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(54) **SYSTEM AND METHOD FOR NEAR SUBSTRATE GAS DELIVERY**

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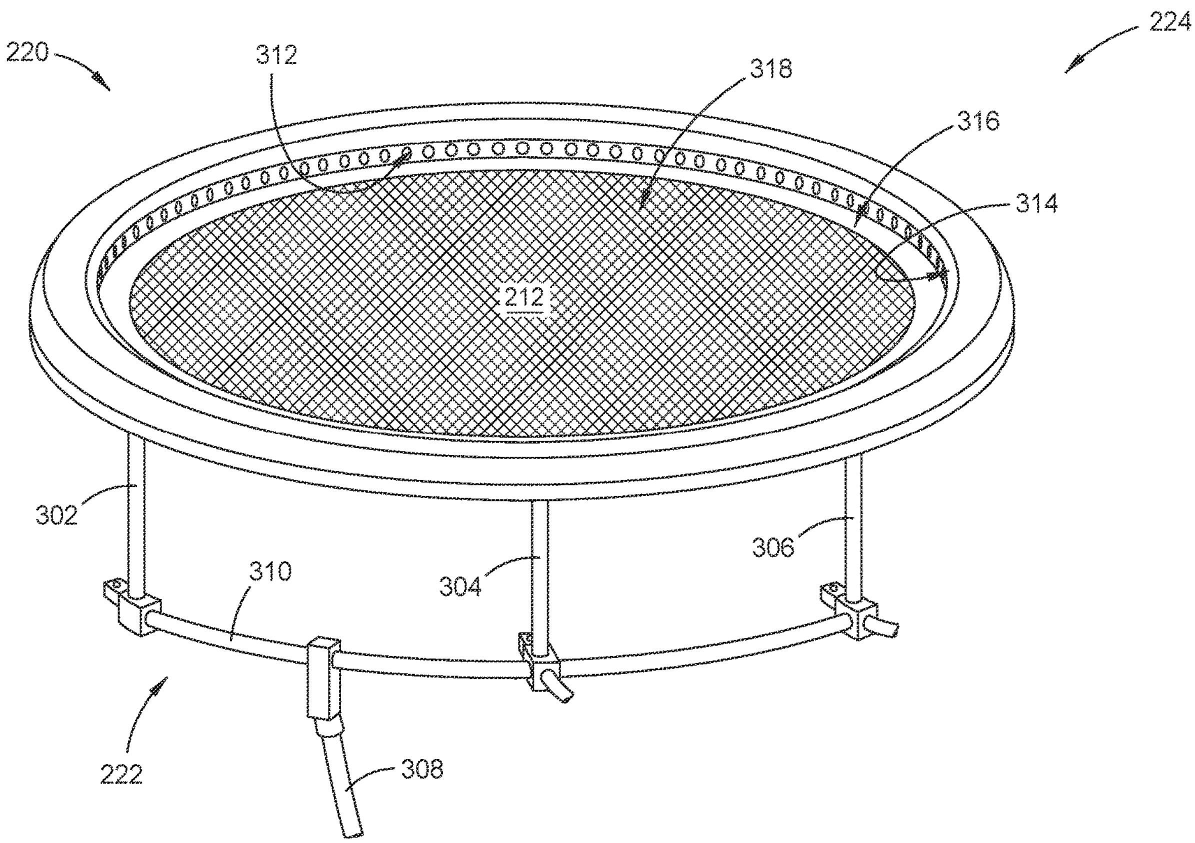
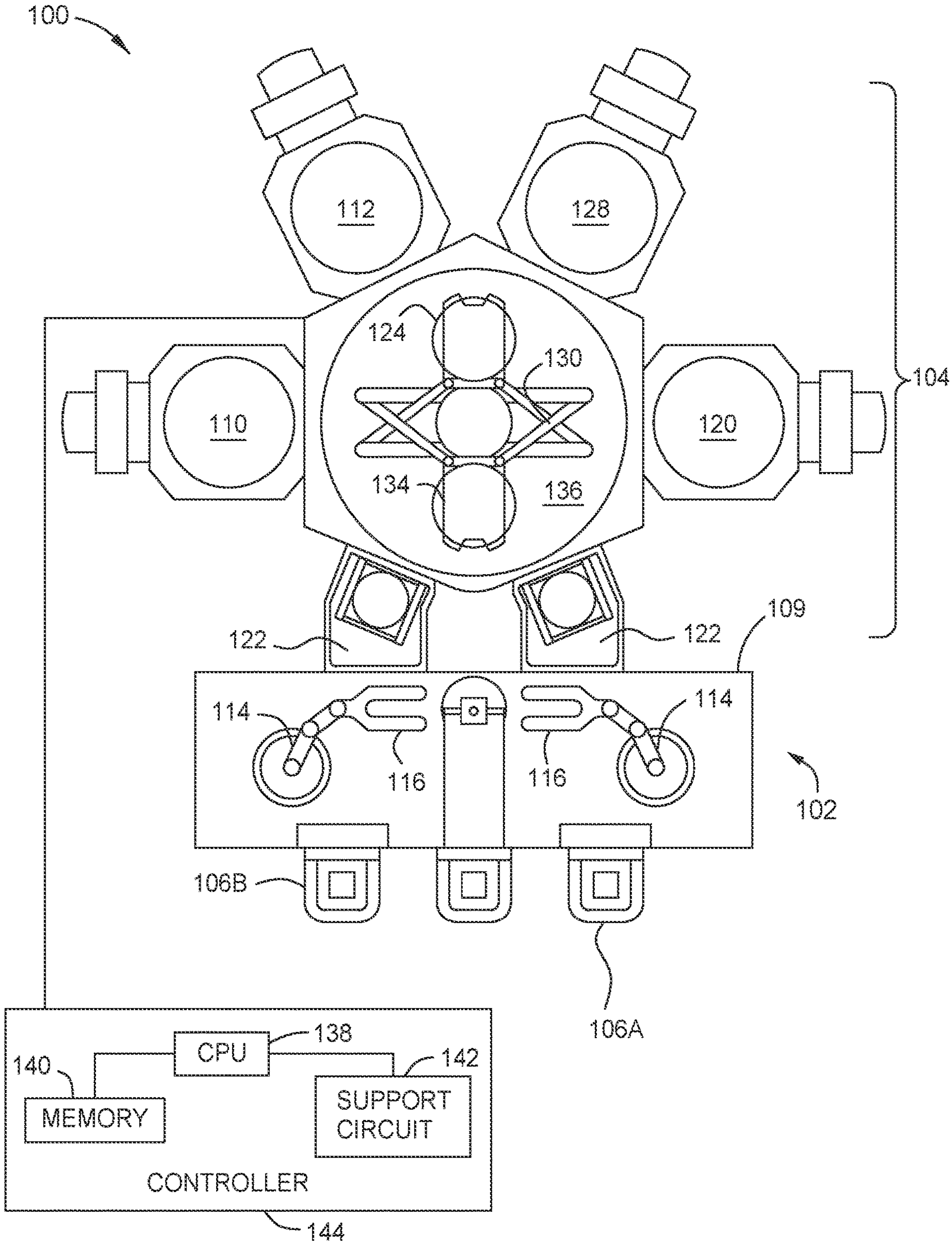
CPC .... ***H01L 21/67069*** (2013.01); ***H01L 21/3065*** (2013.01)

(57) **ABSTRACT**

Disclosed are a gas ring for providing a process gas, a processing chamber having the gas ring, and a gas delivery method. The gas ring includes an annular body surrounding an inner space configured to accommodate a substrate and having a network of gas channels. The network of gas channels includes a plurality of circumferential gas channels coupled with radial gas channels. The plurality of the circumferential gas channels are disposed concentrically around a center of the annular body. The gas ring further includes a plurality of gas inlets and outlets coupled with the network. The gas inlets are disposed along an inner side surface of the annular body. The method includes providing a process gas to the gas ring, flowing the process gas circumferentially and radially along the network of the gas channels, and releasing the process gas via the plurality of gas outlets.





100
112
128
124
130
104
110
120
134
136
122
122
109
114
114
116
116
102
106B
106A
CPU
138
140
142
MEMORY
SUPPORT
CIRCUIT
CONTROLLER
144


FIG. 1

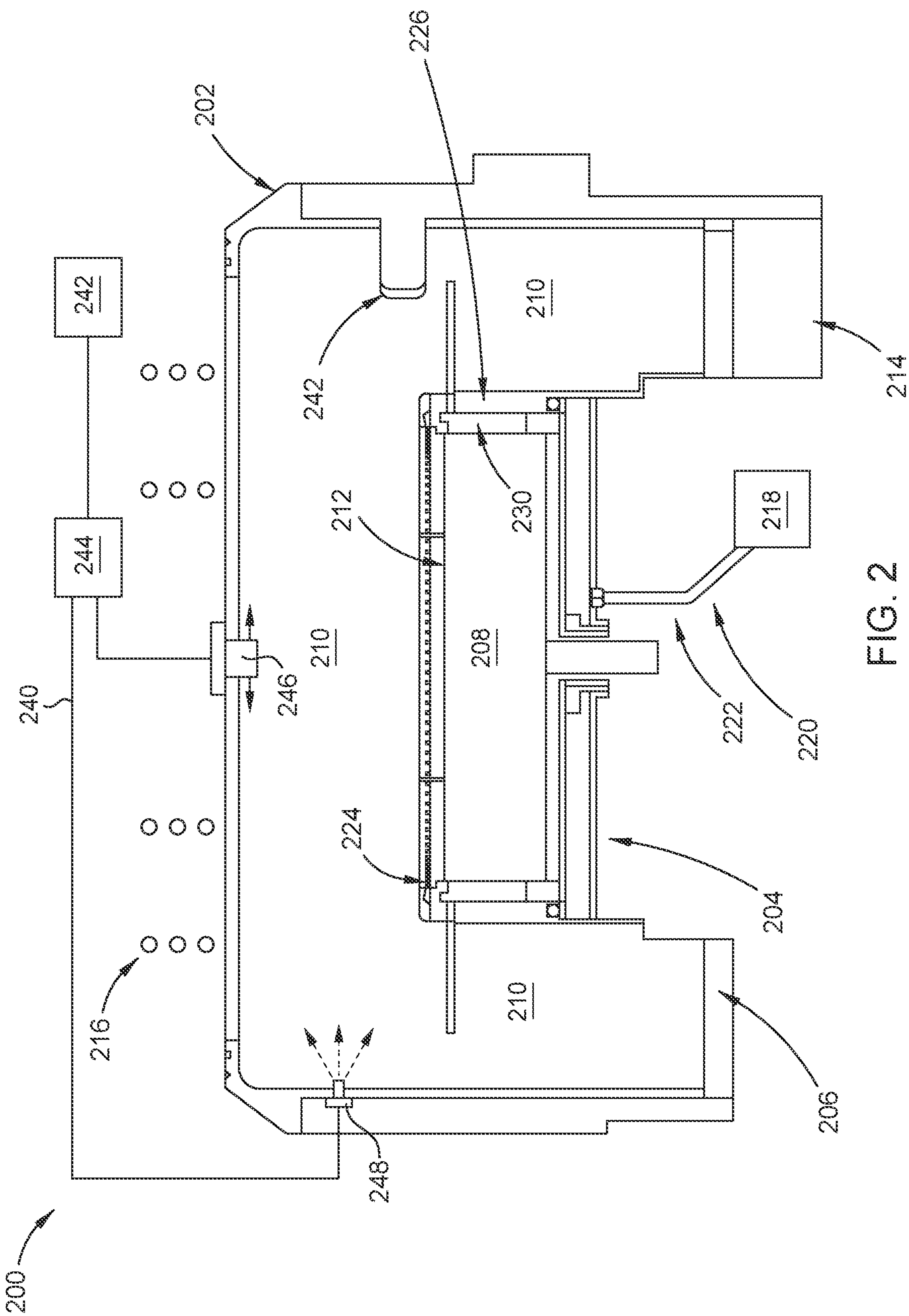

200
202
204
206
208
210
210
210
212
214
216
218
220
222
224
226
230
240
242
242
244
246
248

FIG. 2

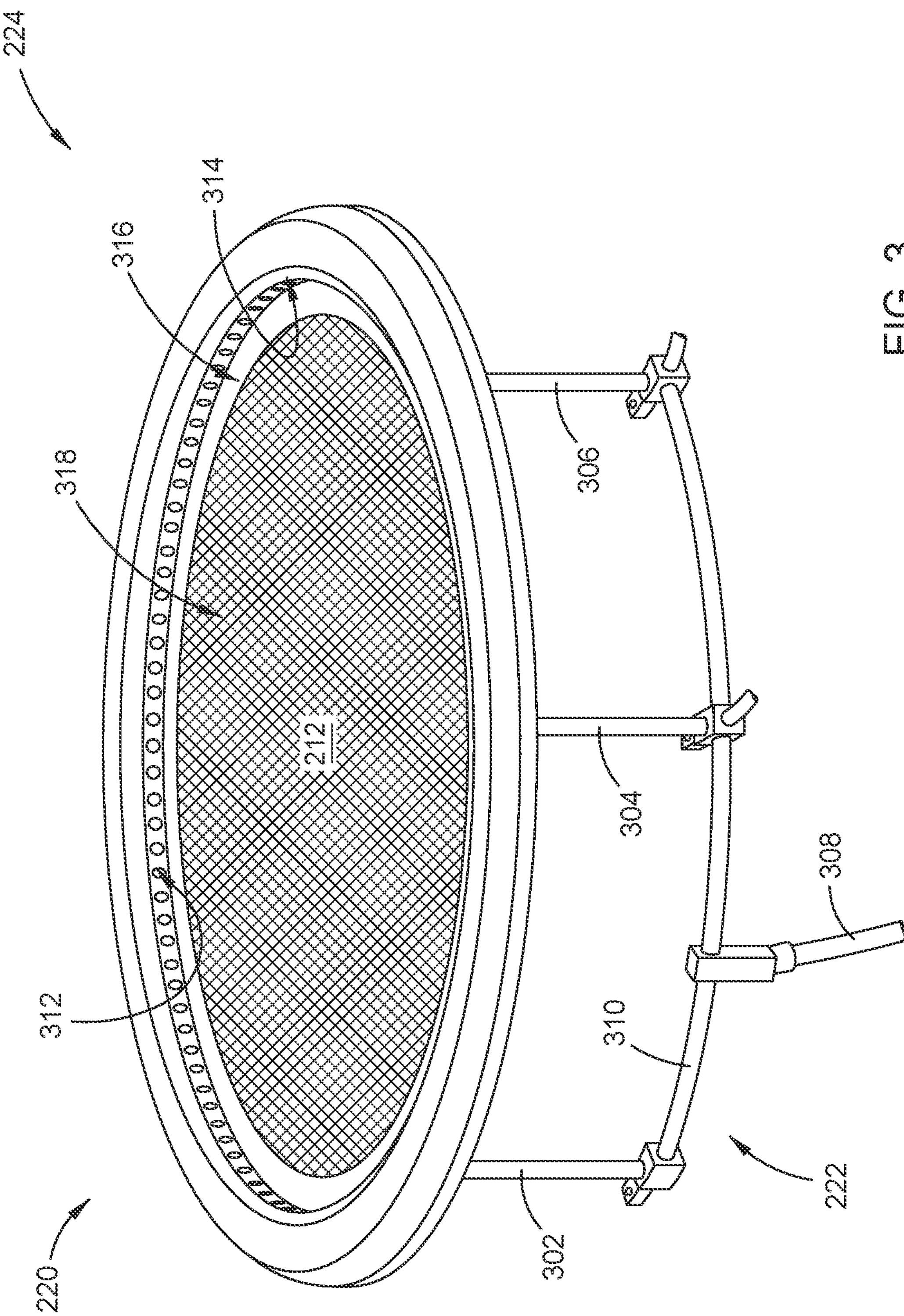



FIG. 3

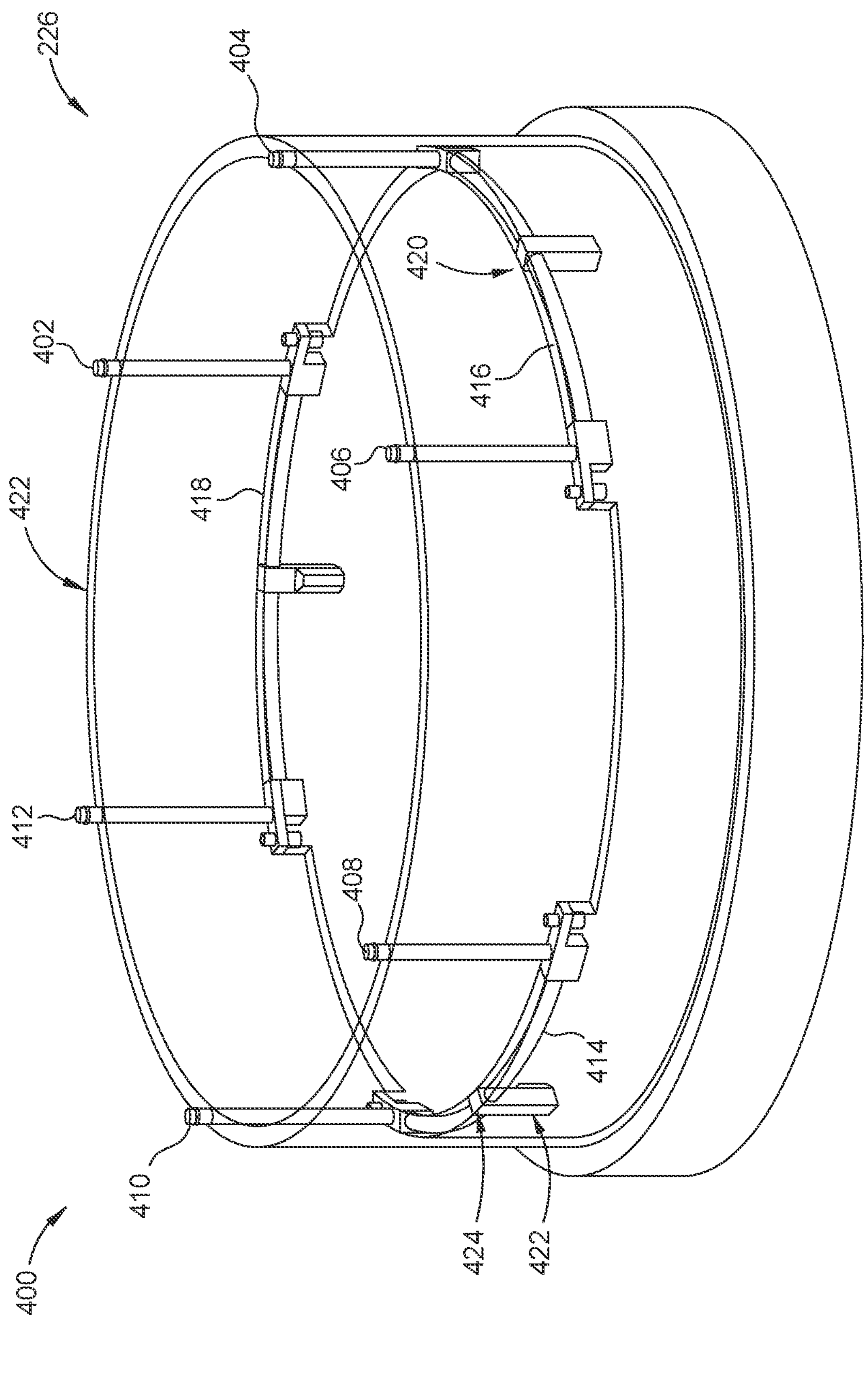
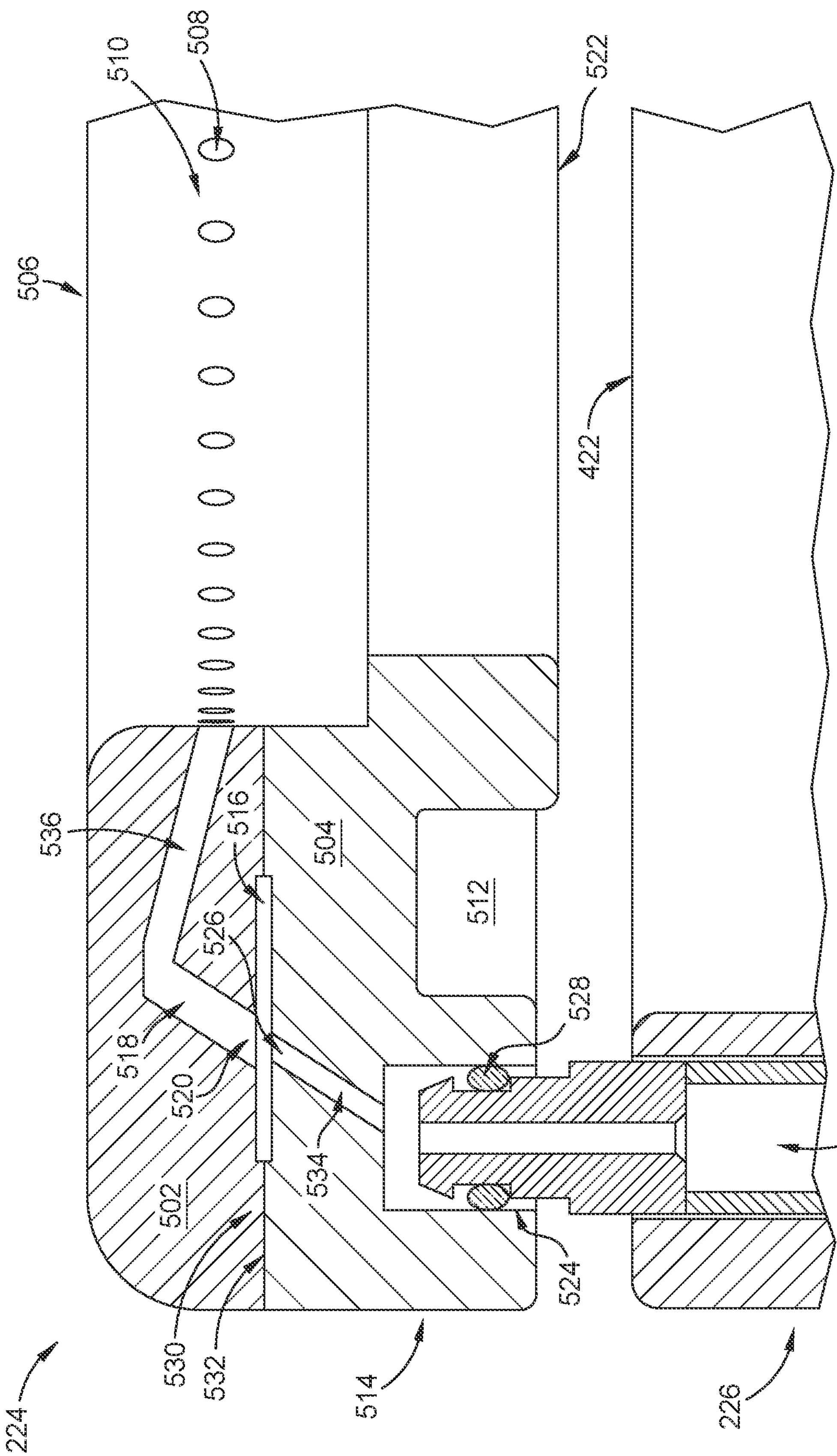



FIG. 4



510
508
522
506
422
536
516
504
512
526
528
518
520
534
302
502
530
532
524
514
226
224


FIG. 5

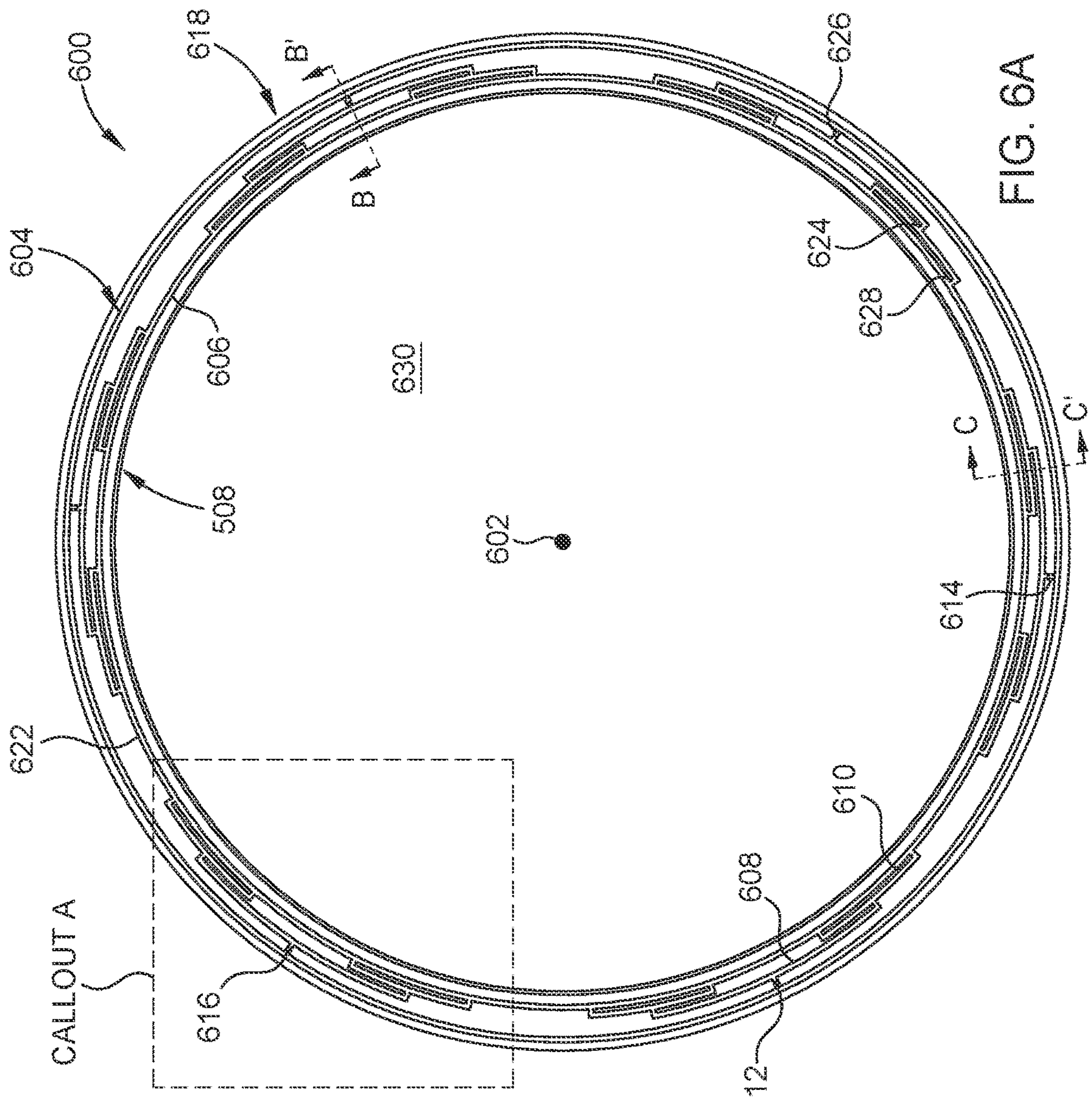

600
618
B'
B
626
604
606
630
624
628
C
C'
508
602
614
622
610
608
CALLOUT A
616
612

FIG. 6A

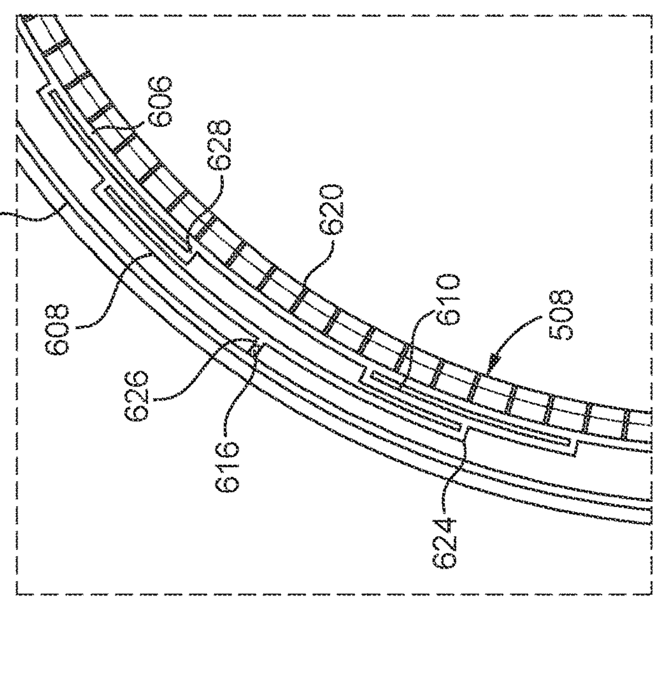

606
628
604
620
610
508
608
626
616
624

FIG. 6B

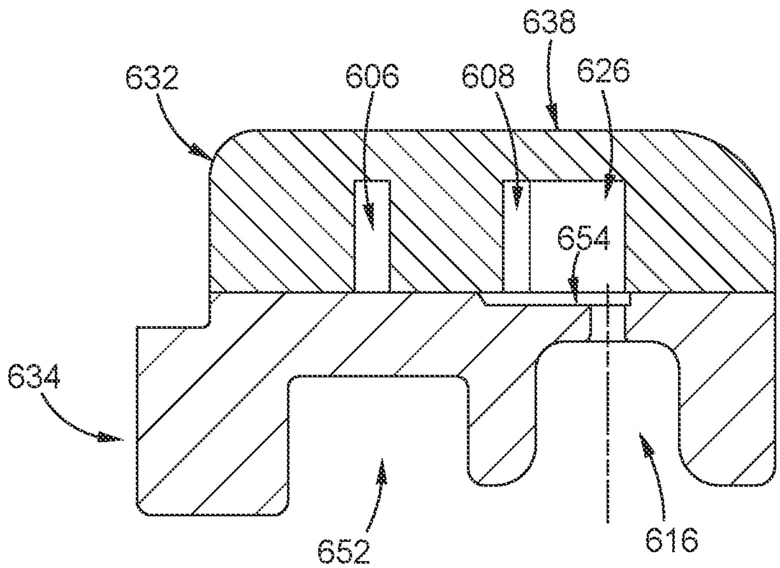

638
632
606
608
626
654
634
652
616

FIG. 6C

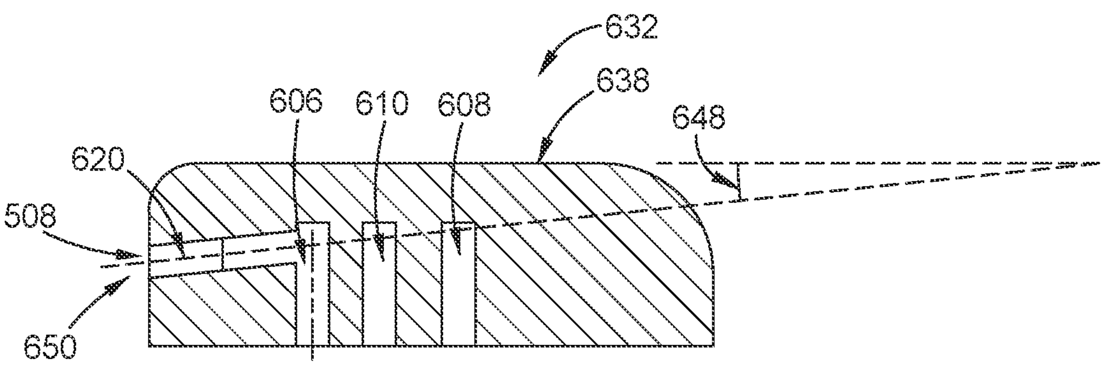

632
638
606
610
608
648
620
508
650

FIG. 6D

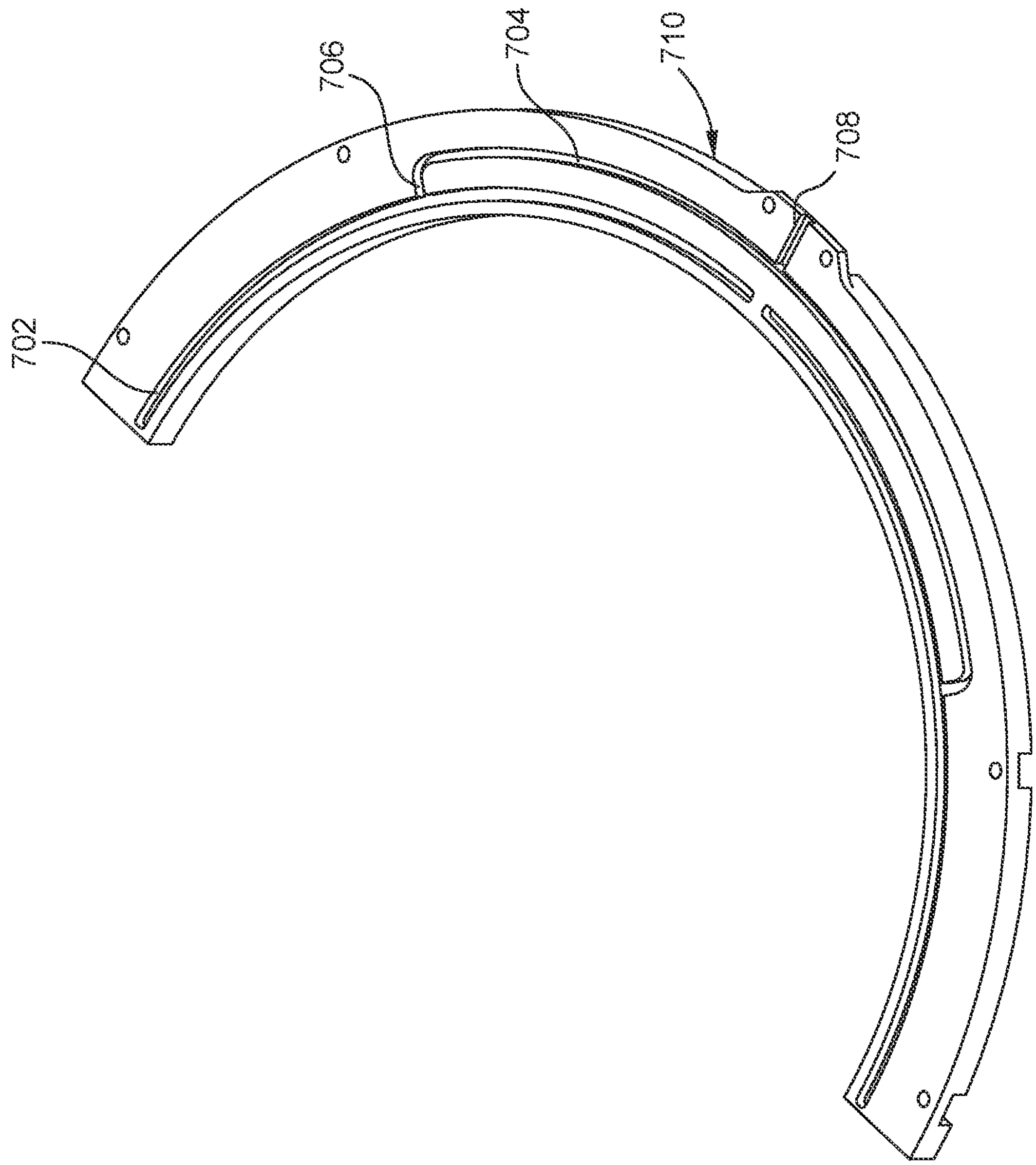



FIG. 7

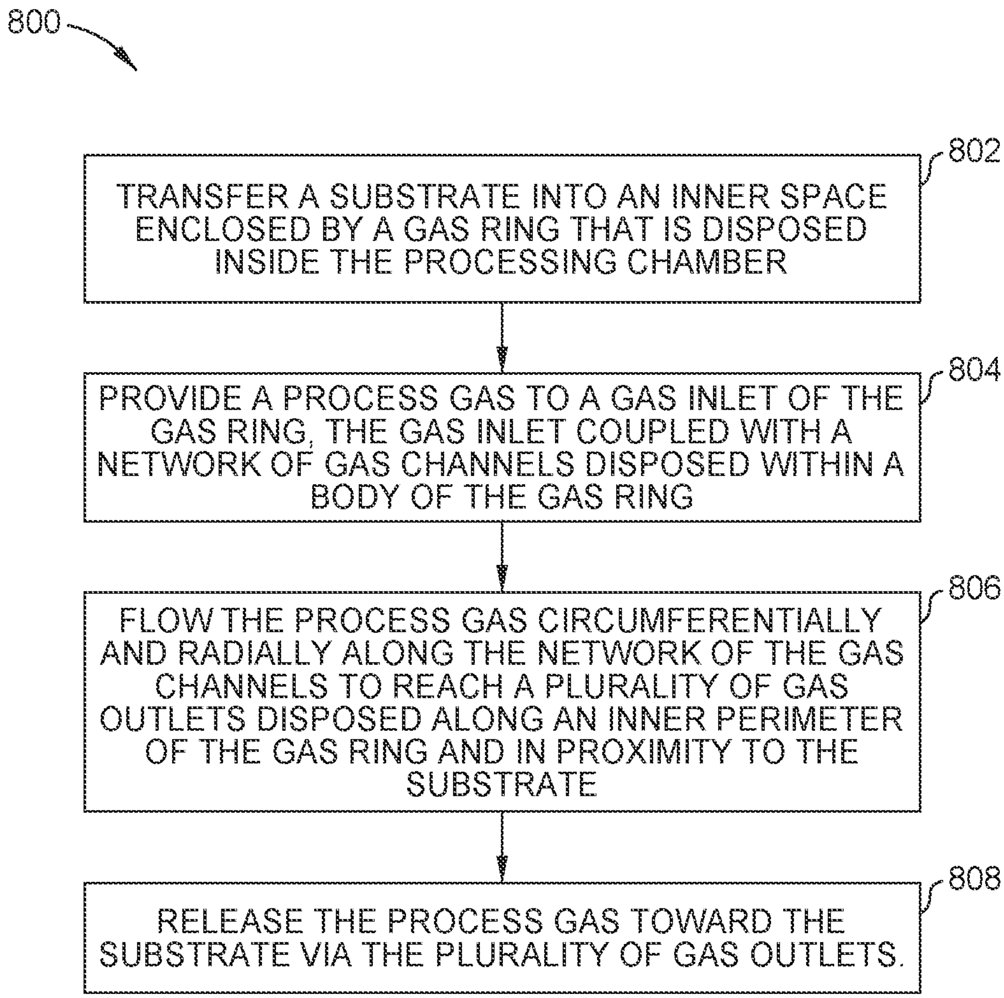

800
802
TRANSFER A SUBSTRATE INTO AN INNER SPACE ENCLOSED BY A GAS RING THAT IS DISPOSED INSIDE THE PROCESSING CHAMBER
804
PROVIDE A PROCESS GAS TO A GAS INLET OF THE GAS RING, THE GAS INLET COUPLED WITH A NETWORK OF GAS CHANNELS DISPOSED WITHIN A BODY OF THE GAS RING
806
FLOW THE PROCESS GAS CIRCUMFERENTIALLY AND RADIALLY ALONG THE NETWORK OF THE GAS CHANNELS TO REACH A PLURALITY OF GAS OUTLETS DISPOSED ALONG AN INNER PERIMETER OF THE GAS RING AND IN PROXIMITY TO THE SUBSTRATE
808
RELEASE THE PROCESS GAS TOWARD THE SUBSTRATE VIA THE PLURALITY OF GAS OUTLETS.

FIG. 8

# SYSTEM AND METHOD FOR NEAR SUBSTRATE GAS DELIVERY

## BACKGROUND

### Field

**[0001]** The present disclosure relates to a system and method for gas delivery to a substrate, and, more specifically, relates to a system configured to provide a near substrate gas delivery.

### Description of the Related Art

**[0002]** In semiconductor processing, a substrate is processed in a chamber filled with process gases. A gas delivery system is used to provide process gases to the chamber. Conventional gas delivery systems may provide process gases from chamber ceiling or from side walls of the chamber. When a conventional gas delivery system that provides process gases from the chamber ceiling is in operation, a center area of a substrate may receive a different flow of the process gas and grow or etch a layer of materials at a different rate compared to the edges of the substrate. As a result, edges of the substrate often experience an uneven growth or removal of material compared to the center of the substrate.

**[0003]** Thus, a need exists for a processing chamber with an improved gas delivery system.

## SUMMARY

**[0004]** Disclosed herein are a gas ring for providing a process gas into a processing chamber, a processing chamber having a gas ring, and a gas delivery method. The gas ring includes an annular body surrounding an inner space configured to accommodate a substrate. The gas ring further includes a network of gas channels disposed within the annular body. The network of gas channels includes a plurality of circumferential gas channels coupled with a plurality of radial gas channels. The plurality of the circumferential gas channels are disposed concentrically around a center of the annular body. The gas ring also includes a plurality of gas inlets coupled with the network of the gas channels; and a plurality of gas outlets coupled with the network of the gas channels and disposed along an inner side surface of the annular body.

**[0005]** In another example, a processing chamber is disclosed that includes a substrate support assembly configured to support a substrate, and a gas delivery system configured to deliver a process gas to the substrate. The gas delivery system includes a gas ring as set forth in the present disclosure.

**[0006]** In yet another example, a gas delivery method is provided. The method provides a process gas into a processing chamber. The gas delivery method includes transferring a substrate into an inner space surrounded by a gas ring that is disposed inside the processing chamber; providing a process gas to a gas inlet of the gas ring, the gas inlet coupled with a network of gas channels disposed within a body of the gas ring; flowing the process gas circumferentially and radially along the network of the gas channels to reach a plurality of gas outlets disposed along an inner side surface of the gas ring and in proximity to an edge of the substrate; and releasing the process gas toward the substrate via the plurality of gas outlets.

## BRIEF DESCRIPTION OF THE DRAWINGS

**[0007]** 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 exemplary embodiments and are therefore not to be considered limiting of its scope, may admit to other equally effective embodiments.

**[0008]** FIG. **1** illustrates a schematic top view of a processing system, according to an embodiment of the present disclosure.

**[0009]** FIG. **2** illustrates a schematic cross-sectional view of a processing chamber having a gas delivery system, according to an embodiment of the present disclosure.

**[0010]** FIG. **3** illustrates a schematic view of the gas delivery system, according to an embodiment of the present disclosure.

**[0011]** FIG. **4** illustrates a schematic perspective view of an installed gas delivery system, according to an embodiment of the present disclosure.

**[0012]** FIG. **5** illustrates a schematic cross-sectional view of a gas ring, according to an embodiment of the present disclosure.

**[0013]** FIG. **6***a* illustrates a schematic top view of a gas ring, according to an embodiment of the present disclosure.

**[0014]** FIG. **6***b* illustrates a schematic view of Callout A of the gas ring in FIG. **6***a*, according to an embodiment of the present disclosure.

**[0015]** FIG. **6***c* illustrates a cross-sectional view of the gas ring along lines B-B' in FIG. **6***a*, according to an embodiment.

**[0016]** FIG. **6***d* illustrates a cross-sectional view of the upper portion of the gas ring along lines C-C' in FIG. **6***a*, according to an embodiment.

**[0017]** FIG. **7** illustrates a schematic bottom view of a gas ring, according to an embodiment of the present disclosure.

**[0018]** FIG. **8** illustrates a gas delivery method, according to an embodiment of the present disclosure.

**[0019]** 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

**[0020]** The disclosure contemplates that terms such as "couples," "coupling," "couple," and "coupled" may include but are not limited to welding, fusing, melting together, interference fitting, and/or fastening such as by using bolts, threaded connections, pins, and/or screws. The disclosure contemplates that terms such as "couples," "coupling," "couple," and "coupled" may include but are not limited to integrally forming. The disclosure contemplates that terms such as "couples," "coupling," "couple," and "coupled" may include but are not limited to direct coupling and/or indirect coupling, such as indirect coupling through components such as links, blocks, and/or frames.

**[0021]** Disclosed herein is a gas delivery system capable of releasing process gases at locations adjacent to an edge of a substrate disposed in a processing chamber. The gas delivery system includes a gas ring disposed in close proximity to an edge of the substrate. The gas ring includes an annular body surrounding an inner space that is configured to accommodate the substrate. The annular body includes a network of gas channels to distribute process gases from a few gas inlets to a plurality of gas outlets. The plurality of gas outlets are disposed at an inner side surface of the annular body. The plurality of gas outlets are disposed in close proximity to the edges of the substrate, such as within a few inches or centimeters or millimeters away from the edges of a substrate. Thus, the gas delivery system is capable of providing a near substrate gas release. The gas delivery system can increase the uniformity of materials deposited or removed on a substrate, especially at edges of the substrate.

**[0022]** The gas delivery system also includes gas lines configured to couple with the gas ring. The gas lines may enter a processing chamber from side walls or from a bottom section of the processing chamber. The gas lines may be disposed inside other parts, such as a sleeve, for protection.

**[0023]** FIG. **1** illustrates a schematic top view of a processing system **100**, according to one or more embodiments. According to an embodiment, the processing system **100** includes a gas delivery system **220** (shown in FIG. **2** and other figures) as described in the present disclosure. The processing system **100** includes one or more load lock chambers **122** (two are shown in FIG. **1**), a processing platform **104**, a factory interface **102**, and a controller **144**. In one or more embodiments, the processing system **100** may be adapted for use in a CENTURA® integrated processing system provided by Applied Materials, Inc., located in Santa Clara, California. It is contemplated that other processing systems (including those from other manufacturers) may be adapted to benefit from the present disclosure.

**[0024]** The processing platform **104** includes a plurality of processing chambers **110**, **112**, **120**, **128**, the one or more load lock chambers **122**, and a transfer chamber **136** that is coupled to the one or more load lock chamber **122**. The transfer chamber **136** can be maintained under vacuum, or can be maintained at an ambient (e.g., atmospheric) pressure. Two load lock chambers **122** are shown in FIG. **1**. The factory interface **102** is coupled to the transfer chamber **136** through the load lock chambers **122**. The gas delivery system **220** can be disposed in one or more of the plurality of processing chambers **110**, **112**, **120**, **128**.

**[0025]** In one or more embodiments, the factory interface **102** includes at least one docking station **109** and at least one factory interface robot **114** to facilitate the transfer of substrates **124**. The docking station **109** is configured to accept one or more front opening unified pods (FOUPs). Two FOUPS **106**A, **106**B are shown in the implementation of FIG. **1**. The factory interface robot **114** having a blade **116** disposed on one end of the robot **114** is configured to transfer one or more substrates from the FOUPS **106**A, **106**B, through the load lock chambers **122**, to the processing platform **104** for processing. Substrates being transferred can be stored at least temporarily in the load lock chambers **122**.

**[0026]** Each of the load lock chambers **122** has a first port interfacing with the factory interface **102** and a second port interfacing with the transfer chamber **136**. The transfer chamber **136** has a vacuum robot **130** disposed therein. The vacuum robot **130** has one or more blades **134** (two are shown in FIG. **1**) capable of transferring the substrates **124** between the load lock chambers **122** and the processing chambers **110**, **112**, **120**, and **128**.

**[0027]** The controller **144** is coupled to the processing system **100** and is used to control processes and methods, such as the operations of the methods described herein (for example the operations of the methods as described in other parts of the present disclosure). The controller **144** includes a central processing unit (CPU) **138**, a memory **140** containing instructions, and support circuits **142** for the CPU. The controller **144** controls various items directly, or via other computers and/or controllers.

**[0028]** FIG. **2** illustrates a processing chamber **200** having a gas delivery system **220** according to an embodiment. The processing chamber **200** may be any one of the processing chambers **110**, **112**, **128**, and **120** as shown in FIG. **1**. The processing chamber **200** illustrated in FIG. **2** includes chamber walls **202** coupled with a base **206**. The processing chamber **200** further includes a substrate support assembly **208** supported by a bottom plate **204** and surrounded by a sleeve **226**. A liner **230** is disposed between the sleeve **226** and the substrate support assembly **208** for protection. The chamber walls **202**, the base **206**, and the bottom plate **204** together enclose a processing region **210**. A substrate support assembly **208** is disposed in the processing region **210** and supports a substrate **212** thereon during processing. The chamber walls **202** include at least one substrate transfer port **242** for transferring the substrate **212** in or out of the processing chamber **200**. The base **206** includes an exhaust port **214** coupled with a pump (not shown) configured to remove effluent gases from the chamber **200**. The chamber **200** may also include a plasma source **216**, such as RF coils, configured to energize the process gases in the processing region **210**. The plasma source **216** may be disposed along a lid or side walls of the processing chamber **200**.

**[0029]** The gas delivery system **220** of the processing chamber **200** is coupled with a plurality of gas sources **218**. The gas delivery system **220** provides process gases from the plurality of gas sources **218** into the processing region **210**. The gas delivery system **220** is configured to release the process gas at a location adjacent to edges of the substrate **212**. According to an embodiment, the location to release the process gas is less than three (3) inches, two (2) inches, one (1) inch, or half (½) inch away from an edge of the substrate **212**. The gas delivery system **220** includes a plurality of gas lines **222** and a gas ring **224**, which will be described in detail in the following sections of the present disclosure. In one example, gas lines **222** of the gas delivery system **220** enter the processing chamber **200** from the bottom, such as the bottom plate **204** or the base **206**, of the processing chamber **200**. In another example, gas lines **222** of the gas delivery system **220** may enter the processing chamber **200** from chamber walls **202**.

**[0030]** The gas ring **224** may be disposed on the sleeve **226** that surrounds the substrate support assembly **208**. The gas ring **224** may additionally couple with a liner **230** of the substrate support assembly **208**. The coupling between the gas ring **224** and the liner **230** is configured to prevent process gases from entering between the sleeve **226** and the liner **230**. The plurality of gas lines **222** may be disposed in other parts of the processing chamber **200**, such as the sleeve **226**.

**[0031]** The processing chamber **200** may also include another gas delivery system **240**. The gas delivery system **240** is configured to provide process gases into the processing region **210** at locations different from those of the gas delivery system **220**. The gas delivery system **240** may be configured to provide a majority of the process gases for processing a substrate, while the gas delivery system **220** functions as an additional tuning knob to fine-tune processing parameters near edges of a substrate. In an embodiment, the gas delivery system **240** includes a gas source **242**, a gas splitter **244**, a center gas nozzle **246**, and one or more side gas nozzles **248**. The gas source **242** provides process gases to the gas splitter **244**, which splits the process gases into two or more streams and then provides the two or more streams of process gases to the center gas nozzle **246** and the one or more side gas nozzle **248**, respectively. The center gas nozzle **246** is disposed inside the processing chamber **200** at a center point above the processing region **210**. The one or more side gas nozzles **248** are disposed along side walls of the processing chamber **200**. In an embodiment, the gas delivery systems **240** and **220** provide the same process gases to the processing chamber **200**, but at different flow rates. Yet in another embodiment, the gas delivery systems **240** and **220** provide different process gases to the processing chamber **200**.

**[0032]** FIG. **3** illustrates a configuration of the gas delivery system **220** according to an embodiment. The gas delivery system **220** includes a plurality of gas lines **222** configured to provide process gases to the gas ring **224**. The gas ring **224** surrounds an inner space **318** that accommodates the substrate **212**. The plurality of gas lines **222** include a plurality of feed lines **302**, **304**, and **306** connected with the gas ring **224**. The plurality of the feed lines **302-306** may connect with the gas ring **224** at any suitable locations, such as a bottom surface, a side surface, or a top surface of the gas ring. The plurality of gas lines **222** may further include a main line **308** and a distribution line **310**. The main line **308** is configured to couple a gas source with the distribution line **310**, which distributes the process gas to a plurality of feed lines. According to an embodiment, the main line **308** has a greater diameter than the distribution line **310**, which has a greater diameter than the feed lines **302-306**. The number of feed lines is not limited to the three (3) feed lines shown in FIG. **3** and can be **6**, **12**, or any other suitable number. In an embodiment, the gas delivery system **220** includes six (6) feed lines arranged at equal distances along the perimeter of the gas ring **224**.

**[0033]** The gas ring **224** is configured to release process gases in close proximity to edges of the substrate **212**. The gas ring **224** includes a plurality of gas outlets **312** disposed at an inner side surface **314** of the gas ring **224**. The size of the gas ring **224** is configured to be slightly greater than that of the substrate **212**. When the gas ring **224** is disposed adjacently to and surrounds the substrate **212**, the gas outlets **312** are near the edge **316** of the substrate **212**, such as less than a few inches. For example, the gas outlets **312** may be less than three, two, or one inches away from the edge **316** of the substrate **212**. The plurality of the gas outlets **312** may be evenly arranged along the entire inner perimeter of the gas ring **224**. According to an embodiment, the angular separation between adjacent gas outlets **312** may be less than six (6), three (3), two (2), or one (1) degrees. The gas ring **224** may be made of aluminum, quartz, ceramic or any other suitable material.

**[0034]** FIG. **4** illustrates a perspective view of a gas delivery system **400** according to an embodiment. The gas delivery system **400** has gas lines that enter the processing chamber **200** from the bottom. The gas delivery system **400** includes six (6) feed lines **402-410** disposed inside the sleeve **226** (shown in FIG. **2**). The feed lines **402-410** are vertically arranged. The sleeve **226** has a circular shape. The feed lines **402-410** may be equidistant from each other along the circumference of the sleeve **226**. For example, the angular separation between adjacent feed lines may be **60** degrees. The feed lines **402-410** enter the sleeve **226** from a bottom surface **420** and exit at a top surface **422** of the sleeve **226**. The distribution lines **414-418** are disposed along the bottom surface **420** of the sleeve **226** and have a shape substantially in conformance with the shape of the sleeve **226**. In one example, each distribution line **414**, **416**, and **418** are coupled with two feed lines such that the process gas is evenly distributed to the two feed lines. In other examples, the distribution line may be coupled with any suitable number of feed lines, such as three (3), four (4), five (5), or even greater number of feed lines. In an embodiment, a stream of a process gas in a delivery line **422** equally splits into two streams at a coupling location **424** where the distribution line **414** is coupled with the delivery line **422**. The two streams will flow into the distribution line **414** in opposite directions toward the feed lines **410** and **408**.

**[0035]** FIG. **5** illustrate a schematic cross-sectional view of the gas ring **224** according to an embodiment. The gas ring **224** includes two portions: an upper portion **502** and a lower portion **504**. Each portion has a substantially annular shape. In an embodiment, the upper portion **502** and the lower portion **504** are made of quartz and fused together. The gas ring **224** has a top surface **506**, an outer side surface **514**, a bottom surface **522**, and an inner side surface **510**. The gas ring **224** is disposed on a top surface **422** of the sleeve **226**. The gas ring **224** is coupled with the feed line **302** to provide process gases into the inner space **318** (shown in FIG. **3**) encircled by the gas ring **224**.

**[0036]** The upper portion **502** includes a plurality of gas outlets **508** disposed at the inner side surface **510**. The plurality of gas outlets **508** are distributed to cover the entire inner perimeter of the gas ring **224**. A network of gas channels, such as gas channels **622** shown in FIG. **6**), is disposed within the gas ring **224** to provide process gases to the plurality of the gas outlets **508**. In an embodiment, an upper conduit **518** is coupled with the gas line **302** to provide process gas into the gas outlets **508**. The upper conduit **518** includes a gas inlet **520** disposed at a bottom surface of the upper portion **502**. The gas inlet **520** is coupled with a gas chamber **516** formed between the upper portion **502** and the lower portion **504**. The gas chamber **516** has a greater diameter than that of the gas inlet **520**. The upper conduit **518** extend upwardly from the gas inlet **520** in an inwardly slanted direction. A plurality of slanted channels **536** are configured to couple the upper conduit **518** with the plurality of gas outlets **508**. In an embodiment, each one of the slanted channel **536** forms an angle with the top surface **506** in the range of between three (3) and ten (10) degrees.

**[0037]** The lower portion **504** includes a gas inlet **524** disposed at a bottom surface **522** and a gas outlet **526** disposed at a top surface **532** of the lower portion **504**. A lower conduit **534** is disposed inside the lower portion **504** and extends between the gas inlet **524** and the gas outlet **526**. The gas outlet **526** and the gas inlet **520** are aligned to avoid any obstruction of the flow of the process gas. The lower conduit **534** and the upper conduit **518** are coaxially aligned. In an example, the diameter of the upper conduit **518** is greater than that of the lower conduit **534**. The lower conduit **534** extends upwardly from the gas inlet **524** in an inwardly slanted direction. In an example, the lower portion **504** includes a groove **512** configured to couple with other parts of the substrate support assembly **208**, such as a liner of the sleeve (shown in FIG. **2**).

**[0038]** As shown in FIG. **5**, the feed line **302** may extend into the gas inlet **524**. The inserted portion of the feed line **302** may include a gas seal **528** disposed in a groove to prevent process gases from leaking out of the gas inlet **524**.

**[0039]** FIG. **6***a* illustrates a schematic top view of a gas ring **600** according to an embodiment. FIG. **6***b* illustrates a schematic configuration of Callout A of the gas ring **600** according to an embodiment. As shown in FIG. **6***a*, the gas ring **600** has an annular shape with a center **602**. The gas ring **600** includes an annular body **618** that surrounds an inner space **630**. The annular body **618** includes a channel network **622** of gas channels for providing process gases into the inner space **630**. The channel network **622** is configured to split the process gas in a balanced manner from gas feed lines to the gas channels and then to the gas outlets. According to an embodiment, the channel network **622** includes a plurality of circumferential gas channels **604**, **606**, **608**, and **610** configured to distribute process gases along a circumferential direction of the annular body **618**. The channel network **622** may also include a plurality of radial gas channels **624**, **626**, and **628** configured to couple the circumferential gas channels **604**, **606**, **608**, and **610**.

**[0040]** According to an embodiment, an outer circumferential gas channel **604** is disposed along an outer perimeter of the annular body **618**. The outer circumferential gas channel **604** may form a complete annular channel along the outer perimeter of the annular body **618**. The outer circumferential channel **604** is formed within the lower portion **504**. According to an embodiment, the plurality of circumferential gas channels **606**, **608**, and **610** are disposed in the upper portion **502** and have smaller diameters than the gas channel **604**.

**[0041]** A plurality of gas inlets **612**, **614**, and **616** are coupled with the outer circumferential gas channel **604**. In an example, the annular body **618** may include six (6) gas inlets. The annular body **618** may include any other number of suitable gas inlets, such as three (3), twelve (12), or thirty six (36) gas inlets. The outer circumferential gas channel **604** can balance the pressure of the process gas distributed by the plurality of gas outlets.

**[0042]** According to an embodiment, an inner circumferential gas channel **606** is disposed along an inner perimeter of the annular body **618**. The inner circumferential gas channel **606** may also form a complete annular channel along the inner perimeter of the annular body **618**. The inner circumferential gas channel **606** is coupled with a plurality of gas outlets **508** via a plurality of gas channels **620**. More detailed descriptions for the configuration among the inner circumferential gas channel and the gas outlet **508** will be provided later in referring to FIG. **6***d*. The plurality of gas outlet **508** may include 30, 60, 120, 240, 360, 720, or more gas outlets.

**[0043]** The circumferential gas channels **608** and **610** are disposed between the outer circumferential gas channel **604** and the inner circumferential gas channel **606**. These intervening circumferential gas channels **608** and **610** include a plurality of channel segments arranged in a recursive and expanding manner. For example, as shown in FIG. **6***b*, the gas channel **608** is arranged inwardly next to the outer circumferential gas channel **604**. In an embodiment, six (6) segments of the gas channel **608** may be evenly distributed along the annular body **618**. Each segment may cover approximately thirty degrees along the circumferential direction of the annular body **618**. A radial gas channel **626** is disposed at a middle point of a segment of the gas channel **608** and couples the gas channel **608** with the gas inlet **616**. At the two ends of the gas channel **608**, two radial channels **624** couple the gas channel **608** with the middle points of two segments of the gas channel **610**. As a result, the number of segments of the gas channel **610** is twelve (12), which doubles the number of segments of the gas channel **608**. At the two ends of the gas channel **610**, two radial gas channels **628** couple the gas channel **610** with the inner circumferential channel **606**. As a result, the gas channel **608** and **610** spread process gas from one (1) gas inlets **616** disposed on the outer circumferential gas channel **604** to four (4) gas inlets disposed on the inner circumferential gas channels **606**. In an embodiment, the angular separation between adjacent gas inlets **616**, **612**, **614** is 60 degrees, the angular separation between adjacent radial channels **624** is 30 degrees, and the angular separation between adjacent radial channels **628** is 15 degrees.

**[0044]** The annular body **618** further includes a plurality of gas channels **620** couples the inner circumferential gas channel **606** with the plurality of the gas outlets **608**. In an example, the plurality of radial channels **620** are substantially oriented toward the center **602**. In another example, the plurality of radial channels **624** and **628** may also be oriented toward the center **602**.

**[0045]** According to an embodiment, the plurality of circumferential gas channels **604**, **606**, **608**, and **610** are concentric around the center **602**. The plurality of circumferential gas channels **604**, **606**, **608**, and **610** are arranged along circles of different diameters, respectively. The size of the plurality of circumferential gas channels may gradually decrease from the outer circumferential channel **604** to the inner circumferential channel **606**.

**[0046]** The gas inlets **612**, **614**, and **616** as shown in FIG. **5**, FIGS. **6***a*, and **6***b* are disposed along a bottom surface of the annular body **618**. The placement of the gas inlets at the bottom surface of the annular body **618** allows a gas delivery line to be embedded in other parts, such as a sleeve, of a processing chamber, as shown in FIG. **4**. An embedded gas line is protected by other parts and does not obstruct any flow of the processing as in the processing chamber.

**[0047]** FIG. **6***c* illustrates a cross-sectional view of the gas ring along lines B-B' in FIG. **6***a*, according to an embodiment. FIG. **6***a* shows an upper portion **632** and a lower portion **634**, which may be separately made and then fused together according to an embodiment. Since the lines B-B' are drawn across a gas inlet, they do not intersect the circumferential gas channel **610**. Thus, only the radial gas channel **626**, the circumferential gas channel **608**, and the inner circumferential channel **606** are shown in FIG. **6***c*. The radial gas channel **626**, the circumferential gas channel **608**, and the inner circumferential channel **606** are disposed within the upper portion **632**. In an embodiment, the gas channels **606**, **608**, and **626** have the same height and are substantially perpendicular to a top surface **638** of the upper portion **632**.

**[0048]** The lower portion **634** includes the gas inlets **616** coupled with a gas plenum **654**. The gas plenum **654**

overlaps with the radial channel **626** and the outer circumferential gas channel **604**. The lower portion **634** further includes a groove **652** configured to couple with another part of the substrate support assembly, such as a liner. In an embodiment, the lower portion **634** and the upper portion **632** are made of quartz and fused together to make an air-tight seal wherever the two portions contact each other.

**[0049]** FIG. **6***d* illustrates a cross-sectional view of the upper portion **632** of the gas ring along lines C-C' in FIG. **6***a*, according to an embodiment. As the lines C-C' are drawn across a gas outlet **508** and all circumferential gas channels, FIG. **6***d* does not show the gas inlet and the radial gas channels. It is noted that the outer circumferential gas channel **604** is disposed within the lower portion **634** and is not shown in FIG. **6***d*.

**[0050]** As shown in FIG. **6***d*, the inner circumferential gas channel **606** is disposed in the upper portion **632**, as well as the circumferential gas channels **608** and **610**. The gas channel **620** couples the gas outlet **508** with the inner circumferential gas channel **606**. In an embodiment, the gas channel **620** is slanted downwardly toward the lower portion **634**. As a result, the gas channel **620** forms an acute angle **648** with a top surface **638** of the upper portion **632**. For example, the gas channel **620** may have a cylindrical shape with an axis **650**. The axis **650** forms the acute angle with the top surface **638**. The acute angle may be between three (3) and ten (10) degrees.

**[0051]** FIG. **7** illustrates a schematic bottom view of an upper portion of an annular body **700** having a gas inlet disposed along an outer side surface, according to an embodiment. Similar with the annular body shown in FIGS. **6***a* and **6***b*, FIG. **7** shows an upper portion **700** of an annular body that includes a plurality of circumferential gas channels **702** and **704** coupled with a plurality of radial gas channels **706**. The upper portion **700** further includes a gas inlet **708** disposed along an outer side surface **710**. When the gas inlet **708** is disposed at the side surface **710**, the gas delivery line may go through side walls of the processing chamber and connect directly with the gas inlet **708**. The configuration of FIG. **7** may simplify the gas delivery path.

**[0052]** FIG. **8** illustrates a gas delivery method **800**, according to an embodiment of the present disclosure. At operation **802**, a robotic arm transfers a substrate into a processing chamber and places the substrate on a surface of a substrate support assembly. The surface is located within an inner space surrounded by a gas ring that is disposed inside the processing chamber. At operation **804**, the gas lines provide a process gas to a gas inlet of the gas ring. The gas inlet coupled with a network of gas channels disposed within a body of the gas ring. At operation **806**, the process gas flows circumferentially and radially along the network of the gas channels to reach a plurality of gas outlets disposed along an inner perimeter of the gas ring and in proximity to the substrate. At operation **808**, the process gas is released from the gas ring and flows toward the substrate via the plurality of gas outlets.

**[0053]** It is contemplated that one or more aspects disclosed herein may be combined. Moreover, it is contemplated that one or more aspects disclosed herein may include some or all of the aforementioned benefits. 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.

What is claimed is:

**1**. A gas ring for providing a process gas into a processing chamber, the gas ring comprising:

an annular body surrounding an inner space configured to accommodate a substrate;

a network of gas channels disposed within the annular body and comprising a plurality of circumferential gas channels coupled with a plurality of radial gas channels, the plurality of the circumferential gas channels being disposed concentrically around a center of the annular body;

a plurality of gas inlets coupled with the network of the gas channels; and

a plurality of gas outlets coupled with the network of the gas channels and disposed along an inner side surface of the annular body.

**2**. The gas ring of claim **1**, further comprising a plurality of slanted channels coupling the plurality of the gas outlets with the network of gas channels and forming an acute angle with a top surface of the annular body.

**3**. The gas ring of claim **1**, wherein the plurality of the circumferential gas channels comprise an inner circumferential gas channel disposed along an inner perimeter of the annular body and forming a circle.

**4**. The gas ring of claim **3**, wherein the plurality of the circumferential gas channels comprise an outer circumferential gas channel disposed along an outer perimeter of the annular body and forming a circle.

**5**. The gas ring of claim **1**, wherein the plurality of the radial gas channels extend radially toward the center of the annular body.

**6**. The gas ring of claim **5**, wherein the plurality of the circumferential gas channels comprise a plurality of segments, and the plurality of the radial gas channels are coupled to an end or a middle point of each segment.

**7**. The gas ring of claim **1**, wherein the plurality of the gas inlets are evenly disposed along an outer side surface of the annular body, or the plurality of the gas inlets are evenly disposed along a bottom surface of the annular body.

**8**. The gas ring of claim **1**, wherein the annular body comprises an upper portion coupled with a lower portion.

**9**. The gas ring of claim **8**, wherein the plurality of the gas outlets are disposed on the upper portion.

**10**. The gas ring of claim **8**, wherein the plurality of the circumferential gas channels comprise an inner circumferential channel disposed within the upper portion.

**11**. The gas ring of claim **8**, wherein the lower portion comprises the plurality of the gas inlets and a plurality of conduits coupling the plurality of the gas inlets with the network of the gas channels.

**12**. The gas ring of claim **11**, wherein the annular body comprises a gas chamber formed between the upper portion and the lower portion, and the plurality of the conduits are coupled with the gas chamber.

**13**. The gas ring of claim **8**, wherein the lower portion further comprises a groove disposed at a bottom surface of the lower portion and configured to couple with another part of the processing chamber.

**14**. The gas ring of claim **1**, wherein the plurality of the gas outlets are configured to release the process gas at locations less than three (3) inches away from an edge of the substrate.

**15**. A processing chamber for processing a substrate, the processing chamber comprising:
- a substrate support assembly configured to support a substrate; and
- a gas delivery system configured to deliver a process gas to the substrate, wherein the gas delivery system comprises a gas ring comprising:
  - an annular body surrounding an inner space for accommodating the substrate;
  - a network of gas channels disposed within the annular body and comprising a plurality of circumferential gas channels coupled with a plurality of radial gas channels, the plurality of the circumferential gas channels being disposed concentrically around a center of the annular body;
  - a plurality of gas inlets coupled with the network of the gas channels; and
  - a plurality of gas outlets coupled with the network of the gas channels and disposed along an inner surface of the annular body.

**16**. The processing chamber of claim **15**, wherein the substrate support assembly comprises a liner configured to protect the substrate support assembly, and the gas ring is coupled with the liner.

**17**. The processing chamber of claim **15**, wherein the substrate support assembly comprises a sleeve, and the gas delivery system comprises a plurality of gas lines disposed within the sleeve.

**18**. The processing chamber of claim **15**, wherein the gas delivery system comprises a plurality of gas lines coupled with the gas ring along an outer side surface of the annular body.

**19**. The processing chamber of claim **15**, wherein the plurality of the circumferential gas channels extend along a circumferential direction of the annular body, and the plurality of the radial gas channels extend radially toward the center of the annular body.

**20**. A gas delivery method for providing a process gas into a processing chamber, the method comprising:
- transferring a substrate into an inner space surrounded by a gas ring that is disposed inside the processing chamber;
- providing a process gas to a gas inlet of the gas ring, the gas inlet coupled with a network of gas channels disposed within a body of the gas ring;
- flowing the process gas circumferentially and radially along the network of the gas channels to reach a plurality of gas outlets disposed along an inner side surface of the gas ring and in proximity to an edge of the substrate; and
- releasing the process gas toward the edge of the substrate via the plurality of gas outlets.

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