber leads to uniform flow of the process gases over the substrates positioned on the substrate carrier.

[00102] Next, contamination or undesired deposition from the process gases in the chamber volume is reduced using the process kit described herein. Since the process gases do not enter the chamber volume, the inner surfaces defining the chamber volume can remain clean for an extended period. Periodic cleaning is only required for the processing region of the chamber.

[00103] Further, the exhaust ring and upper liner cover ring reduce the formation of particulate matter within the process region by preventing process gases from contacting the lower liner assembly and the upper liner assembly within the processing region.

[00104] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

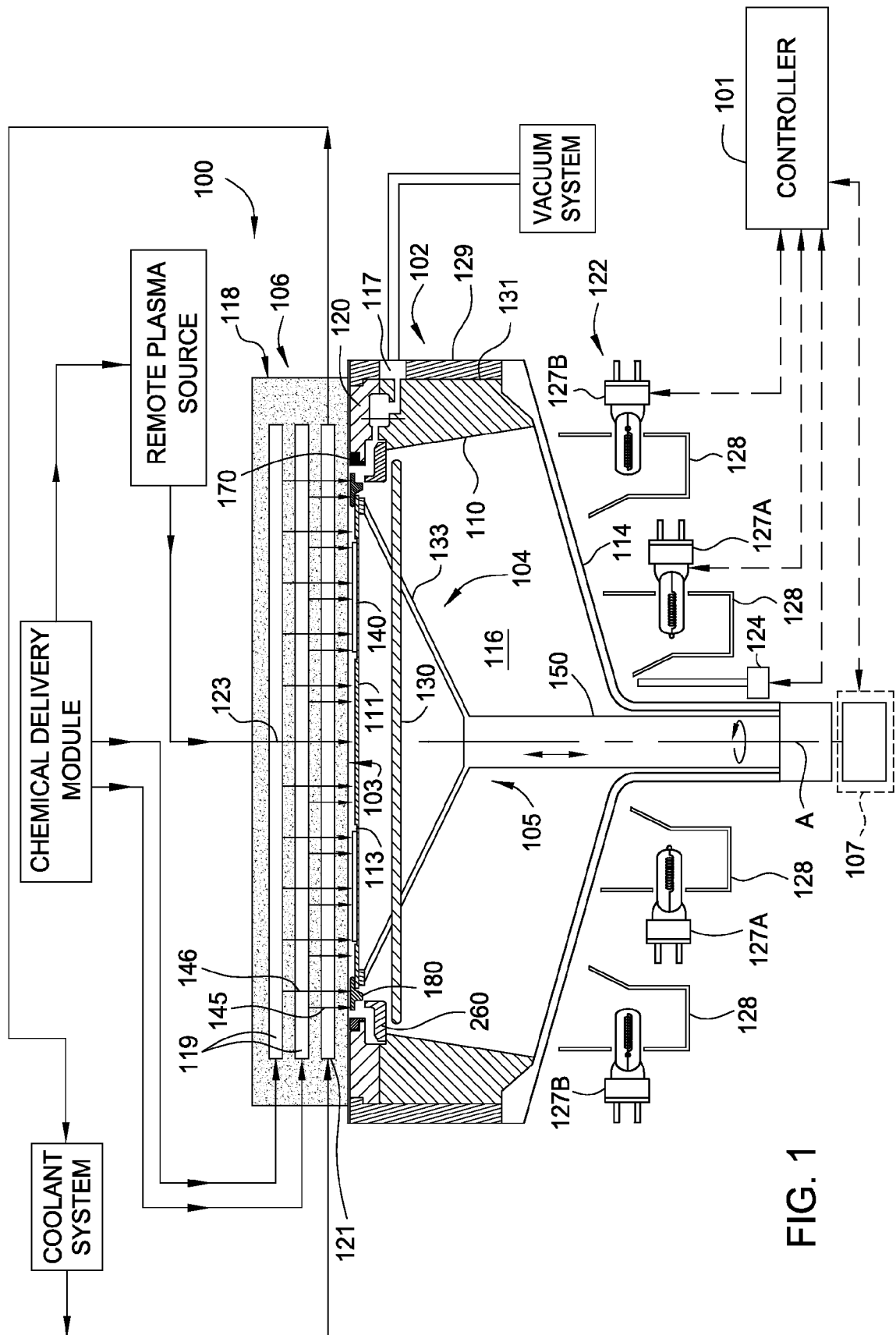
Claims:

1. A method for forming metal nitride films using a processing chamber, comprising:
 - loading multiple substrates onto a substrate support assembly of the processing chamber, wherein the substrate support is in a loading position during the loading multiple substrates and wherein the processing chamber comprises:
 - a chamber body that encloses a processing volume;
 - the support assembly defining a lower edge of the processing volume and having an outer edge and an inner edge for supporting a substrate carrier;
 - a showerhead assembly having multiple gas ports for supplying process gases to the processing volume disposed over the substrate support assembly and defining an upper edge of the processing region;
 - a lower liner assembly coupled with an interior sidewall of the chamber body;
 - an upper liner assembly positioned on the lower liner assembly;
 - an exhaust ring disposed radially inward of the upper liner assembly;
 - and
 - a showerhead liner assembly disposed over the exhaust ring ,
 - wherein the exhaust ring and showerhead liner define a first opening for exhausting process gases from the processing volume;
 - moving the substrate support from the loading position upwards to a processing position, wherein the multiple substrates are positioned in a horizontal plane above a horizontal plane of the first opening; and
 - flowing process gases comprising a metal containing precursor and a nitrogen containing precursor perpendicular to the surfaces of the multiple substrates to form a metal nitride film on the multiple substrates, wherein after contacting the surfaces of the multiple substrates, the process gases flow across the surfaces of the multiple substrates and down toward the first opening between the showerhead liner assembly and the exhaust ring.

2. The method of claim 1, wherein the upper liner assembly, the showerhead liner assembly, and the exhaust ring define an inner circular channel in fluid communication with the processing volume through the first opening.
3. The method of claim 2, wherein the upper liner assembly and the lower liner assembly define an outer circular channel that circumscribes the inner circular channel and is in fluid communication with the inner circular channel via a second opening formed in the upper liner assembly.
4. The method of claim 3, wherein a center of the second opening is positioned above a center of the first opening.
5. The method of claim 3, wherein the outer circular channel is in fluid communication with an exhaust channel formed in the lower liner assembly.
6. The method of claim 5, wherein the exhaust channel is in fluid communication with an exhaust port formed in the chamber body for exhausting processing gases from the processing chamber.
7. The method of claim 6, wherein the metal nitride films are selected from gallium nitride (GaN), aluminum nitride (AlN), indium nitride (InN), aluminum gallium nitride (AlGaN) and indium gallium nitride (InGaN).
8. The method of claim 3, wherein the lower liner assembly, comprises:
 - an annular body having:
 - a top surface;
 - a bottom surface;
 - an inner wall;
 - an outer wall, and

an exhaust channel formed in the top surface of the annular body, wherein the exhaust channel extends around a portion of the circumference of the annular body.

9. The method of claim 8, wherein the upper liner assembly, comprises:
- a top surface;
 - a bottom surface;
 - an inner wall;
 - an outer wall, and
 - an exhaust channel formed in the bottom surface of the annular body, wherein the exhaust channel extends around a portion of the circumference of the annular body and mates with the exhaust channel of the outer circular channel.
10. The method of claim 9, wherein the exhaust ring assembly has a plurality of teeth extending from the exhaust ring assembly wherein the plurality of teeth define a portion of the first opening.
11. The method of claim 10, wherein the showerhead liner assembly comprises:
- an annular body having a planar upper surface; and
 - a cylindrical band extending downward from the annular body, wherein the cylindrical band defines a portion of the first opening.
12. The method of claim 1, wherein the processing chamber further comprises:
- a lower dome structure transparent to thermal energy positioned below the support assembly and defining a chamber volume between the lower dome structure and the support assembly.
13. The method of claim 12, further comprising:
- transmitting electromagnetic energy through the lower dome structure into the processing volume.



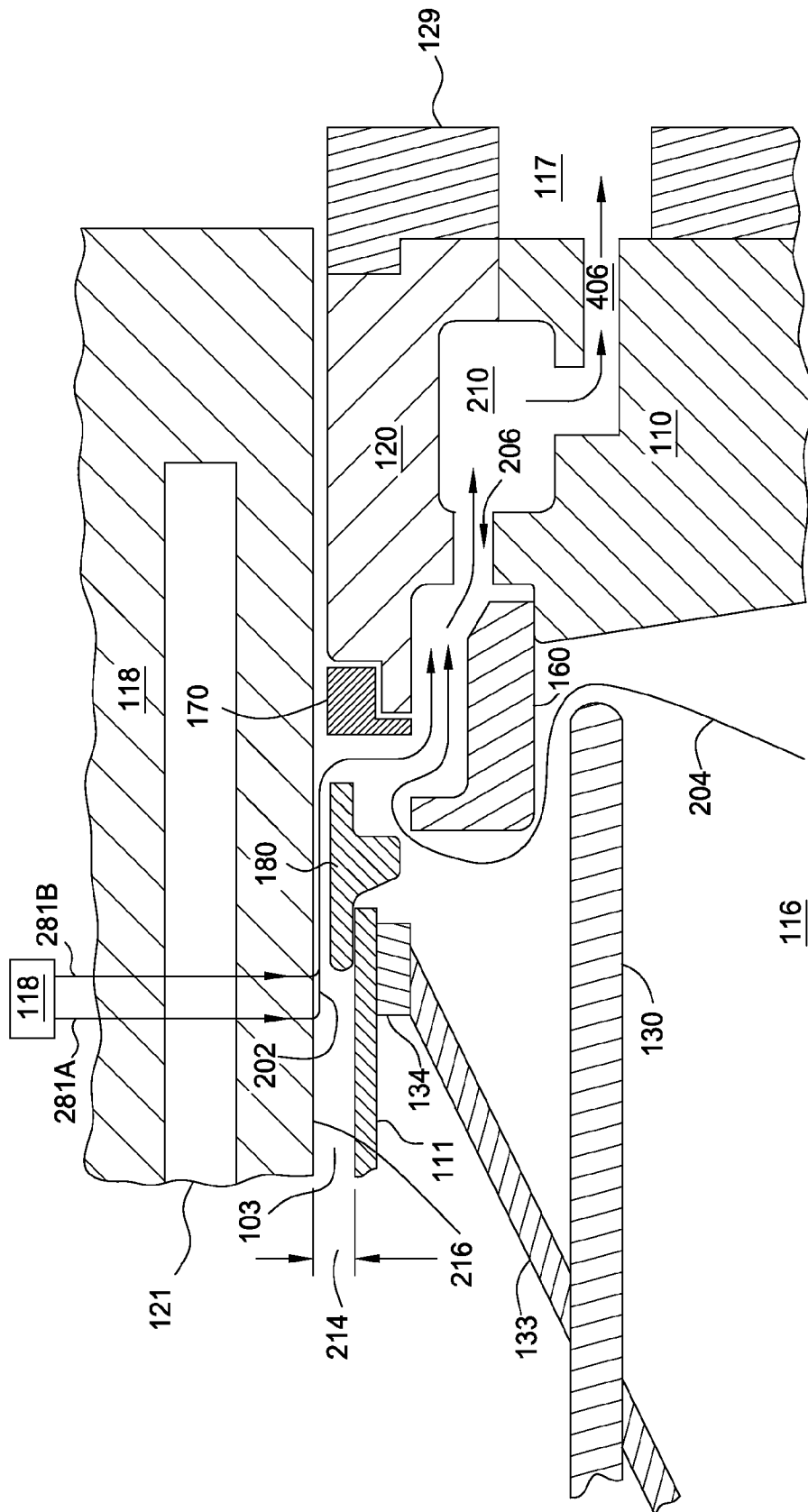


FIG. 2A

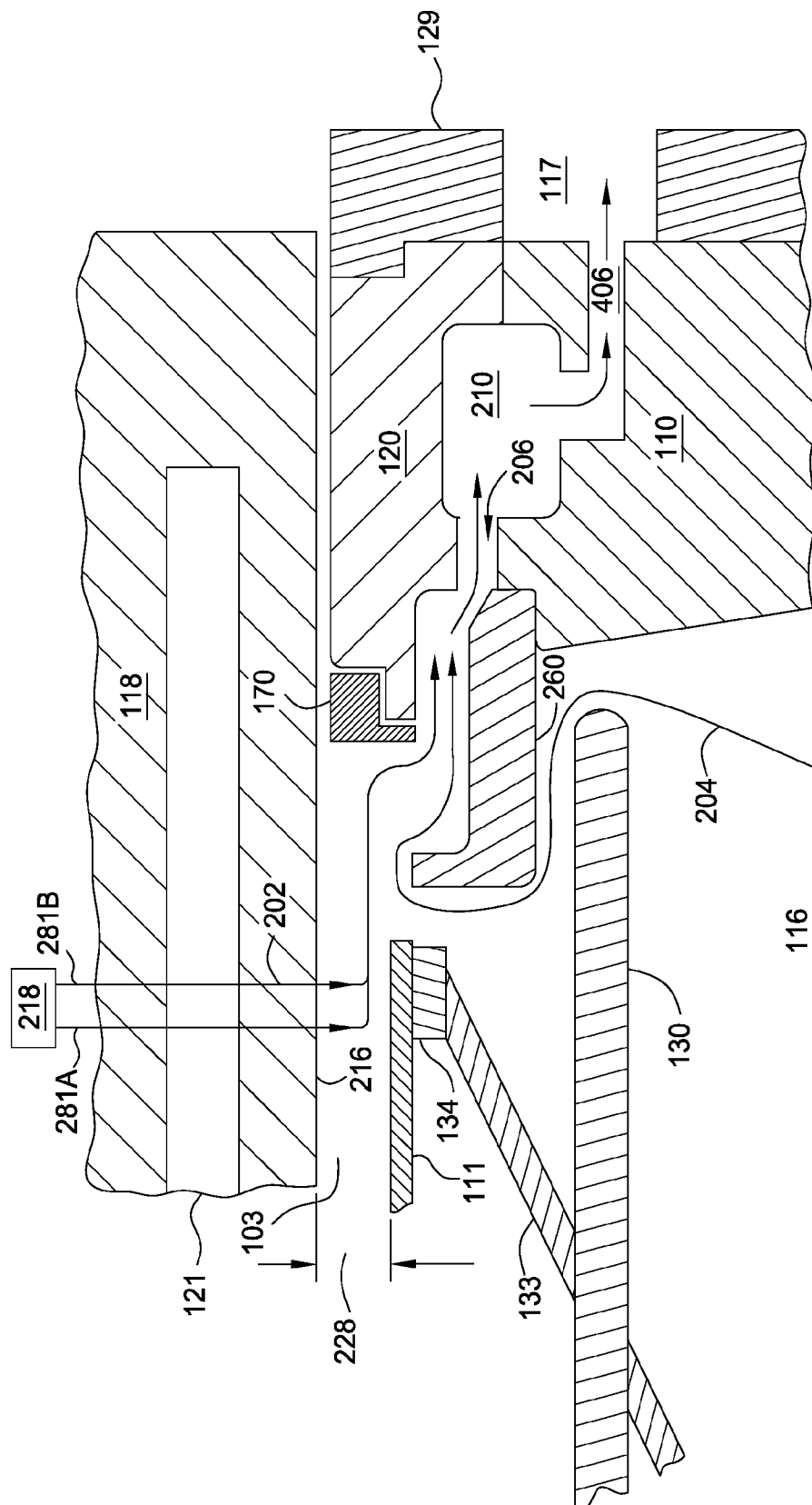


FIG. 2B

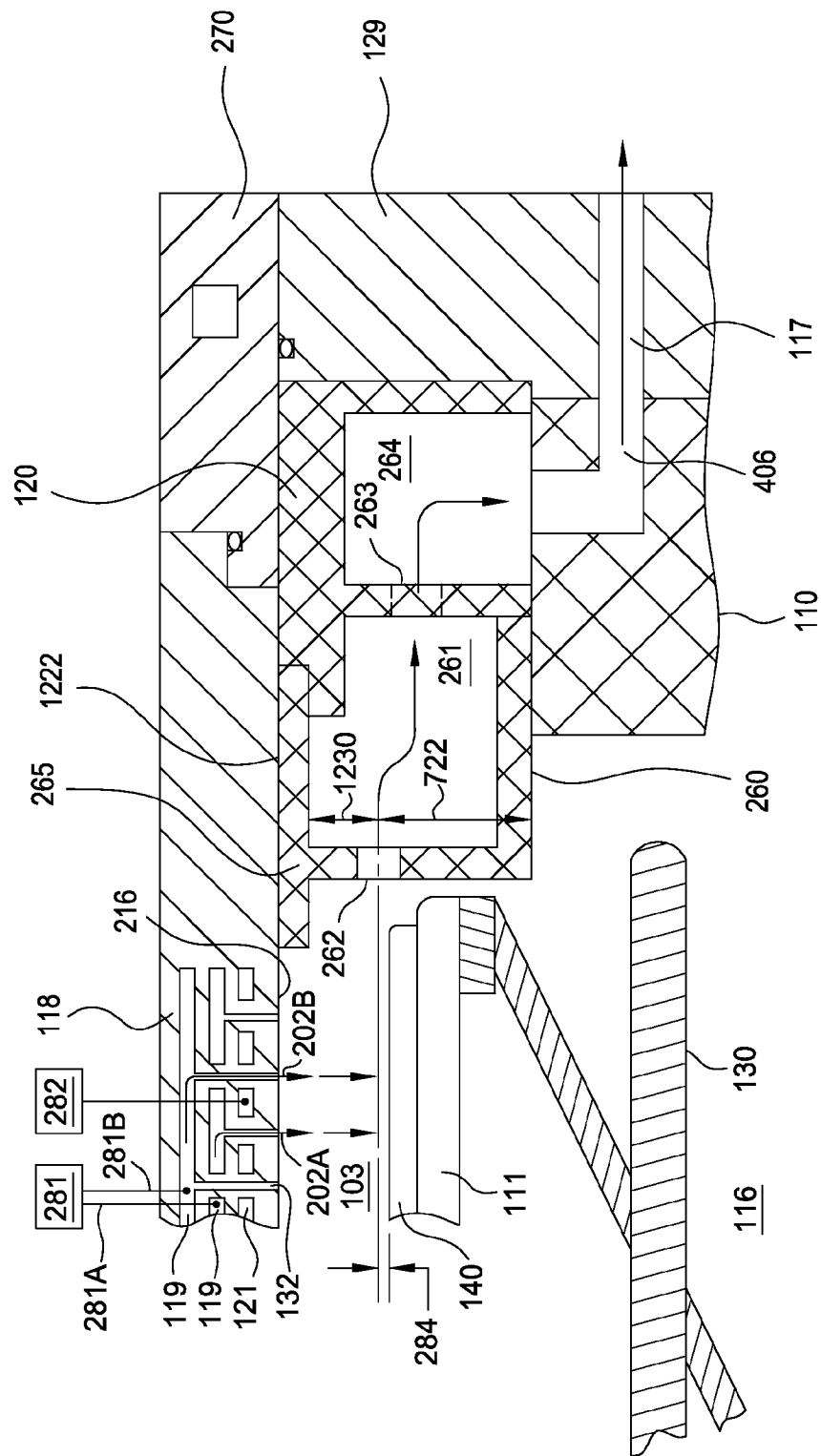


FIG. 2C

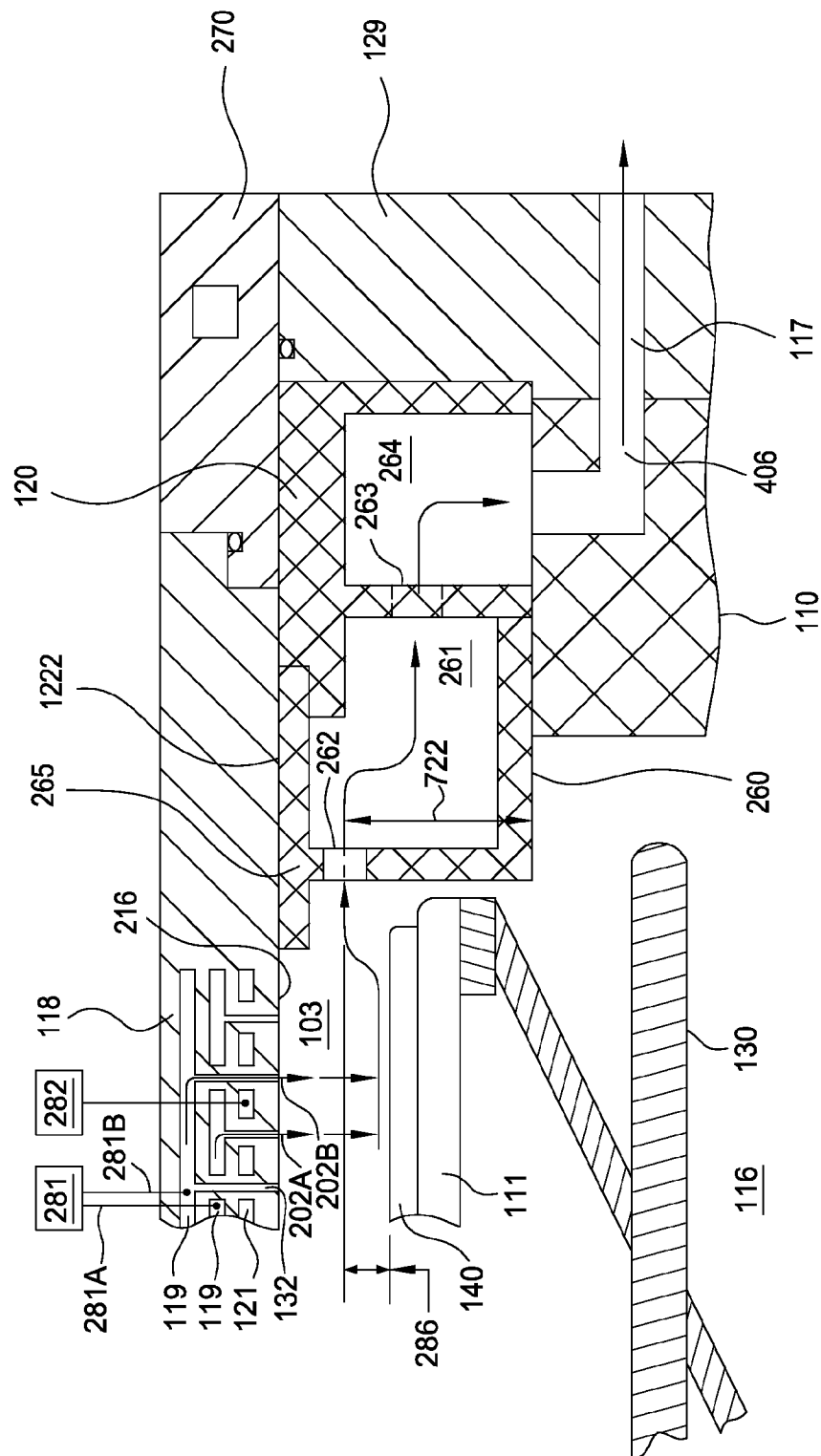


FIG. 2D

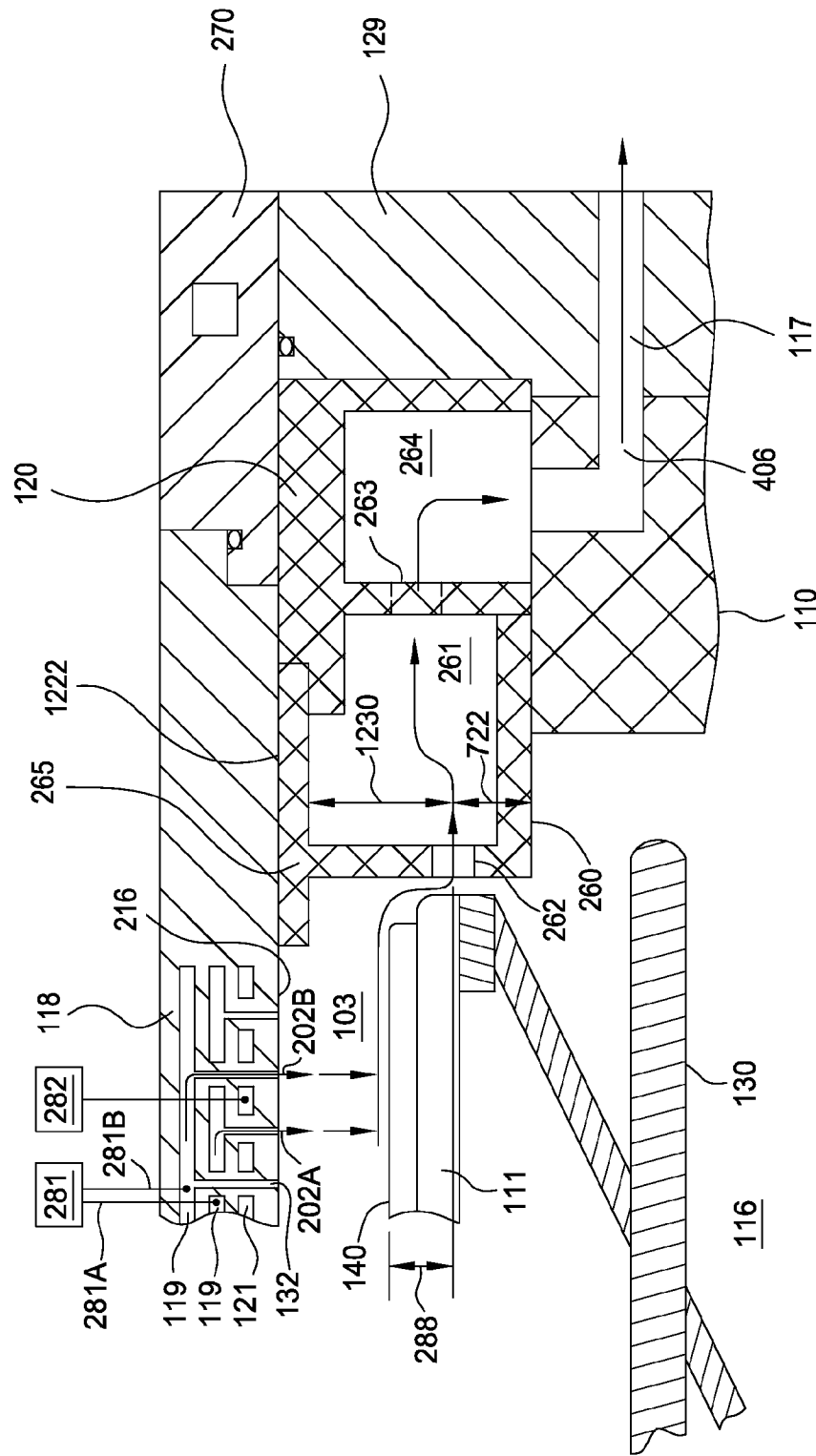


FIG. 2E

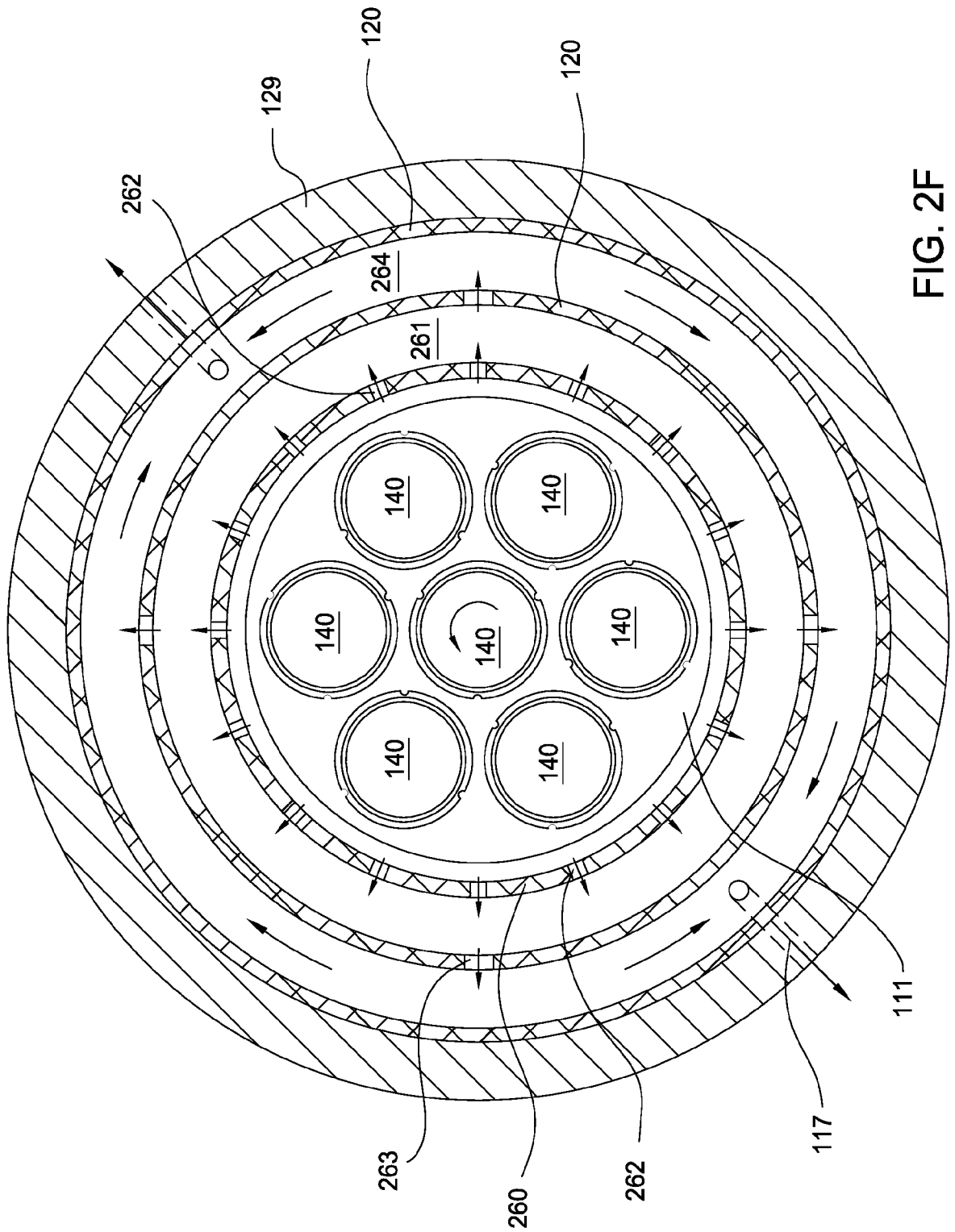


FIG. 2F

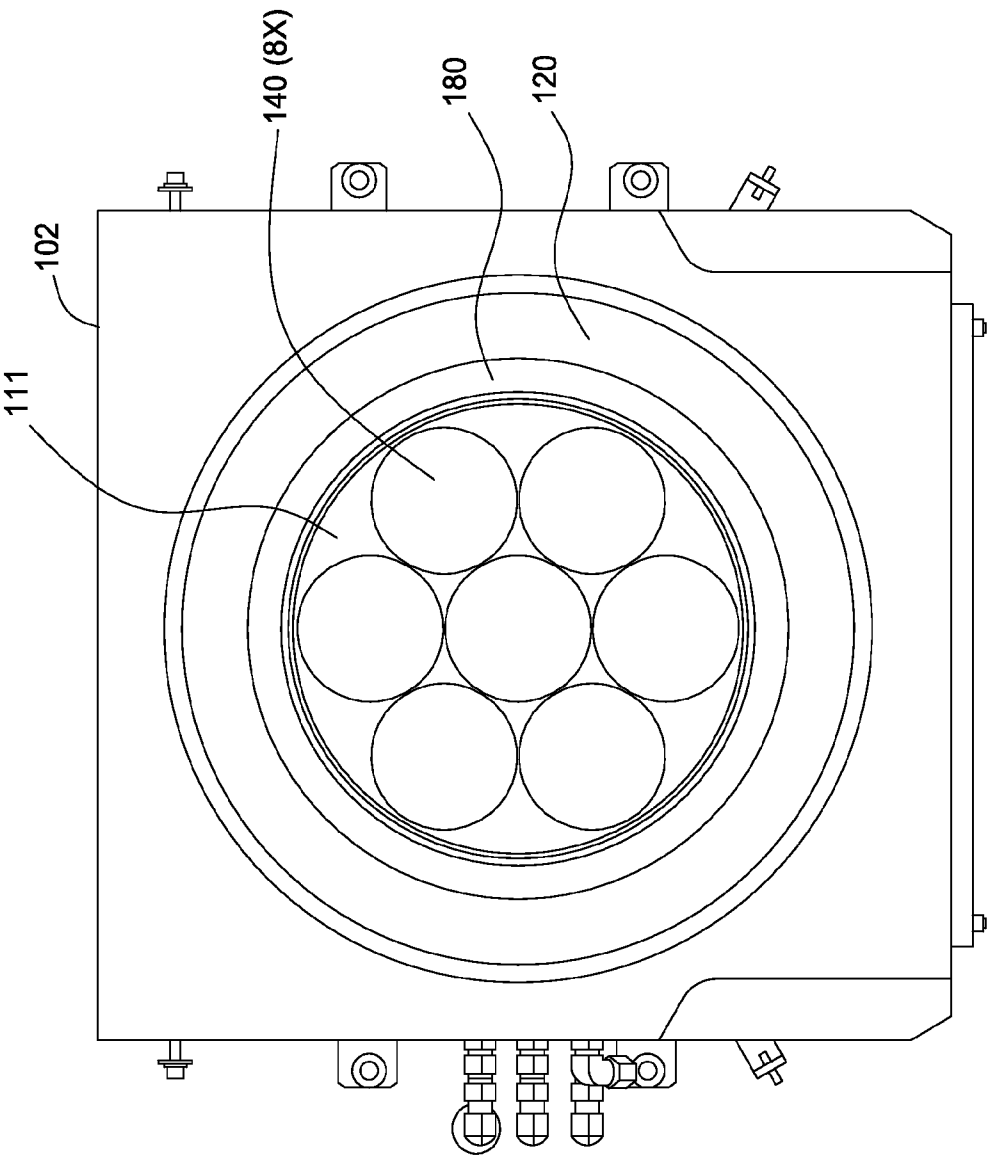


FIG. 3

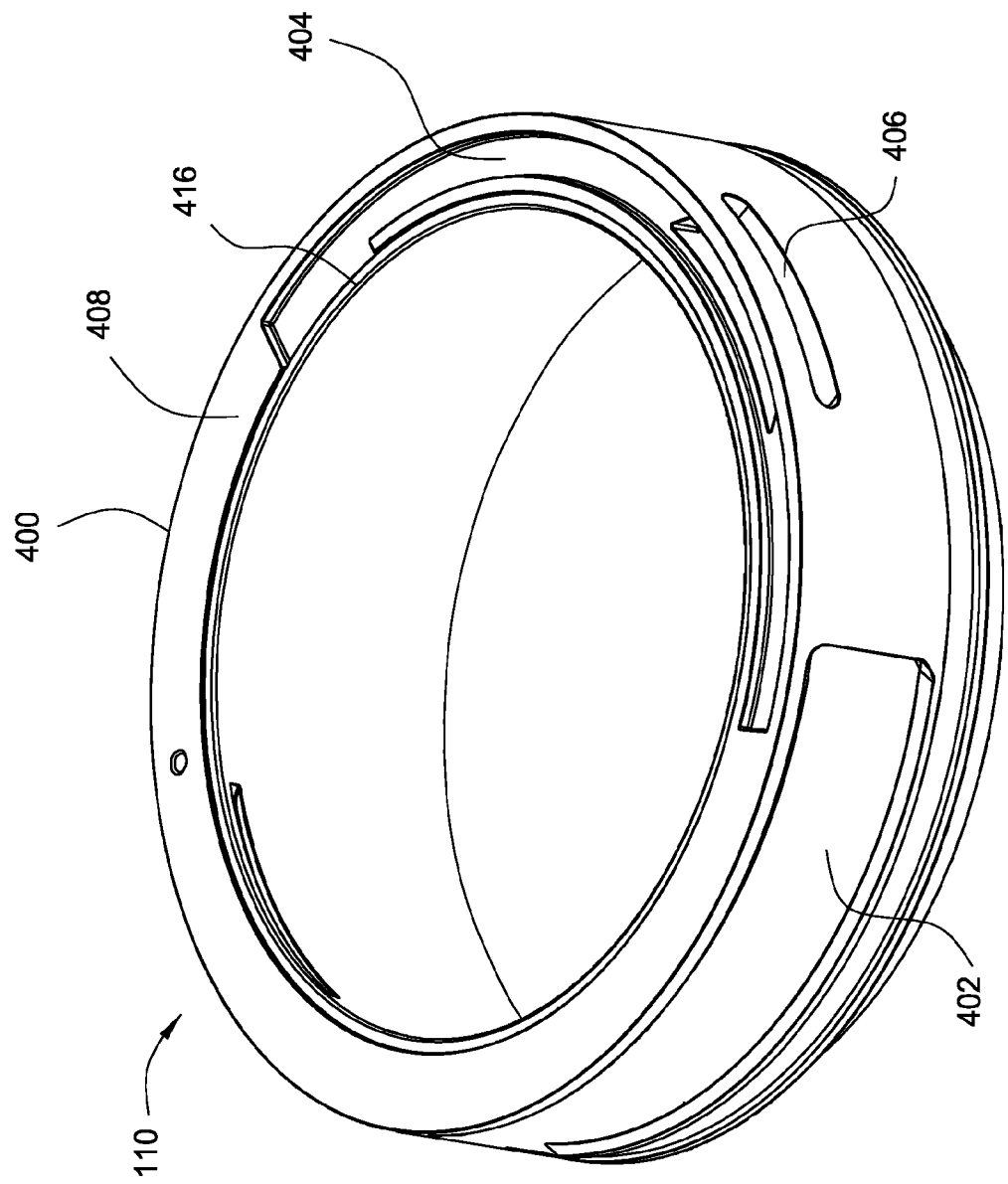


FIG. 4A

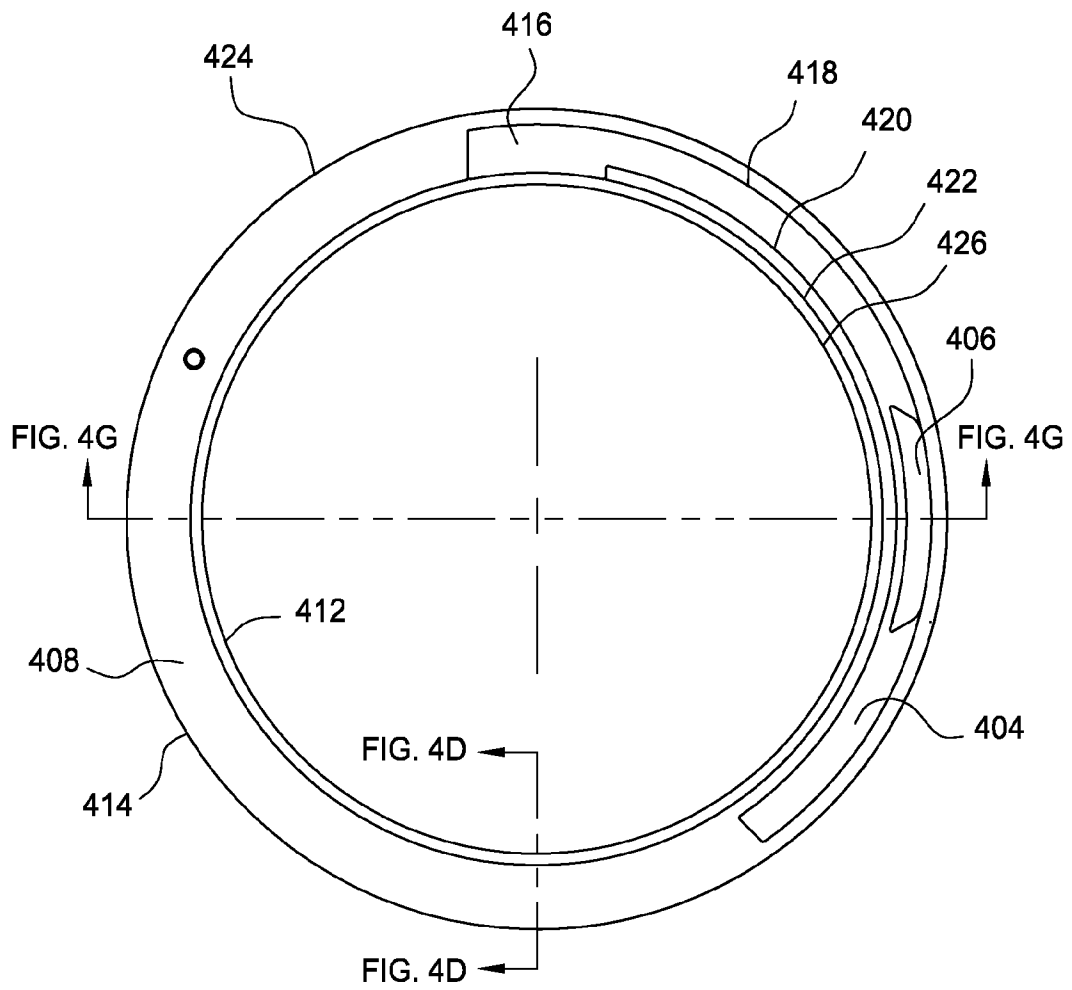


FIG. 4B

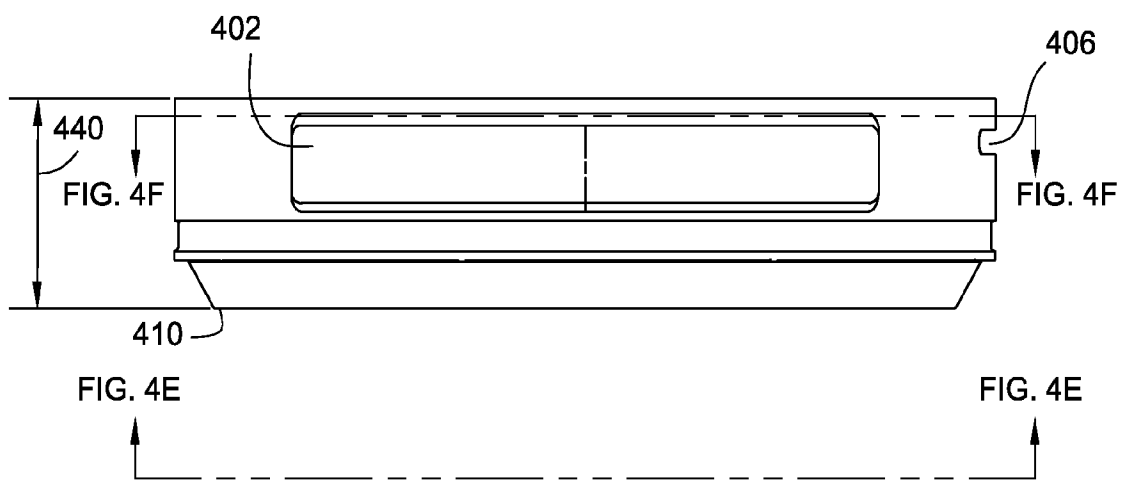


FIG. 4C

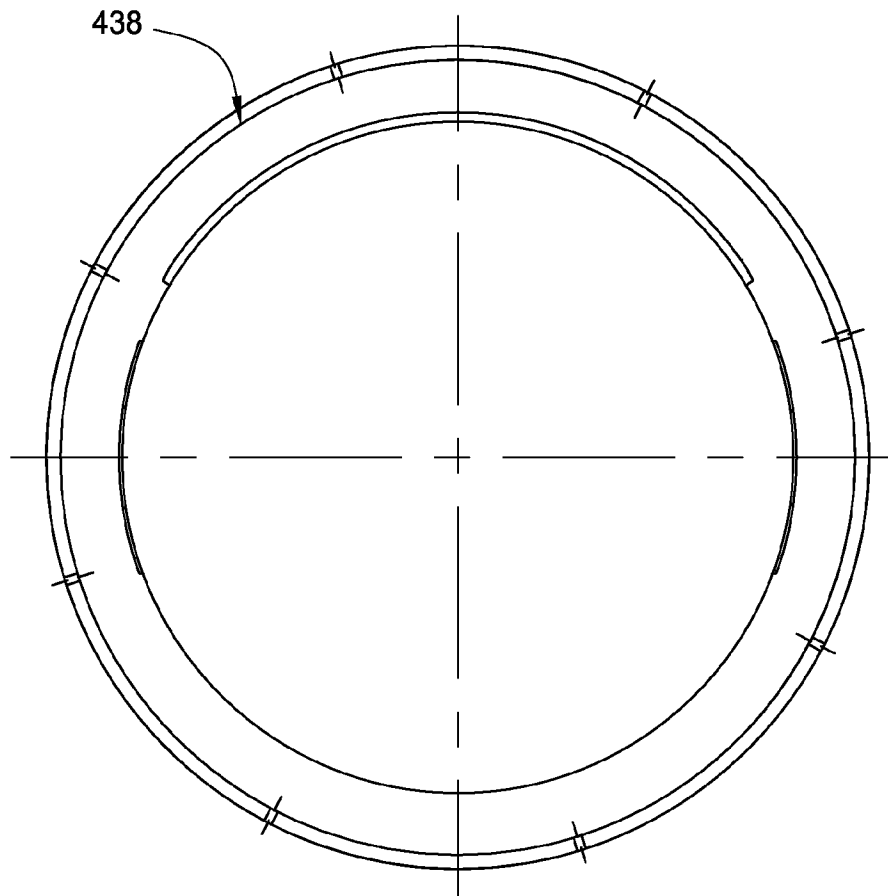


FIG. 4E

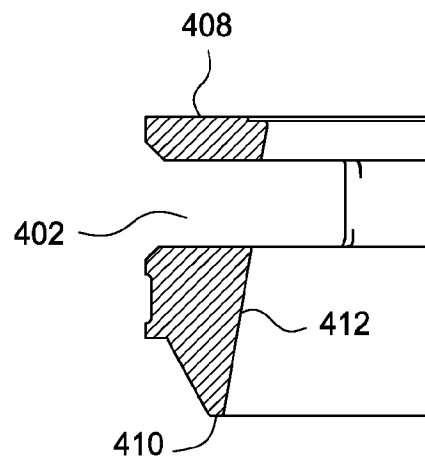


FIG. 4D

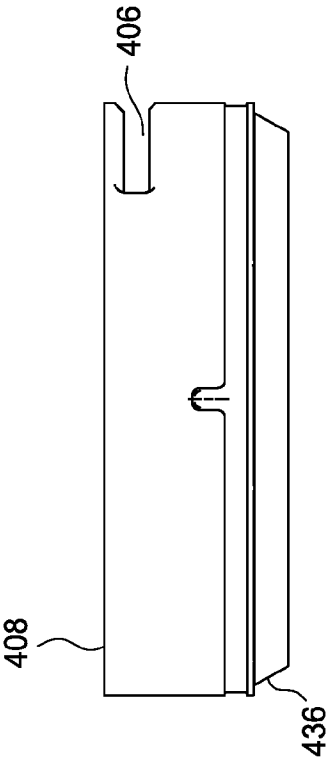
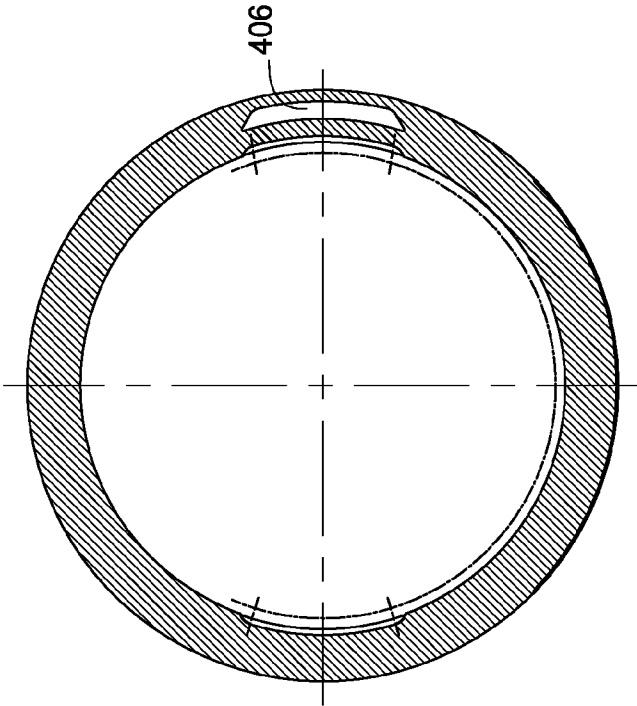


FIG. 4H

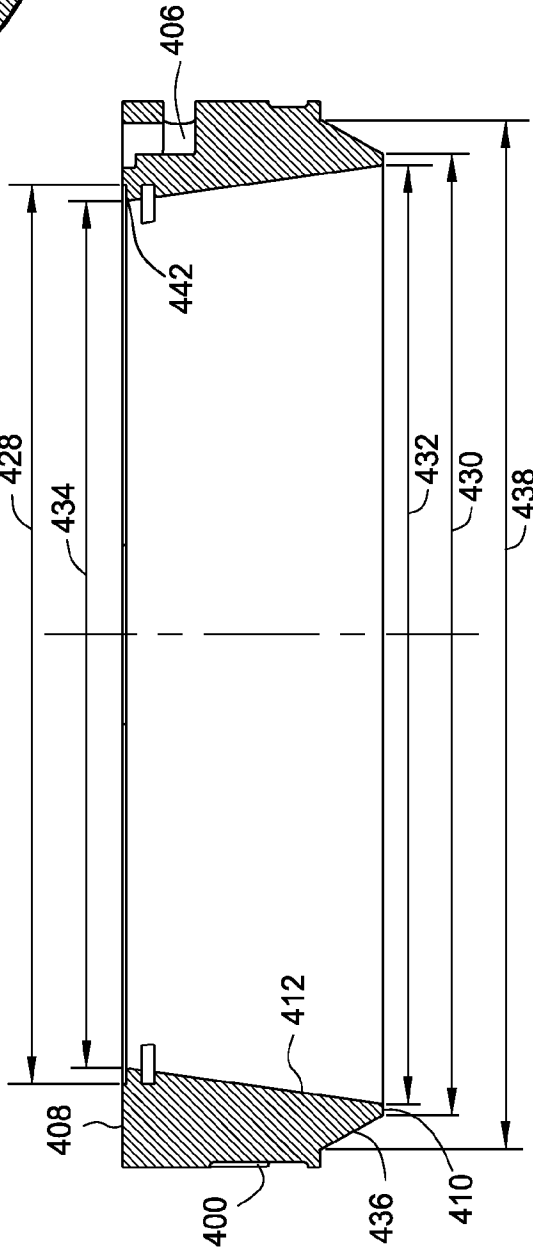


FIG. 4G

FIG. 4F

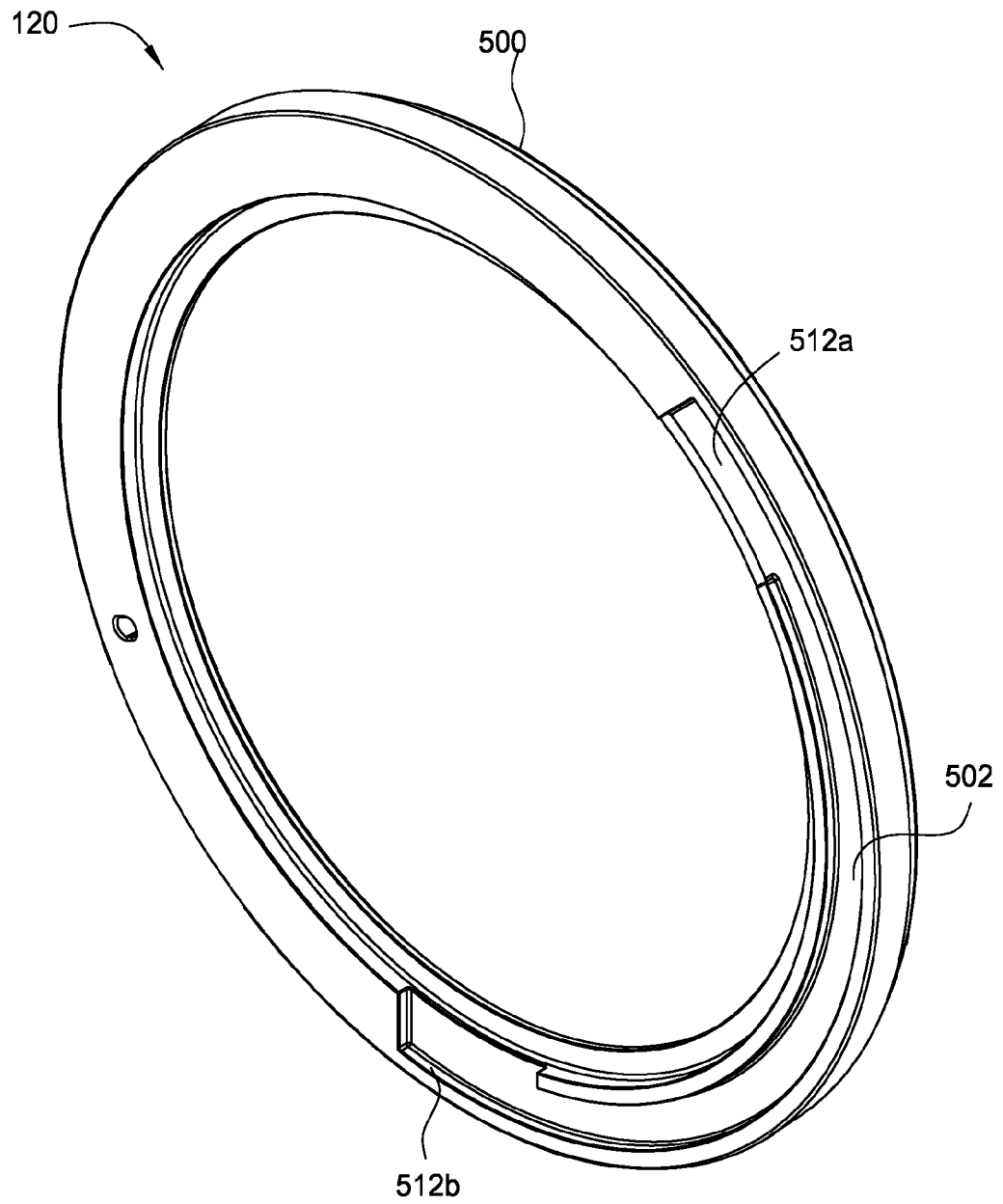


FIG. 5A

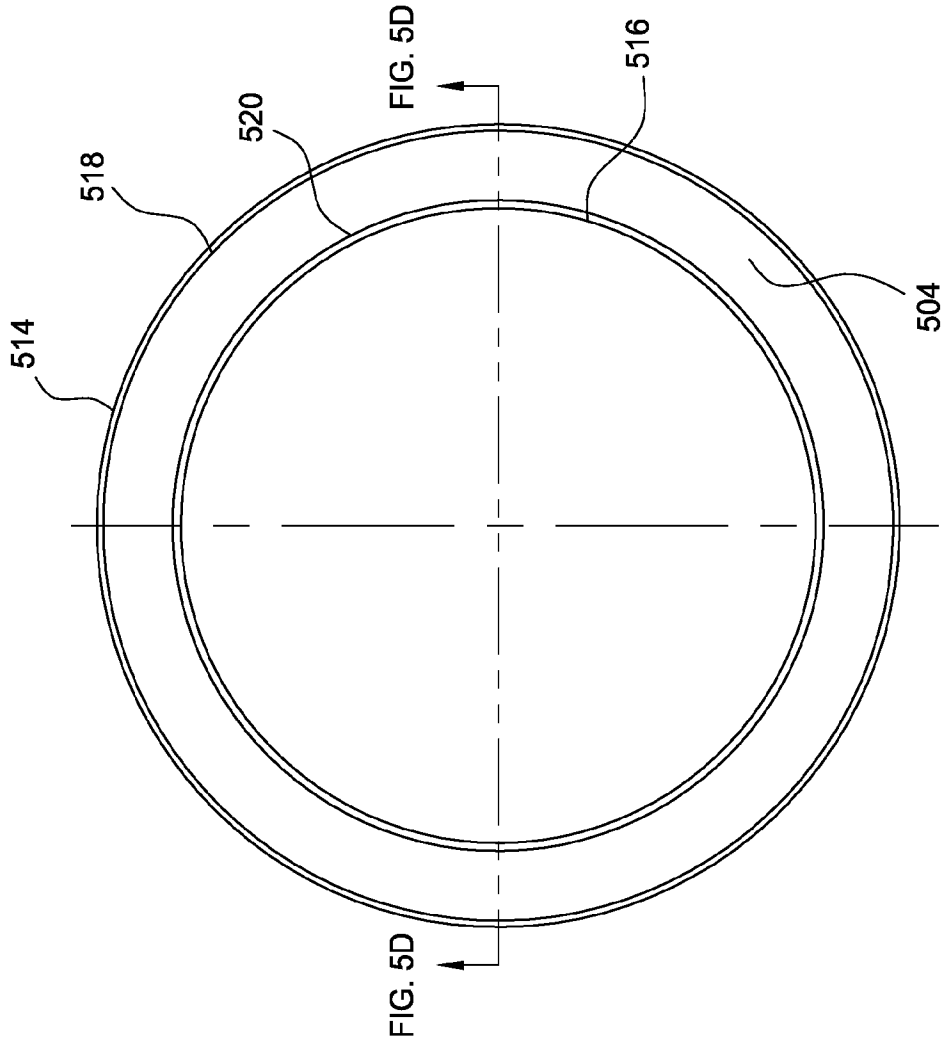


FIG. 5B

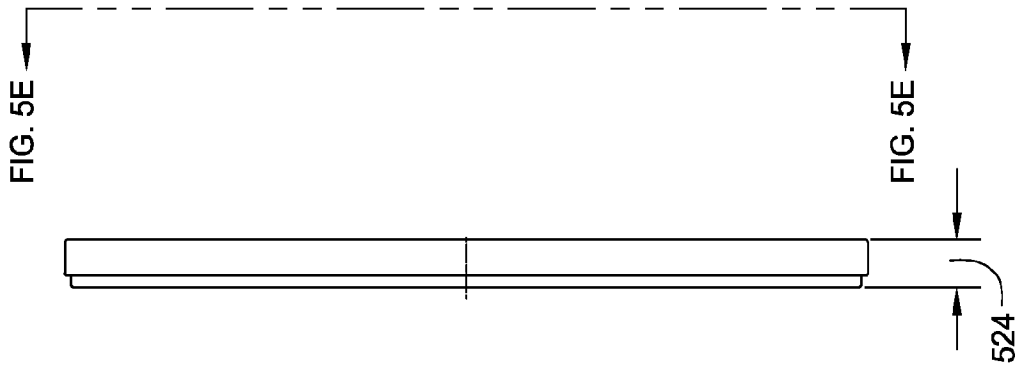


FIG. 5C

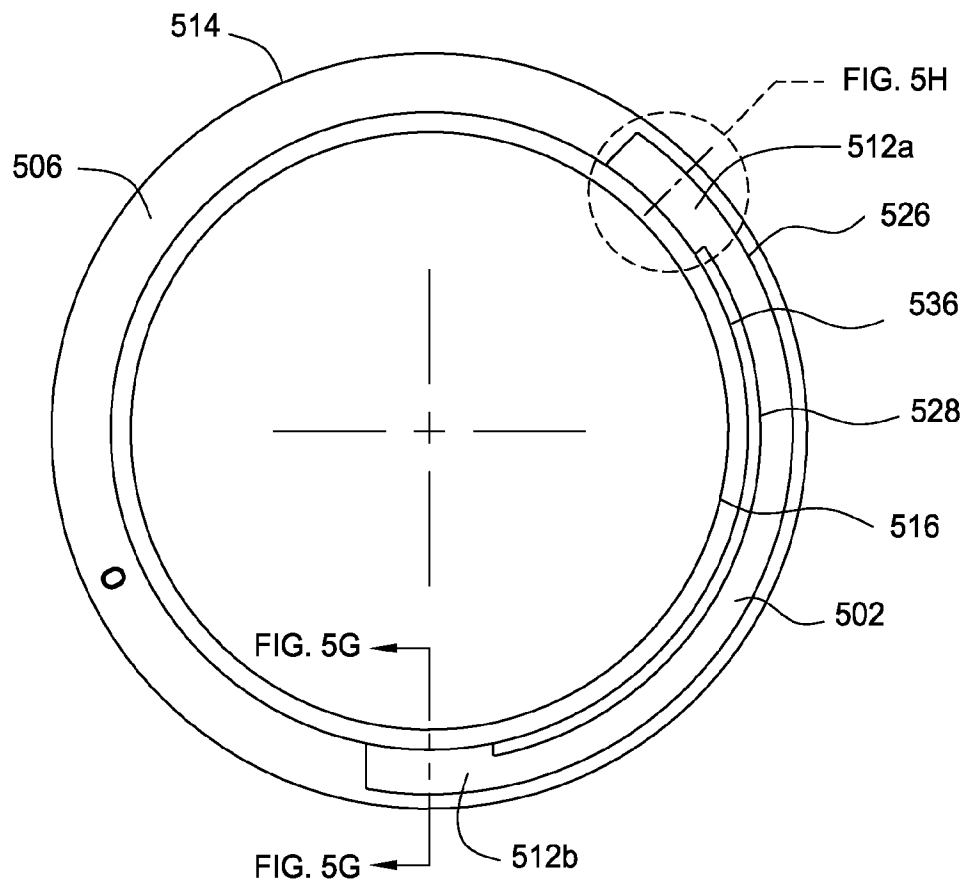


FIG. 5E

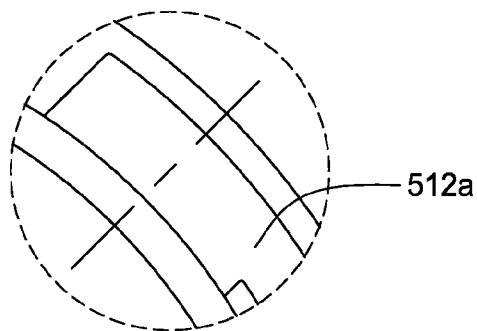


FIG. 5H

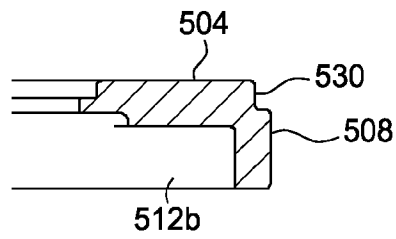


FIG. 5G

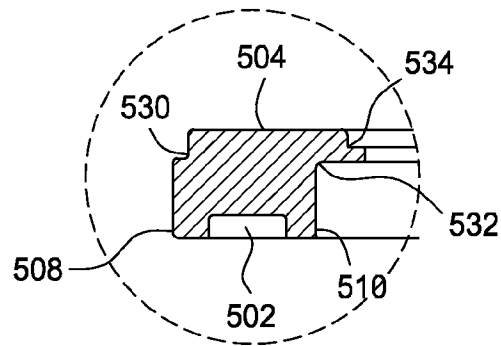


FIG. 5F

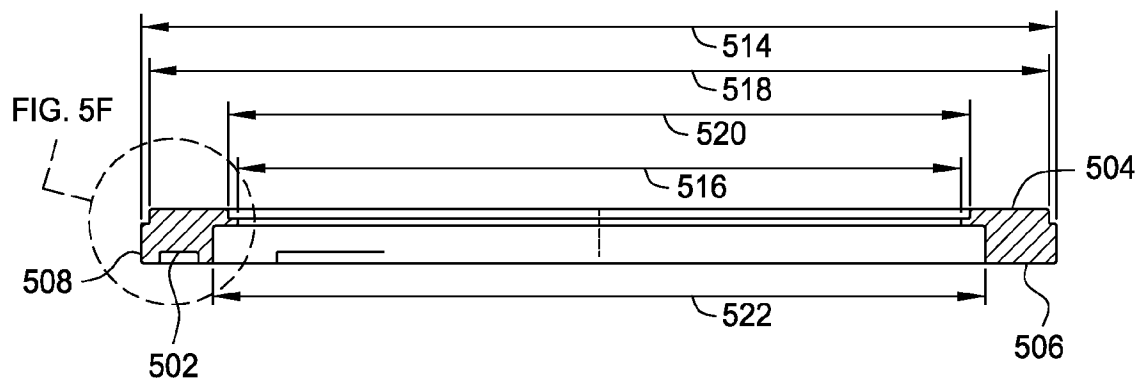


FIG. 5D

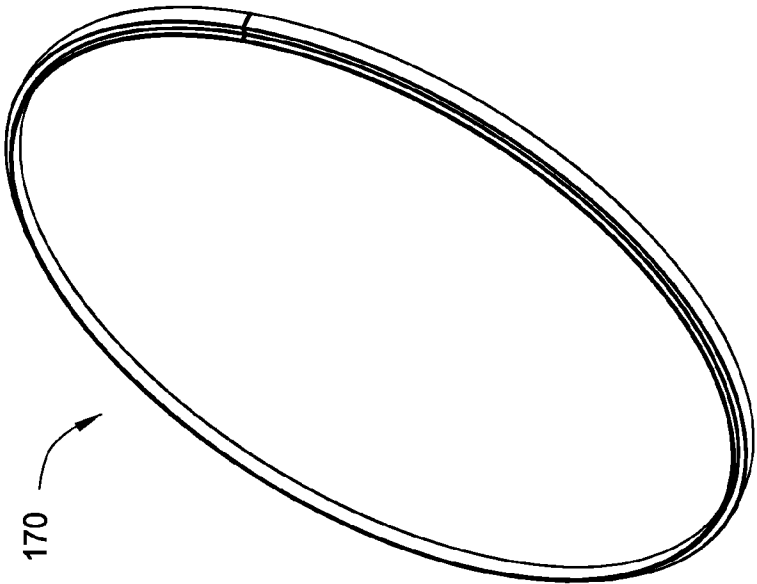


FIG. 6A

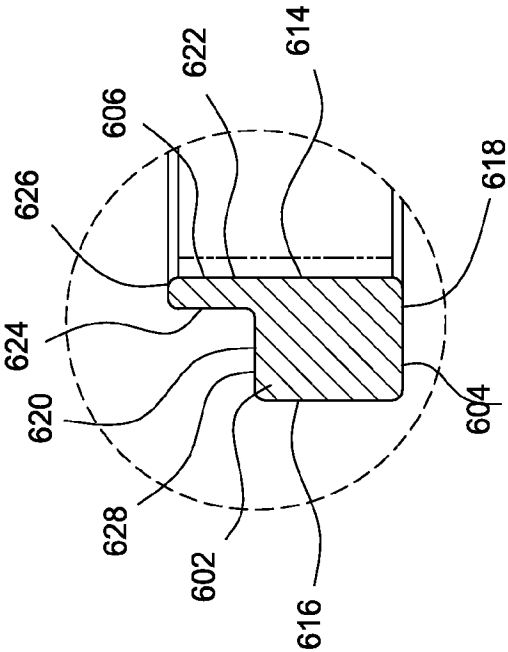


FIG. 6E

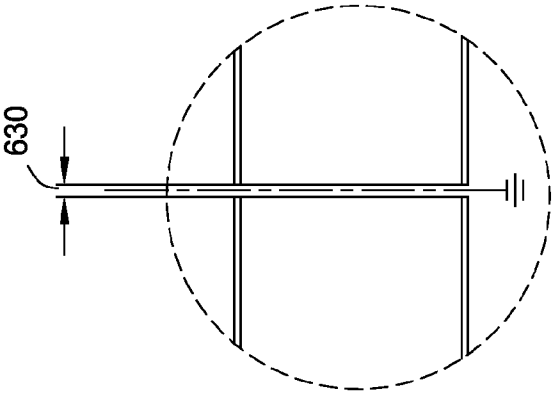


FIG. 6F

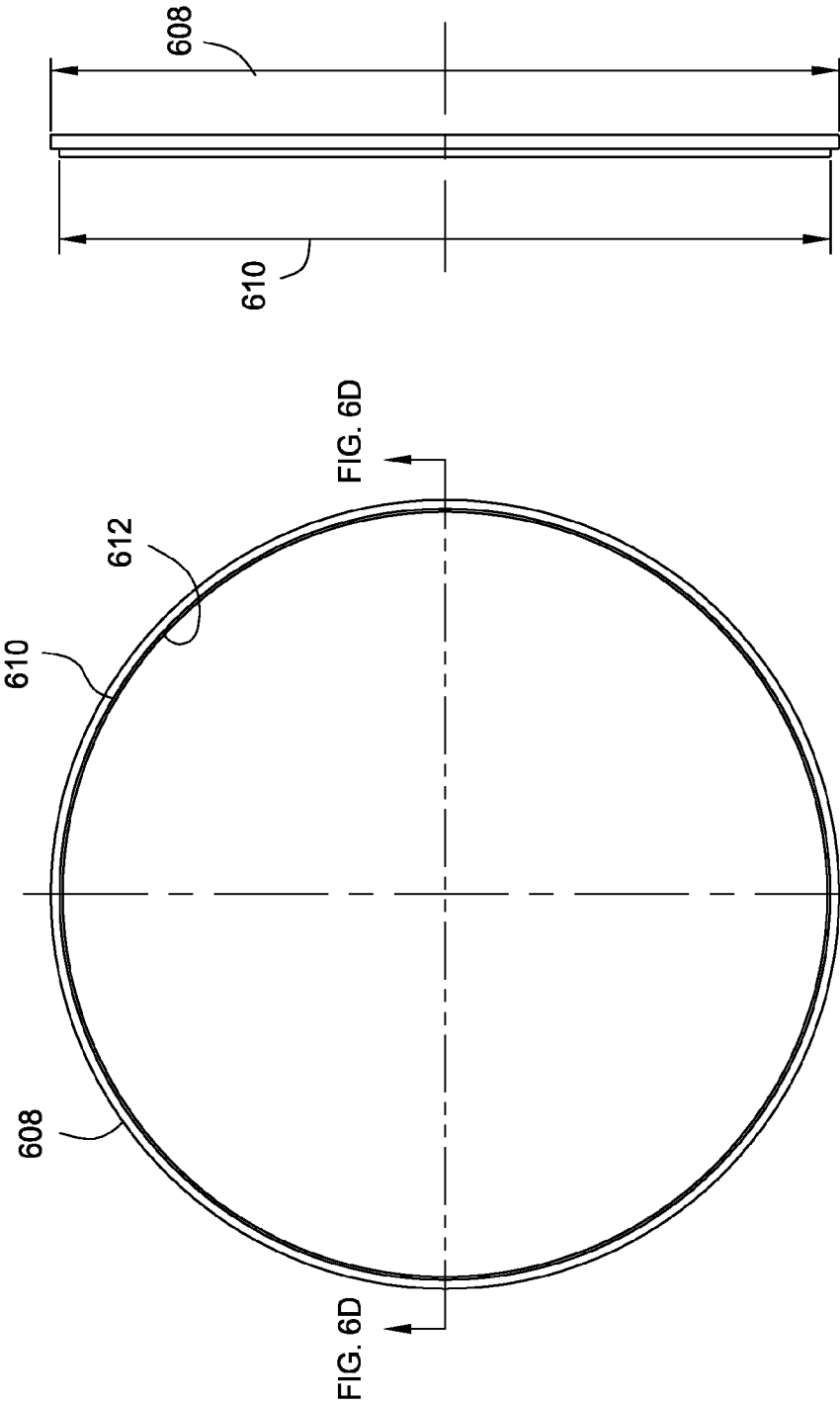


FIG. 6C

FIG. 6B

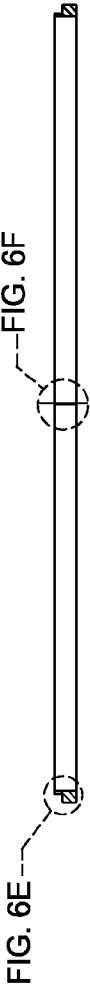
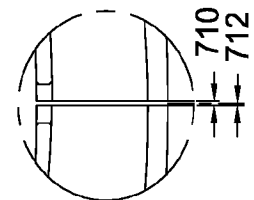
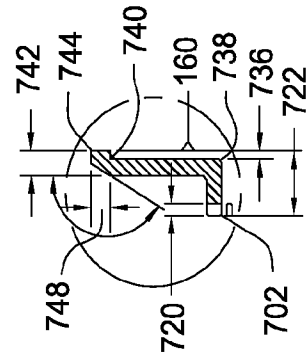
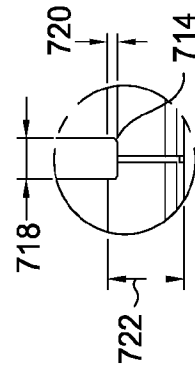
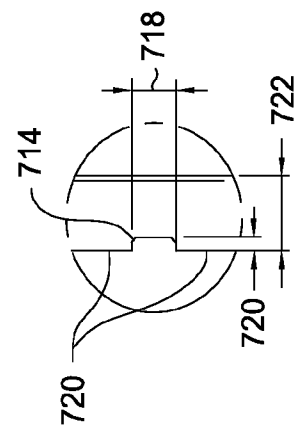
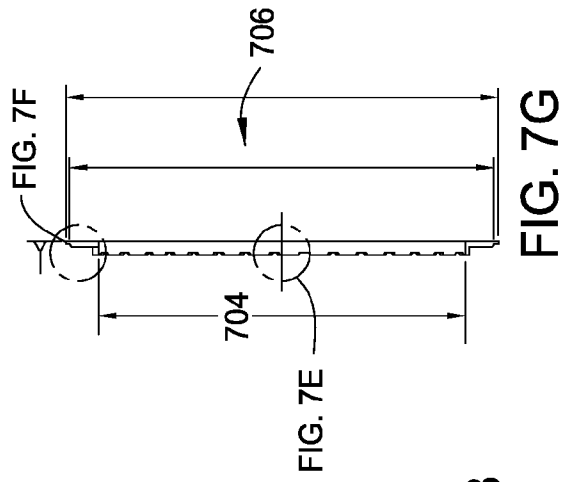
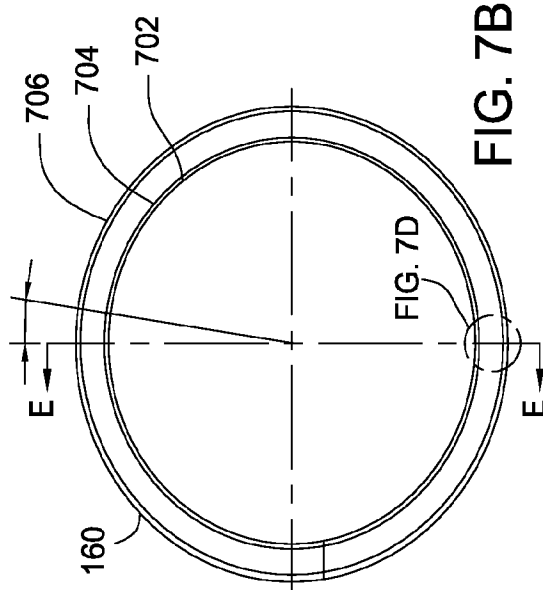
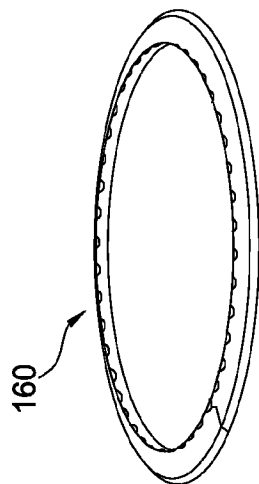
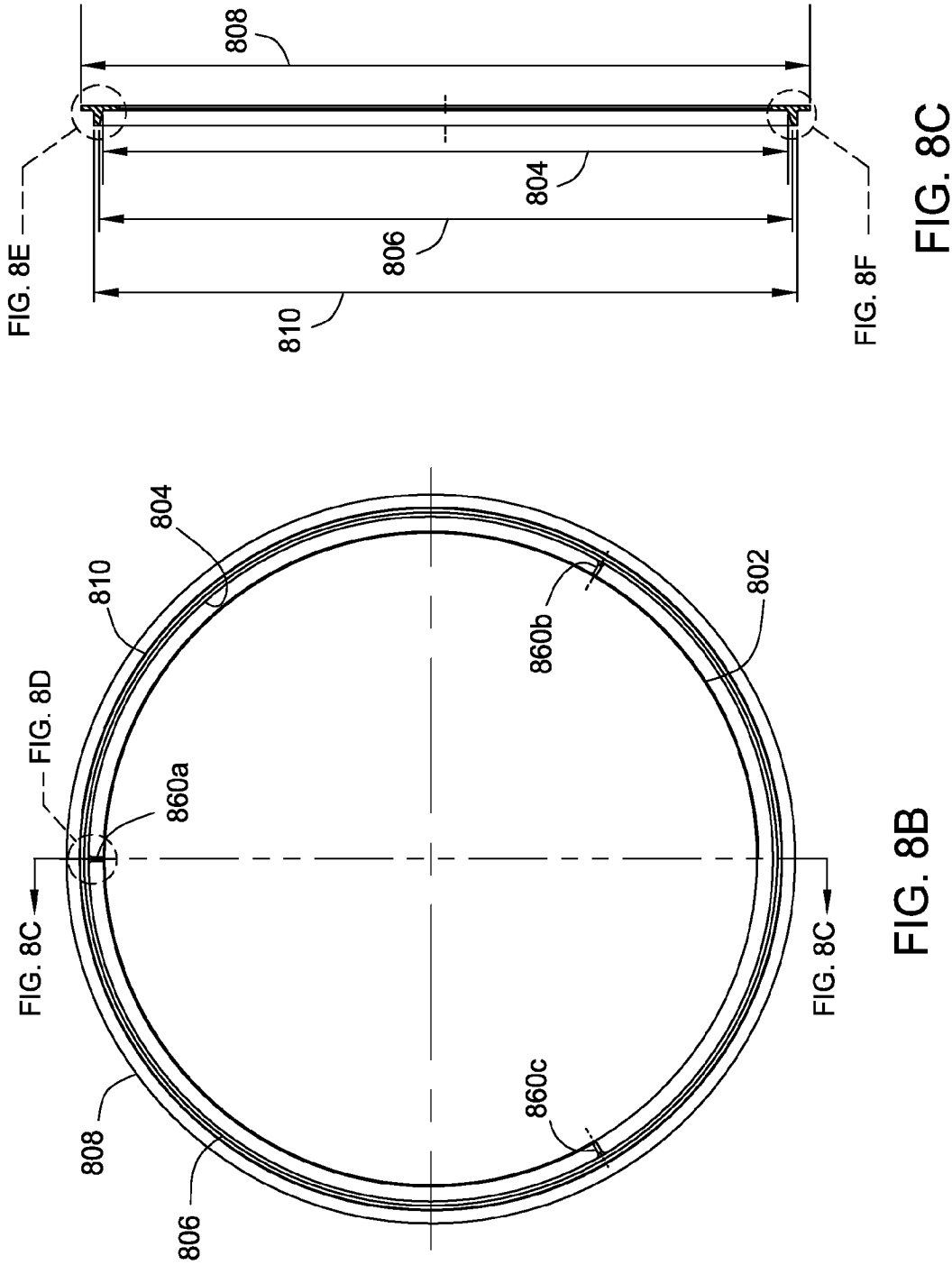


FIG. 6D





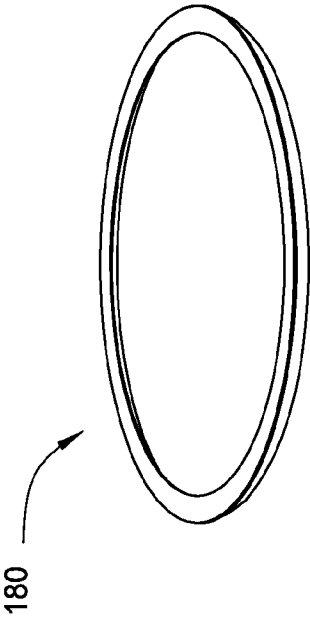


FIG. 8A

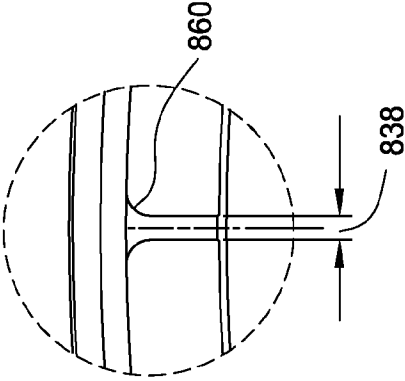


FIG. 8D

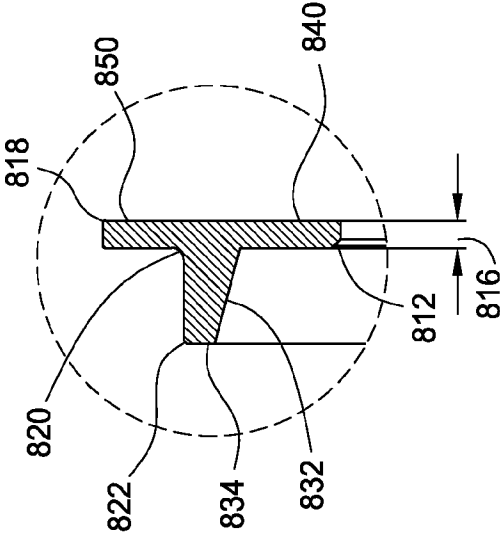


FIG. 8E

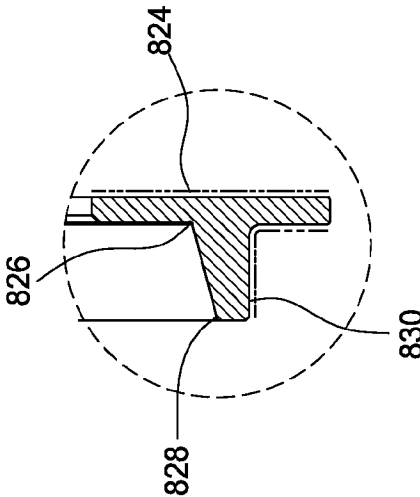
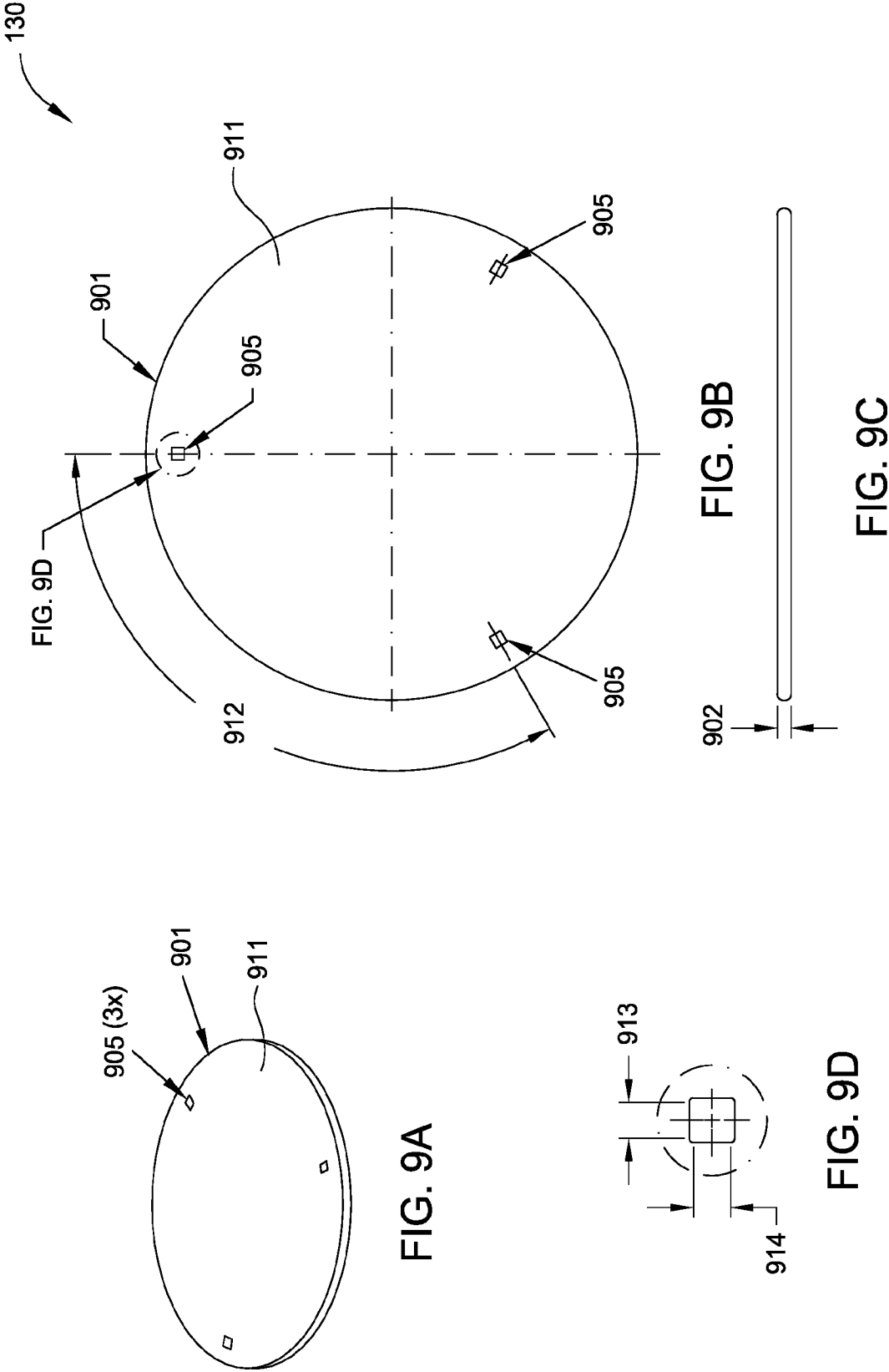


FIG. 8F



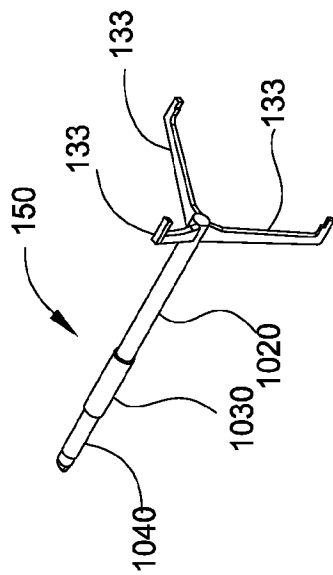


FIG. 10A

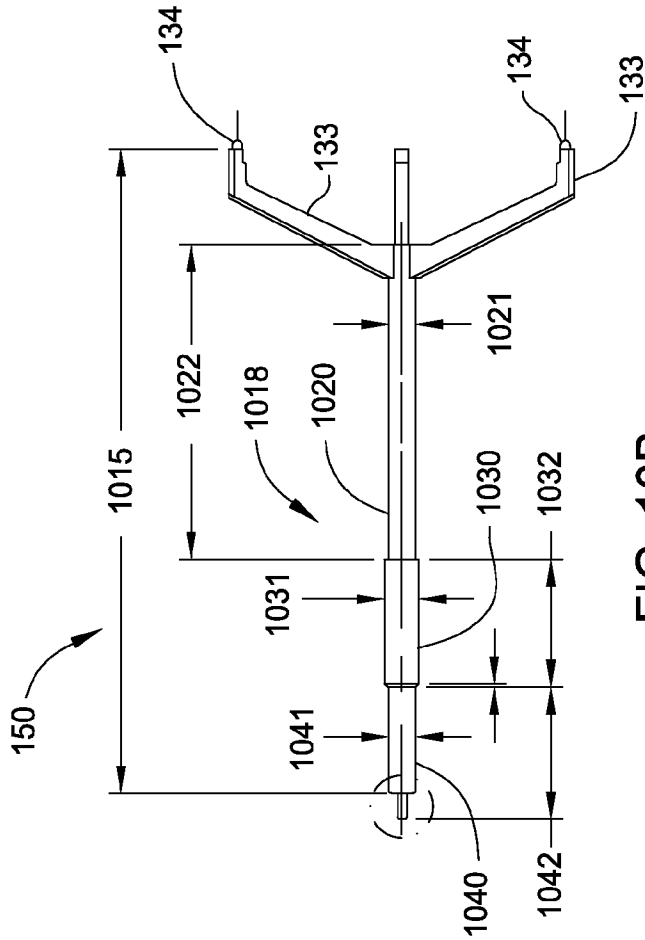


FIG. 10B

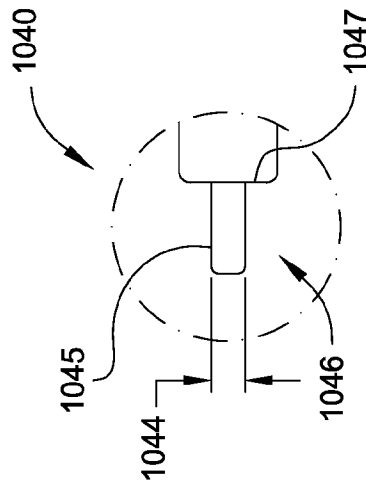


FIG. 10D

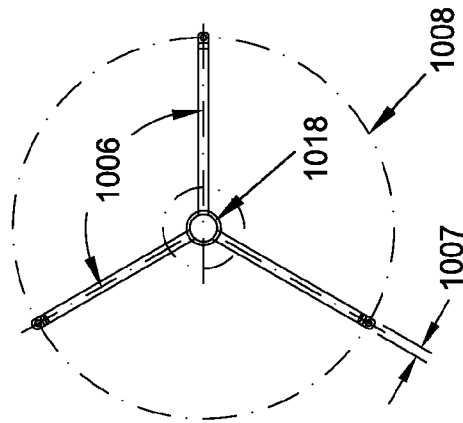


FIG. 10C

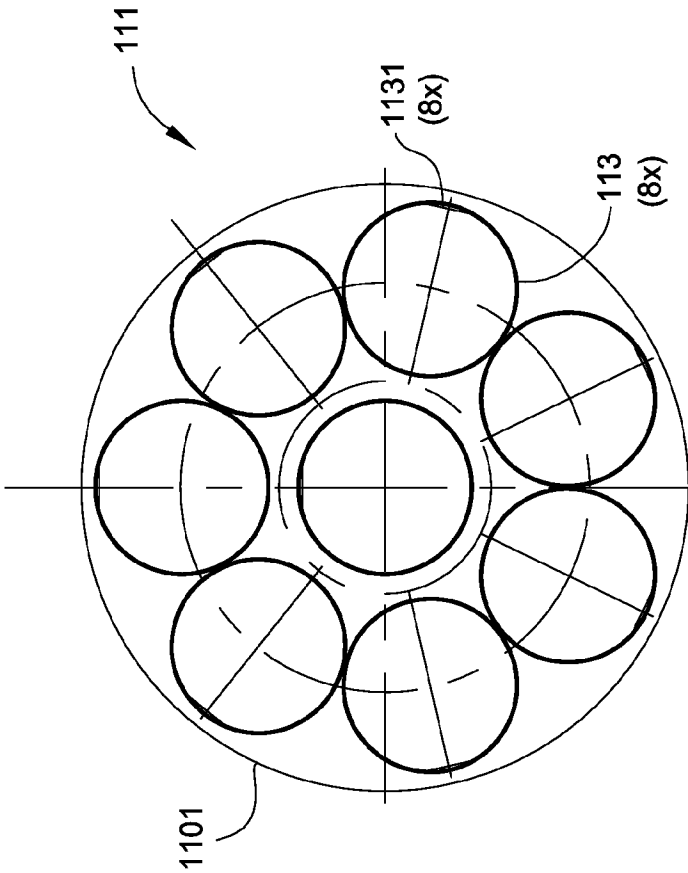


FIG. 11A

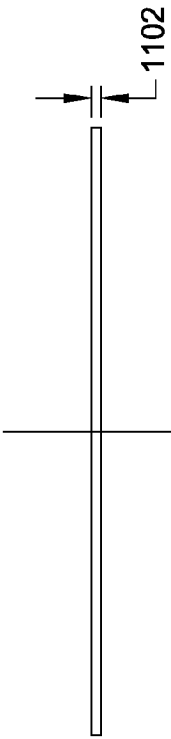


FIG. 11B

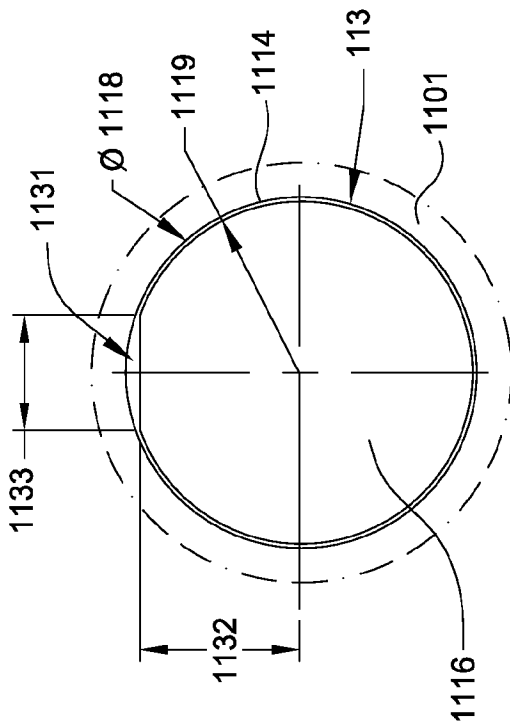


FIG. 11C

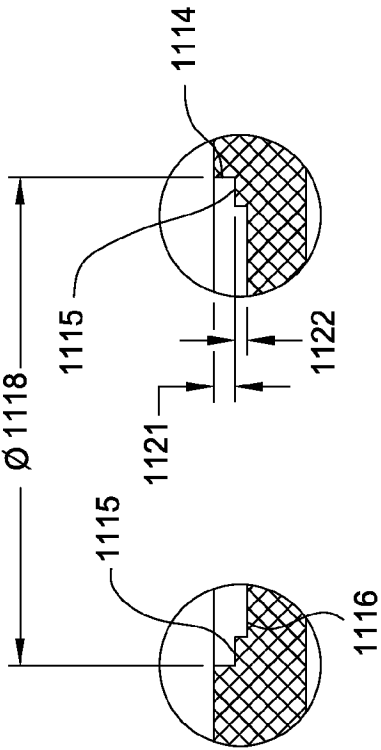


FIG. 11D

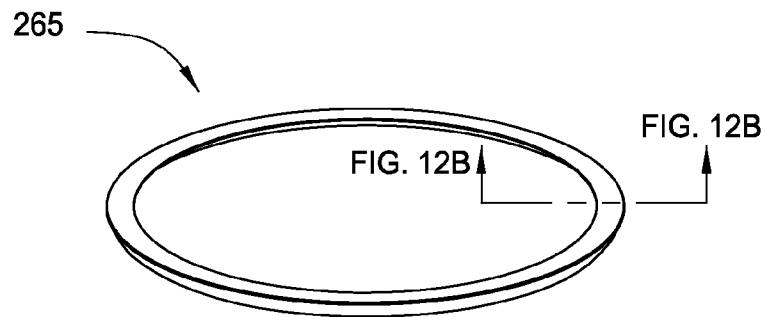


FIG. 12A

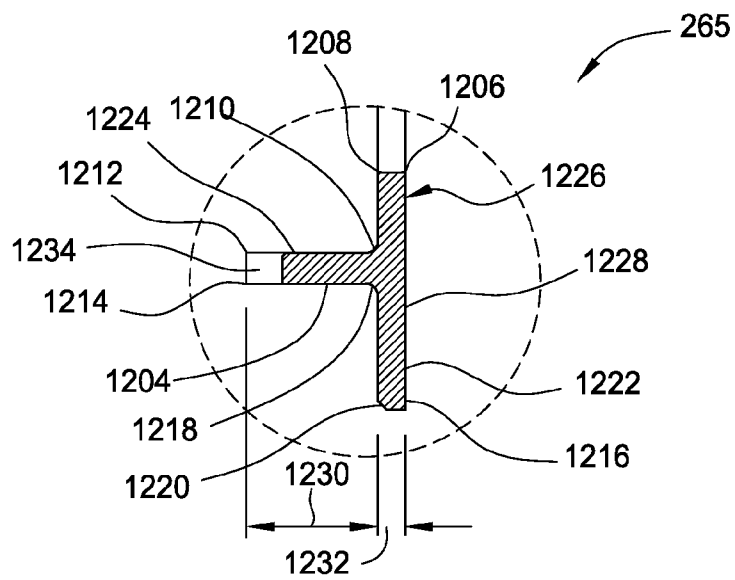


FIG. 12B