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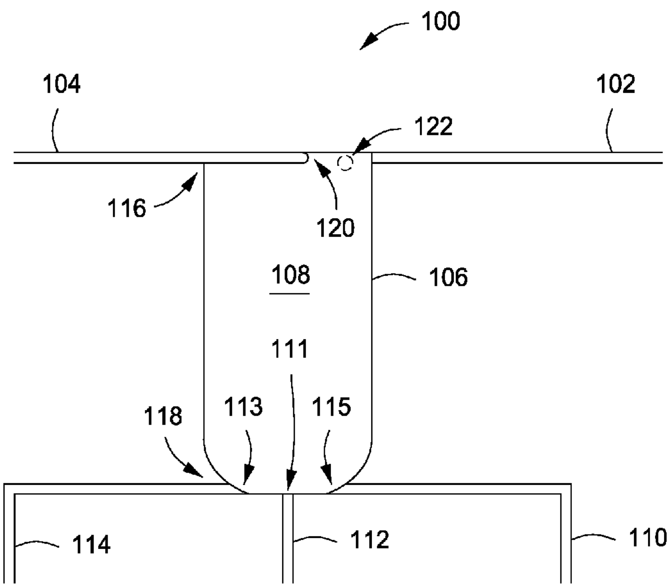

FIG. 1

(57) Abstract: Embodiments of gas mixing apparatus are provided herein. In some embodiments, a gas mixing apparatus may include a container defining an interior volume, the container having a closed top and bottom and a sidewall having a circular cross section with respect to a central axis of the container passing through the top and bottom; a plurality of first inlets coupled to the container proximate the top of the container to provide a plurality of process gases to the interior volume of the container, the plurality of first inlets disposed such that a flow path of the plurality of process gases through the plurality of first inlets is substantially tangential to the sidewall of the container; and an outlet coupled to the container proximate the bottom of the container to allow the plurality of process gases to be removed from the interior volume of the container.

WO 2014/011423 A1

GAS MIXING APPARATUS

FIELD

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

BACKGROUND

[0002] The inventors have observed that many conventional gas delivery systems utilized to deliver multiple process gases to a process chamber can fail to provide a uniform mixture of the process gases to the process chamber. Such a lack in uniformity in a process gas mixture leads to areas of the process chamber receiving higher concentrations of individual components of the process gases, thereby resulting in process non-uniformities.

[0003] Therefore, the inventors have provided an improved gas mixing apparatus.

SUMMARY

[0004] Embodiments of gas mixing apparatus are provided herein. In some embodiments, a gas mixing apparatus may include a container defining an interior volume, the container having a closed top and bottom and a sidewall having a circular cross section with respect to a central axis of the container passing through the top and bottom; a plurality of first inlets coupled to the container proximate the top of the container to provide a plurality of process gases to the interior volume of the container, the plurality of first inlets disposed such that a flow path of the plurality of process gases through the plurality of first inlets is substantially tangential to the sidewall of the container; and an outlet coupled to the container proximate the bottom of the container to allow the plurality of process gases to be removed from the interior volume of the container.

[0005] In some embodiments, an apparatus for processing substrates may include a process chamber having a processing volume; a substrate support disposed within the processing volume; and a gas mixing apparatus coupled to the process chamber to provide a mixture of process gases to the processing volume of the process chamber. The gas mixing apparatus may include a container defining an interior

volume, the container having a closed top and bottom and a sidewall having a circular cross section with respect to a central axis of the container passing through the top and bottom; a plurality of first inlets coupled to the container proximate the top of the container to provide a plurality of process gases to the interior volume of the container, the plurality of first inlets disposed such that a flow path of the plurality of process gases through the plurality of first inlets is substantially tangential to the sidewall of the container; and an outlet coupled to the container proximate the bottom of the container to allow the plurality of process gases to be removed from the interior volume of the container.

[0006] Other and further embodiments of the present invention are described below.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Embodiments of the present invention, briefly summarized above and discussed in greater detail below, can be understood by reference to the illustrative embodiments of the invention depicted in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0008] Figure 1 is a schematic side view of a gas mixing apparatus in accordance with some embodiments of the present invention.

[0009] Figure 2 is a schematic top view of a gas mixing apparatus in accordance with some embodiments of the present invention.

[0010] Figure 3 is a schematic side view of a gas mixing apparatus in accordance with some embodiments of the present invention.

[0011] Figure 4 is a schematic top view of a gas mixing apparatus in accordance with some embodiments of the present invention.

[0012] Figure 5 is a schematic cross sectional side view of a gas mixing apparatus in accordance with some embodiments of the present invention.

[0013] Figure 6 is a schematic cross sectional top view of a gas mixing apparatus in accordance with some embodiments of the present invention.

[0014] Figure 7 is a schematic cross sectional top view of a gas mixing apparatus in accordance with some embodiments of the present invention.

[0015] Figure 8 depicts a schematic side view of a process chamber suitable for use with a gas mixing apparatus in accordance with some embodiments of the present invention.

[0016] Figure 9 depicts a top perspective view of a portion of a process chamber suitable for use with a gas mixing apparatus in accordance with some embodiments of the present invention.

[0017] Figure 10 depicts a top perspective view of a portion of a process chamber suitable for use with a gas mixing apparatus in accordance with some embodiments of the present invention.

[0018] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. The figures are not drawn to scale and may be simplified for clarity. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0019] Embodiments of gas mixing apparatus are provided herein. In some embodiments, the inventive gas mixing apparatus may advantageously provide a more uniform mixture of process gases and/or a more uniform plasma to a process chamber as compared to convention gas delivery systems.

[0020] The inventors have observed that certain semiconductor processes require sufficient mixing of multiple process gases to avoid process non-uniformities. For example, in a seasoning process utilized to clean and/or condition a process chamber in preparation for processing a substrate, a uniform mixture of process gases is typically required to generate a uniform plasma to properly clean the process chamber. However, the inventors have observed that conventional gas delivery systems utilized to deliver multiple process gases to a process chamber can fail to provide a uniform mixture of the process gases to the process chamber, thereby leading to process non-uniformities.

[0021] Accordingly, the inventors have provided embodiments of an improved gas mixing apparatus to deliver multiple process gases to a process chamber. For example, Figure 1 is a schematic side view of a gas mixing apparatus in accordance with some embodiments of the present invention. In some embodiments, the gas mixing apparatus 100 may generally comprise a container 106, a plurality of inlets (*e.g.*, a plurality of first inlets) and an outlet 111. As depicted in Figure 1, first inlet 120 and second inlet 122 are shown. A conduit is coupled to each of the plurality of inlets to facilitate delivery of a gas and/ or plasma from a gas source and/or plasma source. For example, in some embodiments, a first conduit 104 may be coupled to the first inlet 120 and a second conduit 102 may be coupled to the second inlet 122, as shown in Figure 1.

[0022] In some embodiments, the container 106 includes a sidewall with a closed top 116 and bottom 118, thereby defining an inner volume 108. The container 106 may have any shape suitable to allow a desired amount of mixing of the process gas and/or plasma provided to the container 106. In some embodiments, the inner volume of container 106 may have a circular cross section. By providing a circular cross section, the inventors have observed that the process gas and/or plasma provided to the container 106 may flow in a circular or spiral manner, thereby allowing the process gas and/or plasma to mix prior to flowing out of the container via the outlet 111. In some embodiments, the bottom 118 of the container 106 may be flat. Alternatively, in some embodiments, the bottom 118 of the container 106 may be curved or substantially bowl shaped, such as shown in Figure 1. In some embodiments, the container 106 may be substantially cylindrical, as depicted in Figure 1. Alternatively, in some embodiments, the container 106 may be conical or frustoconical, for example, as shown in Figure 3. In such embodiments, a diameter of the container 106 proximate the top 116 of the container may be greater than a diameter of the container 106 proximate the bottom 118 of the container 106.

[0023] Referring back to Figure 1, the container 106 may have any dimensions suitable to provide a suitable residence time of process gases and/or plasma within the container 106 to facilitate a desired mixing of process gases and/or plasma. For example, in some embodiments, the container 106 may have an inner diameter of about 14.3 mm to about 18.6 mm. In some embodiments, the container may have a height of about 38.3 mm to about 58.7 mm.

[0024] The container 106 may be fabricated from any process compatible material, for example any material that is non-reactive to the process gas or plasma provided to the container 106. For example, in some embodiments, the container 106 may be fabricated from a metal, such as stainless steel, aluminum, or the like.

[0025] In some embodiments, an outlet (*e.g.*, the first outlet 111) is disposed proximate the bottom 118 of the container 106 and allows the process gas and/or plasma to flow out of the container 106. The container 106 may have a plurality of outlets to facilitate delivery of the contents of the container 106 to a corresponding plurality of gas delivery zones within a process chamber. For example, in some embodiments, the container 106 may have two or more outlets, such as three outlets (first outlet 111, second outlet 113 and third outlet 115 shown), as shown in Figure 1. In such embodiments, a conduit may be respectively coupled to each outlet to facilitate delivery of the mixed process gas and/or plasma, for example, to a plurality of gas delivery zones of a process chamber. For example, a first conduit 112, second conduit 114, and third conduit 110 may be respectively coupled to the first outlet 111, second outlet 113 and third outlet 115.

[0026] Although only two inlets (*i.e.*, first inlet 120 and second inlet 122) are shown in Figure 1, the container 106 may include any number of inlets suitable to accommodate for any number of process gases and/or plasmas that are to be provided to the container 106. For example, referring to Figure 2, in some embodiments, the container 106 may have four inlets (*i.e.*, first inlet 120, second inlet 122, third inlet 206 and fourth inlet 208 shown). In such embodiments, similar to the first inlet 120 and second inlet 122 discussed above, the third inlet 206 and fourth inlet 208 each have a conduit coupled thereto (*e.g.*, third conduit 202 and fourth conduit 204 coupled to the third inlet 206 and fourth inlet 208, respectively) to facilitate delivery of the gas and/ or plasma from the gas and/or plasma source.

[0027] The plurality of inlets (*e.g.*, first inlet 120, second inlet 122, third inlet 206 and fourth inlet 208) may be disposed about the container 106 in any configuration suitable to provide a desired flow of process gas and/or plasma within the container

106. For example, in some embodiments, each of the first inlet 120, second inlet 122, third inlet 206 and fourth inlet 208 may be disposed about the container 106 such the process gas and/or plasma is provided having a flow direction that is tangential to the cross section of the container 106 (as indicated by arrows 210), such as shown in Figure 2. By providing the flow in such a manner, the inventors have observed that the process gas and/or plasma mixes more completely prior to flowing out of the container via the outlets (*e.g.*, first outlet 111, second outlet 113 and third outlet 115 described above). The inventors believe that the circular cross section of the container 106 and the tangential flow of the process gas and/or plasma cause the process gas and/or plasma to flow in a circular or spiral manner. Such a circular or spiral flow may increase the residence time of the process gas and/or plasma within the container and the turbulence of the process gas and/or plasma, thereby facilitating the mixing of the process gas and/or plasma. In some embodiments, the process gas and/or plasma may be mixed up to 100% mixing (*i.e.*, a complete, or uniform mixing of components).

[0028] Alternatively or in combination, in some embodiments and as depicted in Figure 3, an additional inlet 304 (*e.g.*, a second inlet) may be coupled to the top 306 of the container 106 and configured to provide a flow of process gas and/or plasma in a direction substantially perpendicular to the top 306 of the container 106 (as indicated by arrow 303). In some embodiments, the additional inlet 304 may be utilized to provide a plasma formed in a remote plasma source to the container 106 via an additional conduit 302 while the first inlet 120 and second inlet 122 provide a process gas from a gas source coupled to the first and second inlets 120, 122. For example, in some embodiments the gas mixing apparatus 100 may be coupled to a process chamber (such as in a non-limiting example, a plasma ion immersion implantation reactor, as described below with respect to Figure 8) to provide a mixture of process gases and plasma to perform a seasoning process within the process chamber. In such embodiments, a silicon containing gas for example, silane (SiH_4), may be provided to the container 106 via the first inlet 120, an oxygen containing gas, for example, oxygen gas (O_2), may be provided to the container 106 via the second inlet 122 and an argon (Ar) containing plasma may be provided to the container 106 via the additional inlet 304. When provided in such a configuration, the gases provided via the first inlet 120 and the second inlet 122 may be provided in a direction tangential to the cross section of the container 106 (as indicated by arrows 210 in Figure 2, or arrows 402 in Figure 4) and the plasma provided via the additional inlet 304 may be provided in a direction substantially perpendicular to the top 306 of the container 106 (as indicated by arrow 303, as shown in Figure 3).

[0029] In some embodiments, one or more additional components may be provided within the container 106 to enhance the mixing of the process gases and/or plasma. For example, referring to Figure 5, in some embodiments, a plurality of baffles 501 may be disposed within the container 106. The inventors believe that, when present, the plurality of baffles 501 may increase residence time and turbulence of the flow of the process gases and/or plasma, thereby enhancing the mixing of the process gases and/or plasma.

[0030] The plurality of baffles 501 may be provided in any number or configuration sufficient to increase the aforementioned residence time and turbulence of the flow of the process gases and/or plasma. For example, in some embodiments, the plurality of baffles 501 may comprise one or more baffles (first baffle 502, second baffle 504, third baffle 506, fourth baffle 508 and fifth baffle 510 shown) extending from a wall 505 of the container 106 towards a center 503 of the container 106. In some embodiments, the baffles may extend beyond an axial centerline of the container 106, for example to advantageously maximize the flow path, and therefore residence time, of the gases in the container 106. In some embodiments, the baffles may be disposed substantially parallel with the top 306 of the container 106, such as shown in Figure 5. In some embodiments, each of a plurality of baffles 501 may be disposed such that each baffle is staggered with an adjacent baffle, such as, for example, by being disposed on opposite sides of the container 106. In some embodiments, each of the plurality of baffles 501 may have a height of about 0.5 mm to about 1 mm, or in some embodiments, about 1 mm.

[0031] Alternatively, or in combination, in some embodiments, at least some of the plurality of baffles 501 may be disposed substantially perpendicular to the top of the container 106, for example, such as the first baffle 602, second baffle 604, third baffle 606, and fourth baffle 608 shown in Figure 6. In some embodiments, the plurality of baffles 501 may be flat, as depicted in Figure 6, or may have a curved shape, such as the first baffle 702, second baffle 704, third baffle 706, and fourth baffle 708 shown in Figure 7. In some embodiments, each of the plurality of baffles may have a height of about 0.5 mm to about 1 mm, or in some embodiments, about 10 mm.

[0032] The gas mixing apparatus 100 described above may be utilized to provide a mixture of process gases and/or plasma to any type of processing equipment used to perform processes on a substrate. For example, the gas mixing apparatus 100 may be coupled to a toroidal source plasma ion immersion implantation reactor such as, but not limited to, the CONFORMA™ reactor commercially available from Applied Materials, Inc., of Santa Clara, California. Other process chambers, including those configured for other processes as well as those available from other manufacturers, may also benefit from modification in accordance with the teachings provided herein.

[0033] Referring to Figure 8, a toroidal source plasma immersion ion implantation reactor 800 may generally comprise a cylindrical vacuum chamber 802 defined by a cylindrical side wall 804 and a disk-shaped ceiling 806. A substrate support pedestal 808 at the floor of the chamber 802 supports a substrate 810 to be processed. A gas distribution plate or showerhead 812 on the ceiling 806 receives process gas in its gas manifold 814 from the gas mixing apparatus 100.

[0034] A plurality of gas and/or plasma sources (three sources 852, 854, 856 shown) may be coupled to the gas mixing apparatus 100 to provide process gases and/or plasma to the gas mixing apparatus 100 to be mixed and subsequently provided to the chamber 802. In some embodiments, the gas mixing apparatus 100 may be coupled to an upper manifold 801 disposed above, and coupled to the chamber 802 to distribute the mixed process gases and/or plasma to desired gas delivery zones or regions of the process chamber. In some embodiments, the upper manifold 801 may be coupled directly to the interior of the process chamber or to a lower manifold (*e.g.*, gas distribution plate or showerhead 812) disposed within the chamber 802.

[0035] Referring to Figure 9, in some embodiments, the upper manifold 801 may include a plurality of manifolds. For example , in some embodiments, the plurality of manifolds may include a plurality of gas rings, such as an inner gas ring 904 and an outer gas ring 902, as well as a central injection port 908. Each of the inner gas ring 904 and outer gas ring 902 may comprise a plurality of gas outlets (*e.g.*, a plurality of third gas outlets). Gas outlets 910 are shown for outer gas ring 902 and gas outlets 912 are shown for inner gas ring 904 in Figure 9. The gas outlets 910, 912 are coupled to the chamber 802 and facilitate delivery of the process gas and/or plasma from the inner gas ring 904 and outer gas ring 902 to the interior of the chamber 802 (*e.g.*, via the gas distribution plate or showerhead 812 described above).

[0036] The gas mixing apparatus 100 may be coupled to the upper manifold 801 in any position relative to the upper manifold 801 that is suitable to provide a desired mix of process gas and/or plasma to a desired location within the chamber 802.

[0037] For example, in some embodiments, the gas mixing apparatus 100 may be disposed above the inner gas ring 904, wherein the first conduit 112 is coupled to the inner gas ring 904, the second conduit 114 is coupled to the outer gas ring 902 and the third conduit 110 is coupled to the central injection port 908, such as shown in Figure 9. In such embodiments, an additional conduit 906 may be coupled to the central injection port 908 to facilitate separate delivery of, for example, a plasma from a remote plasma source.

[0038] Alternatively, in some embodiments, the gas mixing apparatus 100 may be disposed above the central injection port 908, wherein the first conduit 112 is coupled to the central injection port 908, the second conduit 114 is coupled to the inner gas ring 904 and the third conduit 110 is coupled to the outer gas ring 902, such as shown in Figure 10. In such embodiments, a plasma from a plasma remote source may be provided to the gas mixing apparatus 100 via the additional conduit 302.

[0039] Referring back to Figure 8, a vacuum pump 820 is coupled to a pumping annulus 822 defined between the substrate support pedestal 808 and the sidewall

804. A processing region 824 is defined between the substrate 810 and the gas distribution plate 812.

[0040] A pair of external reentrant conduits 826, 828 establishes reentrant toroidal paths for plasma currents passing through the processing region 824, and the toroidal paths intersecting in the processing region 824. Each of the conduits 826, 828 has a pair of ends 830 coupled to opposite sides of the chamber. Each conduit 826, 828 is a hollow conductive tube. Each conduit 826, 828 has a D.C. insulation ring 832 preventing the formation of a closed loop conductive path between the two ends of the conduit.

[0041] An annular portion of each conduit 826, 828, is surrounded by an annular magnetic core 834. An excitation coil 836 surrounding the core 834 is coupled to an RF power source 838 through an impedance match device 840. The two RF power sources 838 coupled to respective ones of the cores 836 may be of two slightly different frequencies. The RF power coupled from the RF power generators 838 produces plasma ion currents in closed toroidal paths extending through the respective conduit 826, 828 and through the processing region 824. These ion currents oscillate at the frequency of the respective RF power source 838. Bias power is applied to the substrate support pedestal 808 by a bias power generator 842 through an impedance match circuit 844.

[0042] Plasma formation is performed by introducing a process gas, or mixture of process gases into the chamber 824 through the gas distribution plate 812 and applying sufficient source power from the generators 838 to the reentrant conduits 826, 828 to create toroidal plasma currents in the conduits and in the processing region 824.

[0043] The plasma flux proximate the wafer surface is determined by the wafer bias voltage applied by the RF bias power generator 842. The plasma rate or flux (number of ions sampling the wafer surface per square cm per second) is determined by the plasma density, which is controlled by the level of RF power applied by the RF source power generators 838. The cumulative ion dose (ions/square cm) at the wafer 810 is determined by both the flux and the total time over which the flux is maintained.

[0044] If the wafer support pedestal 808 is an electrostatic chuck, then a buried electrode 846 is provided within an insulating plate 848 of the wafer support pedestal, and the buried electrode 846 is coupled to the bias power generator 842 through the impedance match circuit 844 and/or a DC voltage source 850.

[0045] In operation, and for example, the substrate 810 may be placed on the substrate support pedestal 808 and one or more process gases may be introduced into the chamber 802 to strike a plasma from the process gases. For example, a plasma may be generated from the process gases within the reactor 800 to selectively modify surfaces of the substrate 810 as discussed above. The plasma is formed in the processing region 824 by applying sufficient source power from the generators 838 to the reentrant conduits 826, 828 to create plasma ion currents in the conduits 826, 828 and in the processing region 824 in accordance with the process described above. In some embodiments, the wafer bias voltage delivered by the RF bias power generator 842 can be adjusted to control the flux of ions to the wafer surface, and possibly one or more of the thickness a layer formed on the wafer or the concentration of plasma species embedded in the wafer surface.

[0046] A controller 854 comprises a central processing unit (CPU) 856, a memory 858, and support circuits 860 for the CPU 856 and facilitates control of the components of the chamber 802 and, as such, of the etch process, as discussed below in further detail. To facilitate control of the process chamber 802, for example as described below, the controller 854 may be one of any form of general-purpose computer processor that can be used in an industrial setting for controlling various chambers and sub-processors. The memory 858, or computer-readable medium, of the CPU 856 may be one or more of readily available memory such as random access memory (RAM), read only memory (ROM), floppy disk, hard disk, or any other form of digital storage, local or remote. The support circuits 860 are coupled to the CPU 856 for supporting the processor in a conventional manner. These circuits include cache, power supplies, clock circuits, input/output circuitry and subsystems, and the like. The inventive methods, or at least portions thereof, described herein may be stored in the memory 858 as a software routine. The software routine may also be stored and/or executed by a second CPU (not shown) that is remotely located from the hardware being controlled by the CPU 856.

[0047] Thus, embodiments of gas mixing apparatus have been provided herein that may advantageously provide enhanced mixing of process gases and/or plasma being provided to one or more gas delivery zones.

[0048] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof.

Claims:

1. A gas mixing apparatus, comprising:

a container defining an interior volume, the container having a closed top and bottom and a sidewall having a circular cross section with respect to a central axis of the container passing through the top and bottom;

a plurality of first inlets coupled to the container proximate the top of the container to provide a plurality of process gases to the interior volume of the container, the plurality of first inlets disposed such that a flow path of the plurality of process gases through the plurality of first inlets is substantially tangential to the sidewall of the container; and

an outlet coupled to the container proximate the bottom of the container to allow the plurality of process gases to be removed from the interior volume of the container.

2. The gas mixing apparatus of claim 1, further comprising a plurality of gas sources respectively coupled to the plurality of first inlets.

3. The gas mixing apparatus of claim 2, wherein at least one of the plurality of gas sources is configured to provide a gas in a plasma state.

4. The gas mixing apparatus of claim 1, further comprising:

a second inlet coupled to a top of the container to provide a second process gas to the container, the second inlet disposed such that a flow path of the second process gas through the second inlet is substantially perpendicular to the top of the container.

5. The gas mixing apparatus of claim 4, further comprising a second gas source coupled to the second inlet.

6. The gas mixing apparatus of any of claims 1-5, wherein the bottom of the container is bowl-shaped, having the bowl extending away from the interior volume, wherein the outlet is coupled to the bottom.

7. The gas mixing apparatus of any of claims 1-5, wherein the container has a conical shape, wherein a diameter of the container proximate the top of the container is greater than a diameter of the container proximate the bottom of the container.

8. The gas mixing apparatus of any of claims 1-5, further comprising:
a plurality of baffles disposed within the container.

9. The gas mixing apparatus of claim 8, wherein the plurality of baffles are substantially planar and parallel to the top of the container, wherein each baffle of the plurality of baffles extend from the sidewall of the container toward the central axis of the container.

10. The gas mixing apparatus of claim 8, wherein the plurality of baffles are substantially perpendicular to the top of the container, wherein each baffle of the plurality of baffles extend from a wall of the container toward the central axis of the container.

11. The gas mixing apparatus of any of claims 1-5, further comprising:
a plurality of outlets coupled to the container proximate the bottom of the container; and
a plurality of gas rings, each having a plurality of third gas outlets, wherein the container is fluidly coupled to the plurality of gas rings via the plurality of outlets.

12. The gas mixing apparatus of claim 11, wherein the plurality of gas rings comprise a central injection port, an inner gas ring disposed about the central injection port, and an outer gas ring disposed about the inner gas ring.

13. The gas mixing apparatus of claim 11, wherein the plurality of gas outlets are fluidly coupled to a lower manifold disposed within a process chamber, the lower manifold having a plurality of gas dispersion holes to provide the plurality of process gases to an inner volume of the process chamber.

14. An apparatus for processing substrates, comprising:

a process chamber having a processing volume;

a substrate support disposed within the processing volume; and

a gas mixing apparatus coupled to the process chamber to provide a mixture of process gases to the processing volume of the process chamber, the gas mixing apparatus as described in any of the preceding claims.

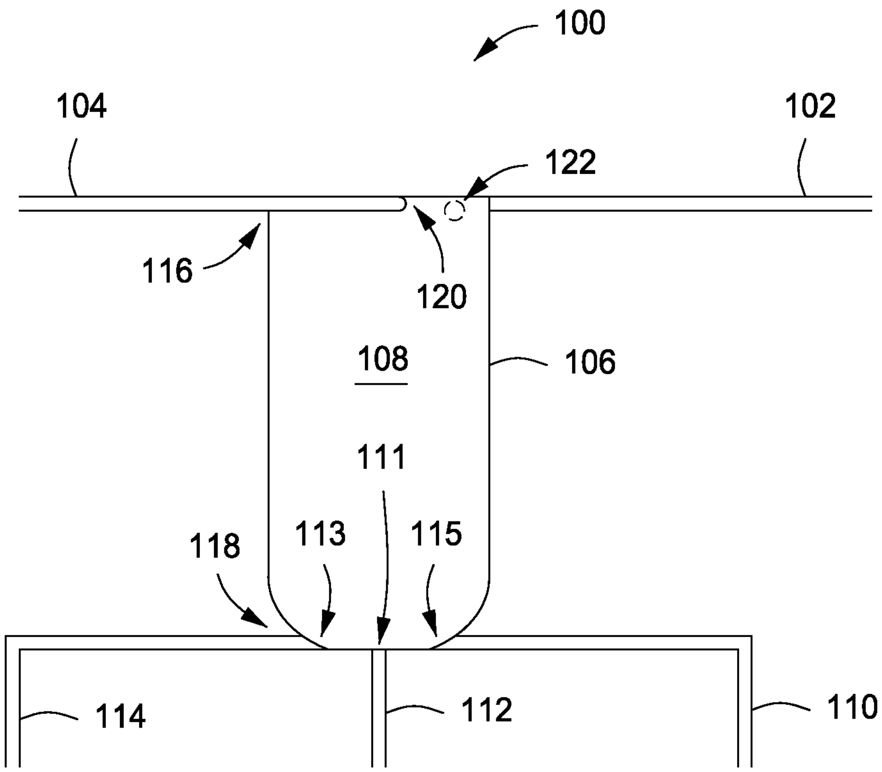
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FIG. 1

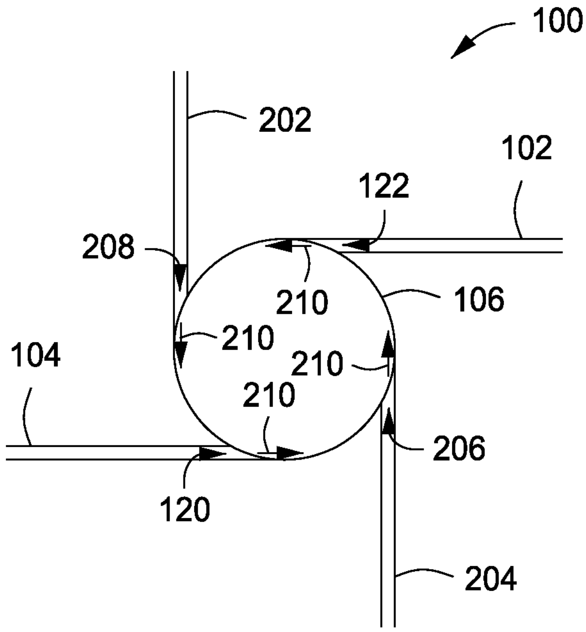
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FIG. 2

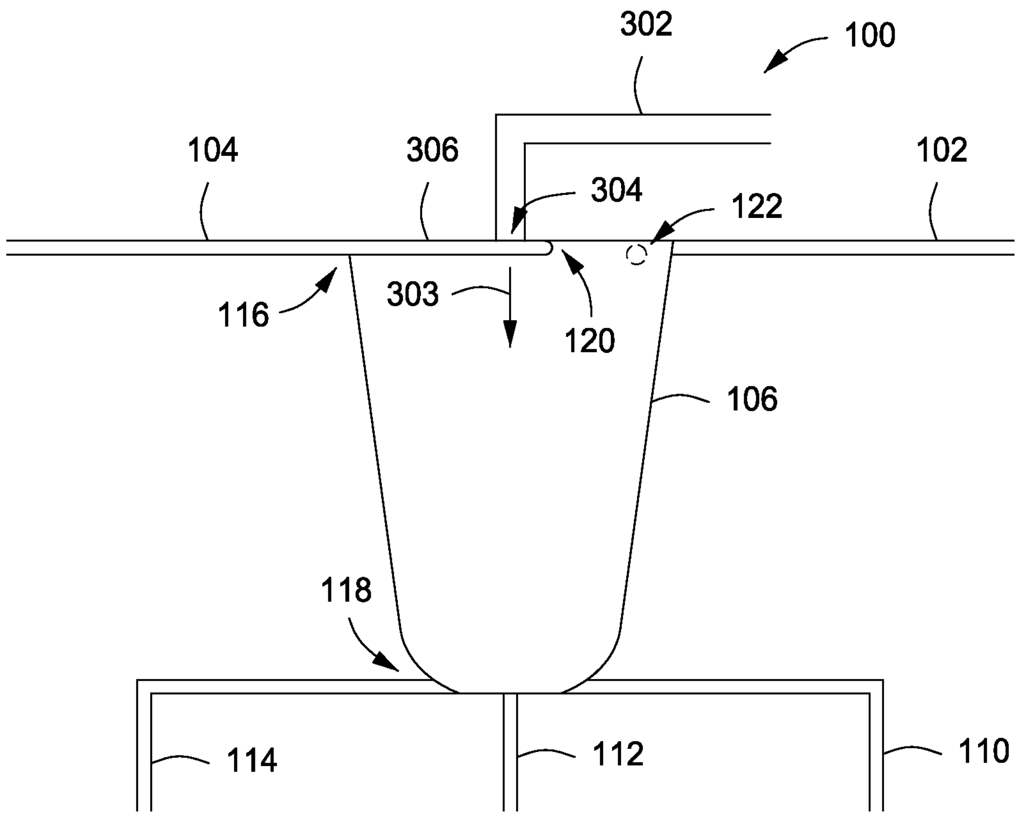
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FIG. 3

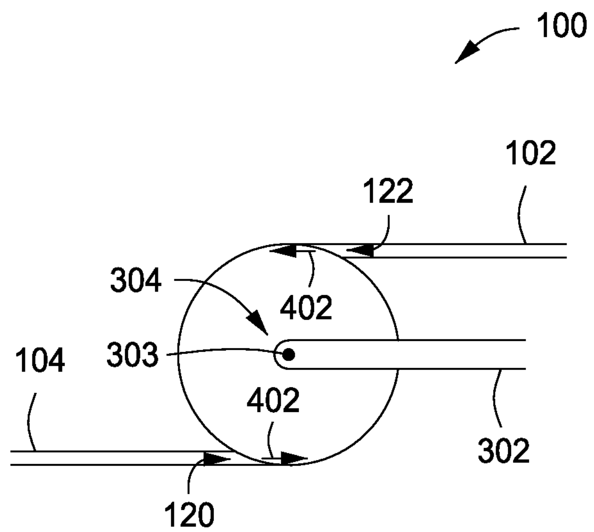
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FIG. 4

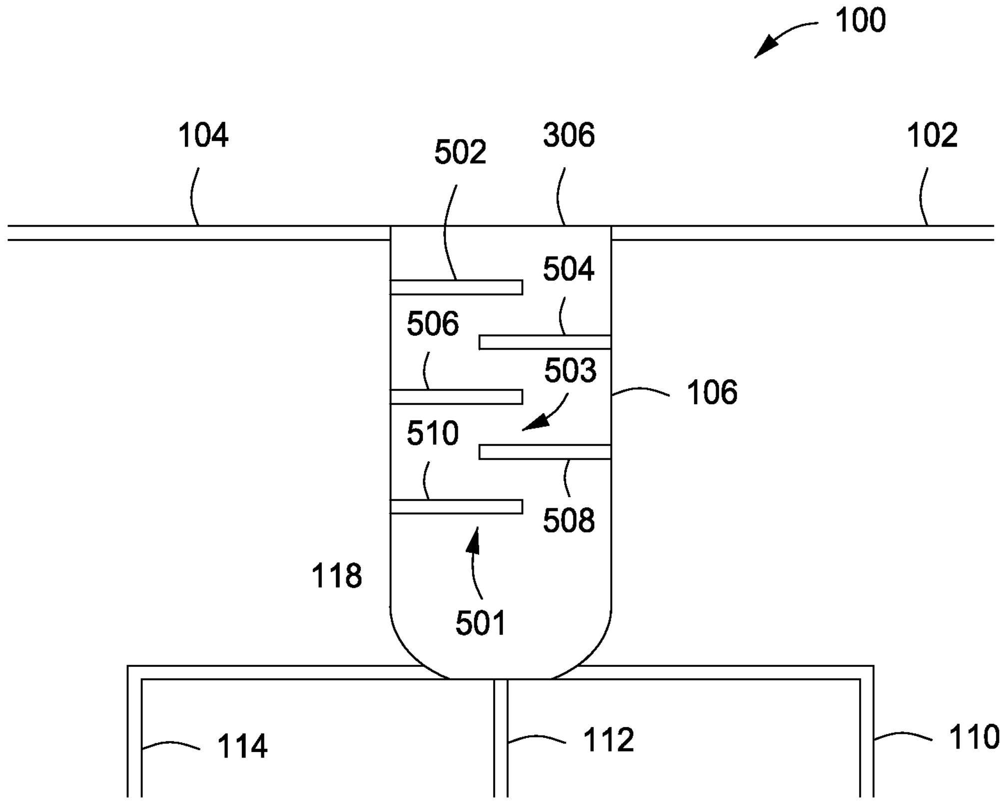


FIG. 5

FIG. 6

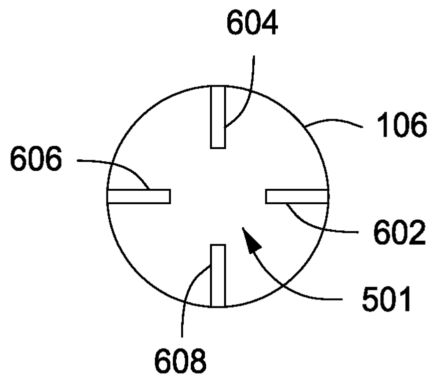
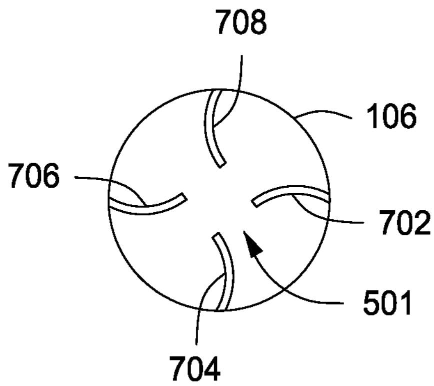
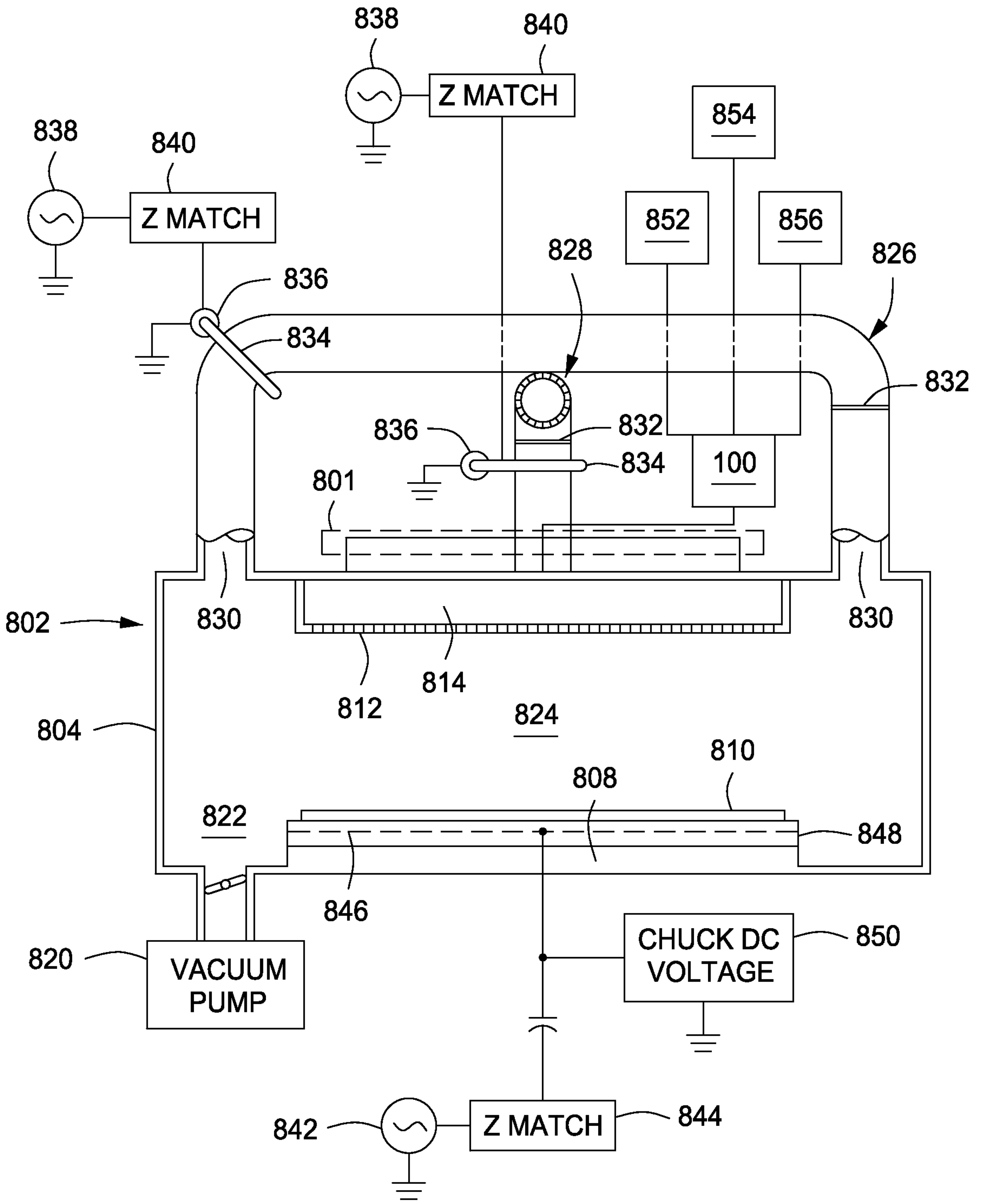


FIG. 7

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Z MATCH
838
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Z MATCH
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801
802
830
830
814
812
824
804
810
808
822
848
846
850
CHUCK DC
VOLTAGE
820
VACUUM
PUMP
842
Z MATCH
844

FIG. 8

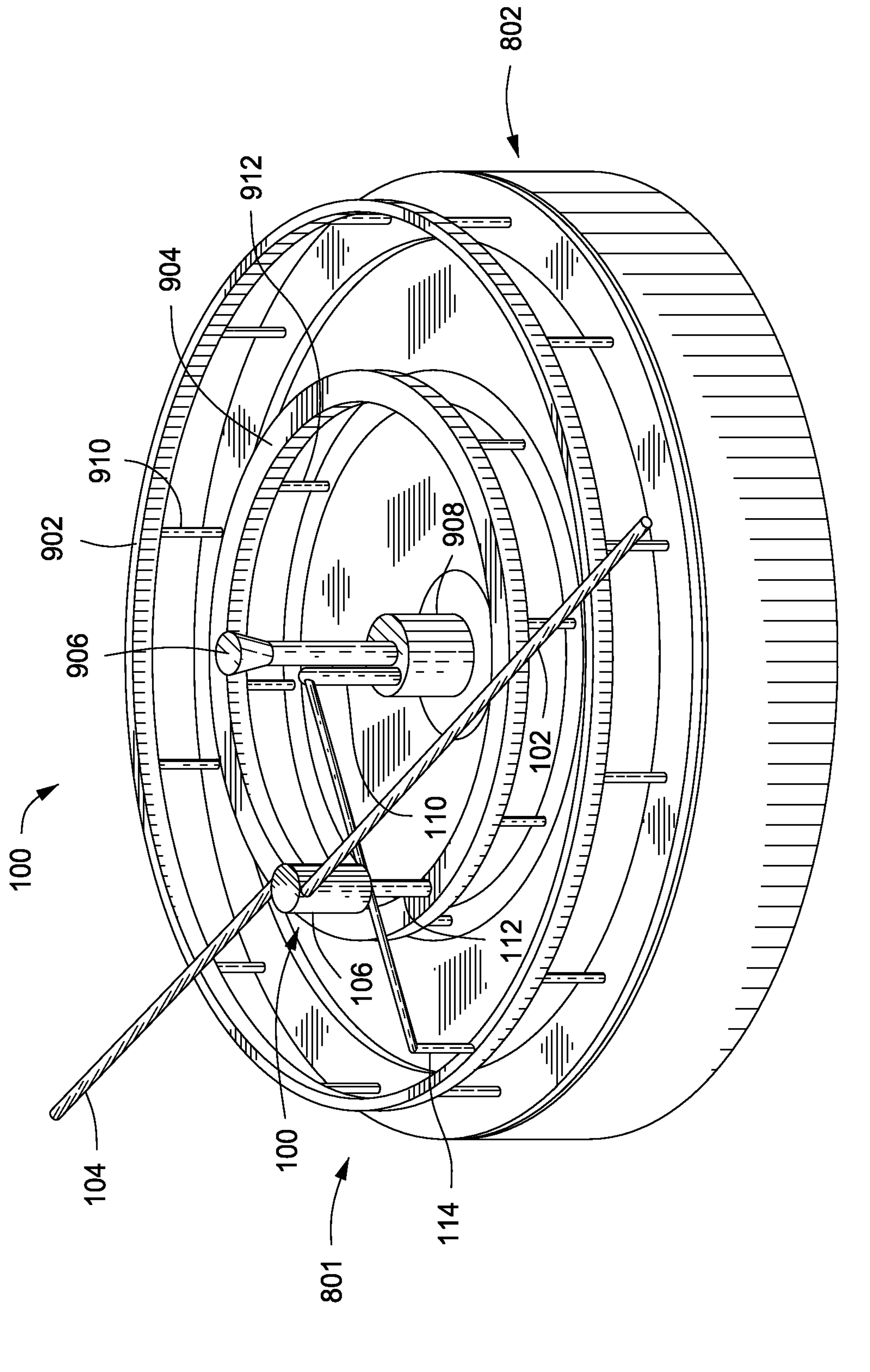

FIG. 9

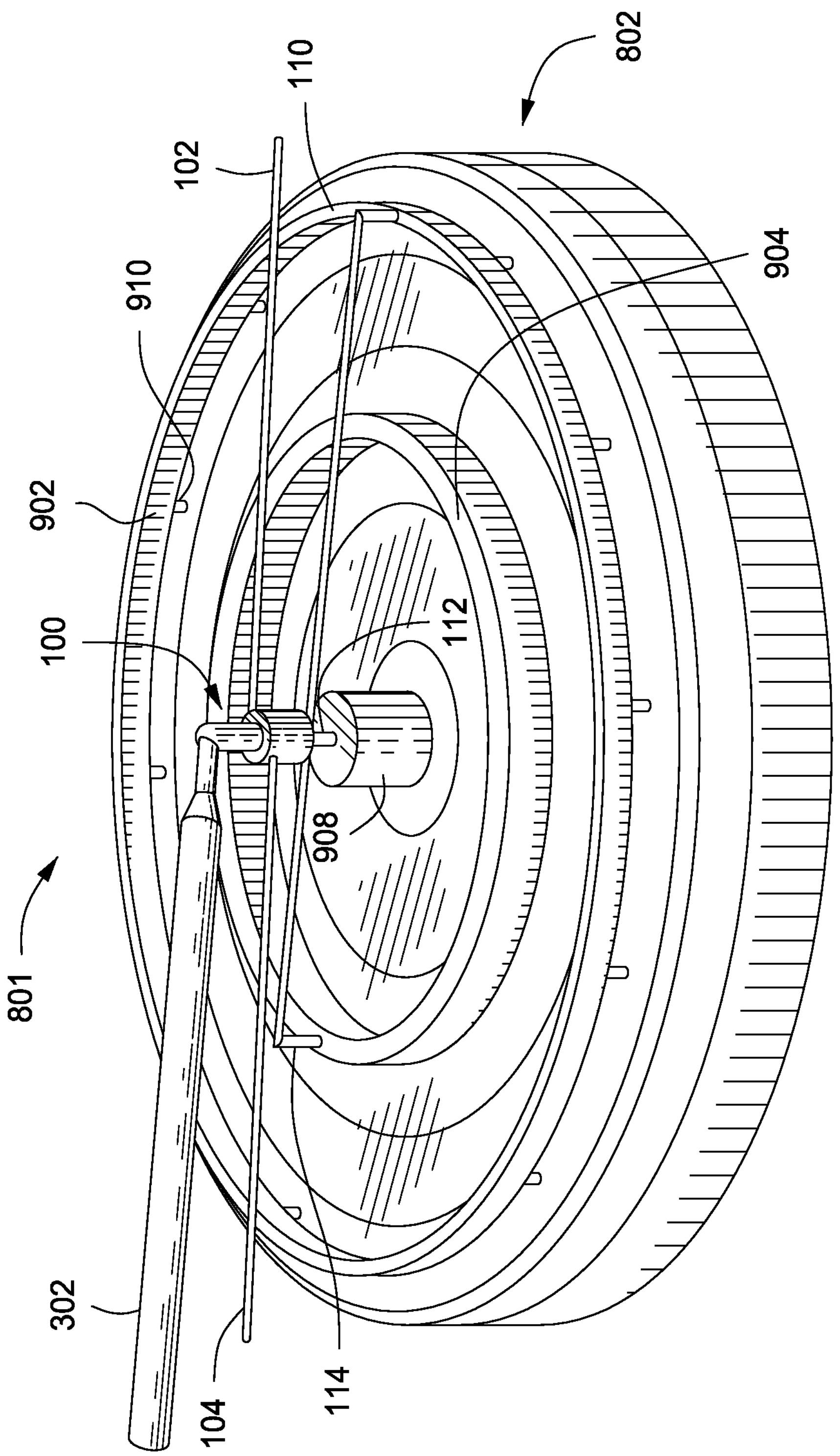

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/048855

A. CLASSIFICATION OF SUBJECT MATTER

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

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01L 21/02; H01L 21/205; F02M 29/04; F02M 29/00; H01L 21/31; C23C 16/455; C01B 3/02; C23C 16/00

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	JP 07-211643 A (HITACHI ELECTRON ENG CO., LTD.) 11 August 1995 See claim 1, paragraphs [0004], [0006]-[0009] and figures 1, 3.	1-7,11-13
Y		8-10
Y	KR 10-2000-0061954 A (EUN KWANG ENERGY CO., LTD.) 25 October 2000 See abstract, pages 3-4 and figure 6.	8-10
A	JP 2003-133300 A (TOKYO ELECTRON LTD.) 09 May 2003 See abstract, paragraphs [0026]-[0040] and figures 1-3.	1-13
A	US 6933010 B2 (TAKAKAZU YAMADA et al.) 23 August 2005 See abstract, column 9, line 15 - column 14, line 41 and figures 1, 3.	1-13
A	US 2011-0203560 A1 (WILLIAM K. WALLACE) 25 August 2011 See abstract, paragraphs [0033]-[0060] and figures 2-3.	1-13

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
27 September 2013 (27.09.2013)	**27 September 2013 (27.09.2013)**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon Metropolitan City, 302-701, Republic of Korea	CHOI Sang Won
Facsimile No. +82-42-472-7140	Telephone No. +82-42-481-8291

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/048855

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☒ Claims Nos.: 14
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required addtional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2013/048855

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 07-211643 A	11/08/1995	None	
KR 10-2000-0061954 A	25/10/2000	None	
JP 2003-133300 A	09/05/2003	None	
US 6933010 B2	23/08/2005	DE 60238272 D1	23/12/2010
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		EP 1452626 A4	04/06/2008
		EP 1452626 B1	10/11/2010
		EP 1452626 B9	18/01/2012
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		EP 1988188 B9	02/05/2012
		JP 2008-133545 A	12/06/2008
		JP 2008-248391 A	16/10/2008
		JP 4157040 B2	24/09/2008
		JP 4773469 B2	14/09/2011
		JP 4812132 B2	09/11/2011
		KR 10-0974848 B1	11/08/2010
		KR 10-1022684 B1	22/03/2011
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		US 2004-0089235 A1	13/05/2004
		US 2005-0211168 A1	29/09/2005
		US 8118935 B2	21/02/2012
		WO 03-048413 A1	12/06/2003
US 2011-0203560 A1	25/08/2011	None	