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(54) Title: ANTENNA ARRAY CONFIGURATIONS FOR PLASMA PROCESSING SYSTEMS

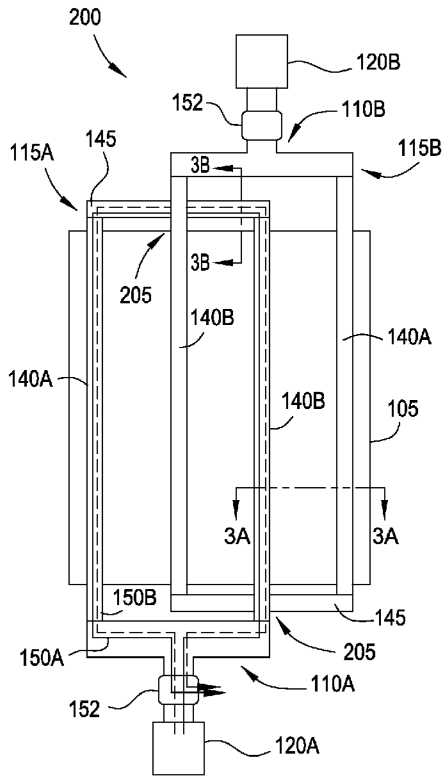

FIG. 2

(57) Abstract: The present disclosure generally relates to a deposition system including a first electromagnetic wave applicator comprising a first closed loop antenna array coupled to a first dedicated radio frequency generator, and a second electromagnetic wave applicator comprising a second closed loop antenna array disposed adjacent the first closed loop antenna array and coupled to a second dedicated radio frequency generator, wherein each of the first closed loop antenna array and the second closed loop antenna array comprises a pair of linear plasma tubes..

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ANTENNA ARRAY CONFIGURATIONS FOR PLASMA PROCESSING SYSTEMS

BACKGROUND

Field

[0001] Embodiments of the present disclosure generally relate to a chemical vapor deposition (CVD) system for processing large area substrates. More specifically, embodiments described herein relate to apparatus and methods for various deposition systems having antenna arrays for transmitting electromagnetic energy to facilitate plasma generation that may be utilized in a CVD system. The antenna arrays may be utilized for transmission of frequencies in the radio frequency spectrum (RF), such as microwave (MW) spectrum, the ultra-high frequency (UHF) spectrum, the very high frequency (VHF) spectrum, and combinations thereof.

Description of the Related Art

[0002] CVD is a process whereby chemical precursors are introduced into a processing chamber, chemically react to form a predetermined compound or material, and deposit onto a substrate within the processing chamber. The CVD process may be used to process large area substrates, such as flat panel displays or solar panels. There are several CVD processes that may be used to deposit layers such as silicon based films for transistors or formation of diodes or p-n junctions. One CVD process is plasma enhanced chemical vapor deposition (PECVD) whereby a plasma is ignited in the chamber to enable or enhance the reactions between the precursors. PECVD may be accomplished by utilizing an inductively coupled plasma source, a capacitively coupled plasma source, a microwave power source and combinations thereof.

[0003] A type of high density plasma source recently used in processing of large area substrates includes a linear leaky waveguide array disposed adjacent a substrate. Each linear waveguide is coupled to a radio frequency generator that transmits electromagnetic energy to each waveguide. The electromagnetic energy is then transmitted into a plasma that excites the chemical precursors and promotes deposition on the substrate. While these systems produce a high density plasma, discharges are sometimes localized in proximity to the waveguides, which produces non-uniform deposition on the substrate. A solution to attempt to provide uniform deposition may be to increase the number of waveguides and decrease the lateral spacing between the waveguides. However, additional waveguide hardware is expensive. For example, an increase in the number of waveguides will correlate to an increase in the number of radio frequency generators and related hardware parts, which adds to the increased cost of the system and, ultimately, the cost of manufacturing devices on flat panel display or solar panels.

[0004] There is a need in the art for a method and apparatus that reduces the cost of manufacturing devices on flat panel display or solar panels.

SUMMARY

[0005] The present disclosure generally relates to a deposition system having closed loop antenna arrays and an apparatus having the same. In one embodiment, a deposition system is disclosed. The deposition system includes a first electromagnetic wave applicator comprising a first closed loop antenna array coupled to a first dedicated radio frequency generator, and a second electromagnetic wave applicator comprising a second closed loop antenna array disposed adjacent the first electromagnetic wave applicator and coupled to a second dedicated radio frequency generator, wherein each of the first closed loop antenna array and the second closed loop antenna array comprises a pair of linear plasma tubes.

[0006] In another embodiment, a deposition system for a chemical vapor deposition process is disclosed. The deposition system includes a gas distribution system comprising one or more gas distribution conduits, and a first closed loop antenna array coupled to a first dedicated radio frequency generator, and a second closed loop antenna array coupled to a second dedicated radio frequency generator, the second closed loop antenna array disposed adjacent to the first closed loop antenna array.

[0007] In another embodiment, an apparatus is disclosed. The apparatus includes a load lock chamber coupled to a substrate loading station, the load lock chamber having two substrate locations that are disposed on opposite sides of a center wall, a robot operable to retrieve a substrate from a substrate stacking module and to place the substrate into each substrate loading station, and a processing chamber coupled to the load lock chamber. The processing chamber includes a deposition system comprising a first electromagnetic wave applicator comprising a first closed loop antenna array coupled to a first dedicated radio frequency generator.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present disclosure can be understood in detail, a more particular description of the inventions described herein, 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 the inventions and are therefore not to be considered limiting of its scope, for the inventions may admit to other equally effective embodiments.

[0009] Figure 1A is a schematic diagram of one embodiment of a deposition system.

[0010] Figure 1B is an exemplary cross-sectional view of a plasma tube of the deposition system of Figure 1A.

[0011] Figure 1C is a partial side view of the deposition system of Figure 1A.

[0012] Figure 2 is a schematic diagram of another embodiment of a portion of a deposition system.

[0013] Figures 3A and 3B are sectional views showing various embodiments of intersections of the deposition system shown in Figure 2.

[0014] Figures 4-8 are partial schematic diagrams showing various embodiments of a deposition system.

[0015] Figure 9 is a schematic representation of a vertical, linear CVD system where embodiments of the deposition systems described herein may be utilized.

[0016] 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

[0017] Embodiments of the disclosure generally relates to a deposition system including multiple antenna array configurations that may be utilized in plasma enhanced chemical vapor deposition (PECVD) systems. The antenna array configurations as described herein may be used to facilitate plasma formation in inductively coupled plasma system, a capacitively coupled plasma system, a microwave power system and combinations thereof. While the exemplary embodiments are described for use in PECVD systems, the deposition system can be used for physical vapor deposition (PVD) systems or processes, etch systems or processes, as well as other types of processes utilized in plasma treatment of large area substrates. The embodiments discussed herein may be practiced utilizing a CVD chamber in a modified AKT® Aristo processing system available from Applied Materials, Inc., Santa Clara, California. It is to be understood that the embodiments may be practiced in other systems as well, including those sold by other manufacturers.

[0018] Figure 1A is a schematic diagram of one embodiment of a deposition system 100 for depositing materials on a substrate 105. The deposition system 100 includes one or more electromagnetic wave applicators, shown as applicator 110A and applicator 110B. Each applicator 110A, 110B comprises a closed loop antenna array 115A, 115B that are each coupled to a respective radio frequency generator 120A and 120B. Each closed loop antenna array 115A, 115B may be a rectangular shape. The deposition system 100 also includes a plurality of gas distribution conduits 125. The gas distribution conduits 125 may be positioned between the substrate 105 and the antenna arrays 115A and 115B. Each gas distribution conduit 125 may be coupled at one end to a manifold 130 that is coupled to a precursor gas source 135. Each gas distribution conduit 125 may include openings (shown in Figure 1C) that distribute the precursor gases during a deposition process. A distal end of each gas distribution conduit 125 (*i.e.*, the end opposite the manifold 130) may be capped to prevent gas flow through the end.

[0019] The diagram shown in Figure 1A may be a plan view or an elevation view depending on the orientation of the substrate 105 that is processed by the deposition system 100. For example, the substrate 105 may be processed by the deposition system 100 in a vertical orientation or the substrate may be processed in a horizontal orientation by the deposition system. As such, the view of Figure 1A may be an elevation view of the deposition system 100 or a plan view of the deposition system 100, respectively.

[0020] Each antenna array 115A, 115B of each applicator 110A, 110B includes two linear plasma tubes 140A and 140B coupled to a common radio frequency generator 120A and 120B provided for the respective applicator 110A, 110B. The plasma tubes 140A, 140B are coupled at an end opposite to the respective radio frequency generator 120A and 120B by a cross-member 145. The cross-member 145 is utilized as an electromagnetic energy interface between the plasma tubes 140A and 140B and allows at least a portion of the electromagnetic energy to pass therethrough. The cross-member 145 may be a coaxial waveguide or other type of hollow air- or solid-dielectric filled member that contains electromagnetic waves therein and facilitates transmission of the waves between the plasma tubes 140A and 140B.

[0021] The energy flow path of each applicator 110A, 110B is shown with the applicator 110A. Electromagnetic energy in radio-frequency (RF) bands, such as very high frequency (VHF), ultra high frequency (UHF) or microwave frequencies is provided by the radio-frequency generator 120A. Each applicator 110A, 110B may operate at a frequency within a range of 300 MHz and 10 GHz, such as about 915 MHz or 2.45 GHz, or about 8.3 GHz. The electromagnetic energy travels from the generator 120A bi-directionally. One energy flow path is shown with the applicator 110A as a wave 150A (solid line) and another opposing energy flow path is shown with the applicator 110A as a wave 150B (dashed line). The energy flow paths indicated by waves 150A and 150B may be traveling waves or a standing wave, or a combination of both, depending on how much RF power is provided to applicator and how much power is absorbed in plasma. The electromagnetic energy from either flow path is conducted from one plasma tube to another plasma tube across the cross-member 145. If the energy of waves 150A and 150B is sufficient that the waves complete the whole loop, the applicator operates as a resonator. The energy flow paths indicated as waves 150A and 150B originate from the radio frequency generator 120A, and a portion of the energy may terminate at an isolator 152. The isolator 152 may be utilized to prevent electromagnetic energy from re-entering the radio-frequency generator 120A. While not shown, the energy flow paths may be similar in both of the applicators 110A and 110B.

[0022] Figure 1B is a cross-sectional view of the plasma tube 140A along lines 1B-1B of Figure 1A. The plasma tube 140A shown in Figure 1B is exemplary and may be identical to the cross-section of the plasma tube 140B. In one embodiment, the plasma tube 140A includes an inner conductor 155, which may be a metallic material having good conductive characteristics, such as copper. The plasma tube 140A may also include an outer conductor 160 disposed about the inner conductor 155. The outer conductor 160 may comprise a conductive material, such as copper. The plasma tube 140A also includes a dielectric cover 165 that is disposed about the inner conductor 155. The dielectric cover 165 may comprise a quartz or a ceramic material. A space 170 is defined between the inner conductor 155 and one or both of the outer conductor 160 and the dielectric cover 165. The space 170 is typically sealed from the outside environment by one or both of the outer conductor 160 (when implemented into the plasma tube 140A) and the dielectric cover 165. For example, the space 170 may be sealed by the dielectric cover 165 to enable a pressure therein that is substantially equal to atmospheric pressure. In some embodiments, openings (shown in Figure 1C) are formed in the outer conductor 160, which enable a portion of the electromagnetic energy (*i.e.*, waves 150A, 150B) formed in the space 170 by the radio frequency generators 120A and 120B (shown in Figure 1A) to radiate outside the respective applicator 110A and 110B. While the cross-section of the plasma tube 140A is shown as circular, the plasma tube 140A may include other shapes, such as rectangular or other polygonal shapes. In some embodiments, the plasma tube 140A may not include the inner conductor 155 and/or the outer conductor 160. Instead, the plasma tube 140A may comprise a solid dielectric material, such as a ceramic material, having one or more sides or portions thereof at least partially covered by a conductive material.

[0023] Figure 1C is a partial side view of the deposition system 100 of Figure 1A along lines 1C-1C. Portions of the plasma tube 140A and the gas distribution conduit 125 is shown positioned adjacent the substrate 105. While the gas distribution conduit 125 is shown positioned between the substrate 105 and the plasma tube 140A, the gas distribution conduit 125 may be coplanar with the plasma tube 140A, or spaced farther away from the substrate 105 than the plasma tube 140A.

[0024] Openings 175 are shown in the gas distribution conduit 125 to allow process gases to flow therethrough. A cap 180 is shown on a distal end of the gas distribution conduit 125 to prevent flow of gases out of the end of the gas distribution conduit 125. The openings 175 may be spaced and/or sized to equalize gas flow across the length of the gas distribution conduit 125. For example, at least a *por*tion of the openings 175 may be greater in size, greater in number and/or spaced at a smaller pitch than other openings 175 to control conductance across the length of the gas distribution conduit 125. In some embodiments, the openings 175 near the distal end of the gas distribution conduit 125 may be larger and/or spaced at a smaller pitch than openings 175 proximate the manifold 130.

[0025] In some embodiments, when the outer conductor 160 is used, the outer conductor 160 of the plasma tube 140A includes openings, such as slots 185 (shown in dashed lines). The slots 185 may be spaced and/or sized to enable power application axially (*i.e.*, across the length of the plasma tube

140A). For example, at least a portion of the slots 185 may be greater in size, greater in number and/or spaced at a smaller pitch than other slots 185 to control wave propagation outside of the plasma tube 140A across the length of the plasma tube 140A. In one embodiment, the slots 185 near a proximal end 190 of the plasma tube 140A (*i.e.*, near the radio frequency generator 120A (shown in Figure 1A)) may be smaller and/or spaced at a larger pitch than slots 185 proximate the cross-member 145. Each of the slots 185 may be a single semi-annular opening formed in the outer conductor 160 as shown. Alternatively, each of the slots 185 may include two or more adjacent semi-annular openings to form a slot-pair or slot-group.

[0026] Figure 2 is a schematic diagram of another embodiment of a portion of a deposition system 200 for depositing materials on a substrate 105. As in other embodiments, the deposition system 200 includes the applicator 110A and the applicator 110B, each comprising a closed loop antenna array 115A, 115B, respectively. In this view, the gas distribution conduits 125 are not shown so the closed loop antenna arrays 115A, 115B may be shown in more detail. Similar to Figure 1A, the diagram shown in Figure 2 may be a plan view or an elevation view depending on the orientation of the substrate 105 that is processed by the deposition system 200. For example, the substrate 105 may be processed by the deposition system 200 in a vertical orientation or the substrate 105 may be processed in a horizontal orientation by the deposition system. As such, the view of Figure 2 may be an elevation view of the deposition system 200 or a plan view of the deposition system 200, respectively.

[0027] Components of the deposition system 200 that share the same reference numerals as components of the deposition system 100 described in Figures 1A-1C will not be repeated for brevity. Unless otherwise noted, the components of Figures 1A-1C sharing the same reference numerals as those in Figure 2 operate similarly.

[0028] In the embodiment shown, each of the closed loop antenna arrays 115A, 115B include a plasma tube 140A and a plasma tube 140B coupled to a respective radio frequency generator 120A, 120B on one end and a cross-member 145 at the other end. In one embodiment, the plasma tubes 140A and 140B of each closed loop antenna array 115A, 115B is coplanar in a plane that is substantially parallel to the plane of the substrate 105. In some embodiments, one or both of the cross-members 145 are coplanar with one or both of the plasma tubes 140A and 140B.

[0029] In one embodiment, the deposition system 200 includes a first closed loop antenna array 115A that is meshed with a second closed loop antenna array 115B. In this embodiment, each of the closed loop antenna arrays 115A, 115B include an intersection 205 where a cross-member 145 crosses the plasma tube 140B. In one aspect, the intersection 205 provides an interface between crossing components such that one or both of the plasma tube 140B and the cross-member 145 is coplanar in a plane that is substantially parallel to the plane of the substrate 105. In one embodiment, the intersection 205 is located outside of the area of the substrate 105 such that all plasma tubes 140A and 140B are substantially coplanar within the area of the substrate 105.

[0030] While the deposition system 200 is shown schematically in Figure 2 having the radio frequency generators 120A and 120B extending in a common plane of the plasma tubes 140A, 140B, one or both of the radio frequency generators 120A and 120B may be positioned substantially normal to the plane of the plasma tubes 140A, 140B (*i.e.*, into or out of the page) in order to reduce the footprint of the closed loop antenna arrays 115A, 115B.

[0031] Figures 3A and 3B are sectional views showing various embodiments of the intersections 205 shown in Figure 2. In Figure 3A, the cross-member 145 includes a U-shaped section 300 that at least partially surrounds the plasma tube 140B. The U-shaped section 300 provides an interface at the intersection 205 that provides substantial coplanarity between a first end 305 and a second end 310 of the cross-member 145. Additionally, the plasma tube 140B is substantially coplanar with one or both of the first end 305 and the second end 310 of the cross-member 145. In Figure 3B, the plasma tube 140B includes a bend 315 that at least partially surrounds the cross-member 145. The bend 315 may be an elbow having at least a 45 degree angle that provides an offset in the length of the plasma tube 140B allowing the plasma tube 140B to be bifurcated into two substantially parallel planes about the cross-member 145.

[0032] Figures 4-8 are schematic diagrams showing various embodiments of a portion of a deposition system 400-800 for depositing materials on a substrate 105. Components of the deposition systems 400-800 that share the same reference numerals as components of the deposition system 200 described in Figures 2-3B will not be repeated for brevity. Unless otherwise noted, the components of Figures 1A-3B sharing the same reference numerals as those in Figures 4-8 operate similarly. Similar to Figure 2, the diagrams shown in each of Figures 4-8 may be a plan view or an elevation view depending on the orientation of the substrate 105 that is processed by the respective deposition system. For example, the substrate 105 may be processed by the deposition system in a vertical orientation or the substrate 105 may be processed in a horizontal orientation by the deposition system. As such, the views of Figures 4-8 may be an elevation view or a plan view, respectively.

[0033] The deposition system 400 is similar to the deposition system 200 shown in Figure 2 with the exception of a pair of isolators 152 disposed on a cross-member 405 positioned adjacent respective radio frequency generators 120A and 120B. The isolators 152 make each closed loop antenna array 115A, 115B a non-resonant load. After the waves travel one complete loop in the applicator, shown as paths 150A and 150B, a portion of the wave energy that is not absorbed in plasma does not re-enter the applicator but it is guided out of the applicator and terminates at isolators 152. The closed loop antenna arrays 115A, 115B also include intersections 205 as described in Figure 2. One or both of the intersections 205 may be configured as the intersection 205 shown in Figure 3A and the intersection 205 shown in Figure 3B.

[0034] The deposition system 500 shown in Figure 5 is similar to the deposition system 100 shown in Figure 1A with the exception of a first tuning device 505 disposed on each of the closed loop antenna arrays 115A, 115B. Each of the first tuning devices 505 are utilized as a variable impedance component that may vary the effective length of the electromagnetic wave path, which may be used to adjust power coupling of each closed loop antenna array 115A, 115B. The first tuning device 505 may be a stub tuner or a T-junction with a movable short. Electrically, each of the first tuning devices 505 is a variable shunt impedance in the transmission line circuit of each of the closed loop antenna arrays 115A, 115B.

[0035] The deposition system 600 shown in Figure 6 is similar to the deposition system 500 shown in Figure 5 with the exception of a second tuner device 605 being used instead of the first tuning devices 505. Each of the second tuning devices 605 may be a stub tuner or a movable short. Additionally, each second tuning device 605 may be a partial reflector that reflects a portion of the electromagnetic energy in the waves 150A, 150B. Electrically, each of second tuning device 605 is a variable series impedance in the transmission line circuit of each of the closed loop antenna arrays 115A, 115B.

[0036] The deposition system 700 shown in Figure 7 is similar to the deposition system 200 shown in Figure 2 with the exception of a pair of tuning devices 705 on each of the closed loop antenna arrays 115A, 115B. Each of the tuning devices 705 may be similar to the first tuning devices 505 or the second tuning device 605 described in Figures 5 and 6. The pair of tuning devices 705 on each of the closed loop antenna arrays 115A, 115B provides a power balancing aspect between plasma tubes 140A, 140B on each closed loop, and together work also as tuners for adjusting power coupling to respective applicators 115A and 115B.

[0037] The deposition system 800 shown in Figure 8 is similar to the deposition system 400 shown in Figure 4 with the exception of a pair of tuning devices 705 disposed on each of the closed loop antenna arrays 115A, 115B. Each of the tuning devices 705 may be the same as the first tuning device 505 described in Figure 5 or the second tuning device describe in Figure 6. The pair of tuning devices 705 on each of the closed loop antenna arrays 115A, 115B provides a power balancing aspect between plasma tubes 140A, 140B on each closed loop and adjusting power coupling to the respective applicator. The isolators 152 make each closed loop antenna array 115A, 115B a non-resonant load.

[0038] Figure 9 is a schematic representation of a vertical, linear CVD system 900 where embodiments of the deposition systems 100, 200, 400, 500, 600, 700 and 800 may be utilized. The system 900 may be sized to process substrates having a surface area up to or greater than about 90,000 cm^2 and able to process more than 90 substrates per hour. The system 900 may be configured to deposit materials on substrates as the substrates are moving relative to the deposition systems 100, 200, 400, 500, 600, 700 and 800 (*i.e.*, dynamic). Alternatively, the system 900 may be configured to deposit materials on substrates as the substrates are stationary relative to the deposition systems 100, 200, 400, 500, 600, 700 and 800 (*i.e.*, static).

[0039] The system 900 preferably includes two separate processing lines 905A, 905B coupled together by a common system control platform 910 to form a twin process line configuration/layout. Each processing line 905A, 905B of the system 900 is also configured to process two substrates at a time. A common power supply, common and/or shared pumping and exhaust components and a common gas panel may be used for the twin processing lines 905A, 905B. Each processing line 905A, 905B may process more than 45 substrates per hour for a system total of greater than 90 substrates per hour. It is also contemplated that the system may be configured using a single process line or more than two process lines. While the system 900 is configured to process substrates vertically, the system may be configured to process substrates in a non-vertical plane, such as horizontally.

[0040] There are several benefits to the twin processing lines 905A, 905B for vertical substrate processing. Because the chambers are arranged vertically, the footprint of the system 900 is about the same as a single, conventional horizontal processing line. Thus, within approximately the same footprint, two processing lines 905A, 905B are present, which is beneficial to the manufacturer in conserving floor space in the fabrication facility. To help understand the meaning of the term "vertical", consider a flat panel display. The flat panel display, such as a computer monitor, has a length, a width and a thickness. When the flat panel display is vertical, either the length or width extends perpendicular from the ground plane while the thickness is parallel to the ground plane. Conversely, when a flat panel display is horizontal, both the length and width are parallel to the ground plane while the thickness is perpendicular to the ground plane.

[0041] Each processing line 905A, 905B includes a substrate stacking module 915A, 915B from which fresh substrates (*i.e.*, substrates which have not yet been processed within the system 900) are retrieved and processed substrates are stored. Atmospheric robots 920A, 920B retrieve substrates from the substrate stacking modules 915A, 915B and place the substrates into a dual substrate loading station 925A, 925B. It is to be understood that while the substrate stacking module 915A, 915B is shown having substrates stacked in a horizontal orientation, substrates disposed in the substrate stacking module 915A, 915B may be maintained in a vertical orientation similar to how the substrates are held in the dual substrate loading station 925A, 925B. The fresh substrates are then moved into dual substrate load lock chamber modules 930A, 930B and then to a dual substrate processing chamber modules 935A, 935B. Each of the dual substrate processing chamber modules 935A, 935B may include embodiments of the deposition systems 100, 200, 400, 500, 600, 700 and 800 as described herein. Each deposition system 100, 200, 400, 500, 600, 700 or 800 utilized in each processing chamber modules 935A, 935B may be positioned between two substrates such that both substrates may be processed in each processing chamber module 935A, 935B utilizing a single deposition system 100, 200, 400, 500, 600, 700 or 800. The substrates, now processed, then return through one of the dual substrate load lock chamber modules 930A, 930B to one of the dual substrate loading stations 925A, 925B, where the substrates are retrieved by one of the atmospheric robots 920A, 920B and returned to one of the substrate stacking modules 915A, 915B.

[0042] The deposition systems 100, 200, 400, 500, 600, 700 and 800 as described herein having the closed loop antenna arrays 115A, 115B lower cost of ownership as the number of antennae hardware (radio frequency generators, isolators, and tuners) is significantly reduced. For example, conventionally, two power sources (radio frequency generators) would be utilized to operate each plasma tube 140A and 140B (*i.e.*, one per end of each tube 140A, 140B), but only a single power source is used to operate each closed loop antenna array 115A and 115B (including both plasma tubes 140A and 140B), which reduces number of power sources by factor of 4. Thus, cost of power sources and related hardware parts is significantly reduced, which reduces cost of ownership. Additionally, by utilizing a vertical CVD system, multiple substrates may be processed simultaneously. Processing multiple substrates simultaneously reduces the cost of manufacturing which may increase the manufacturer's profits.

[0043] While the foregoing is directed to embodiments of the inventions disclosed herein, other and further embodiments may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

Claims:

1. A deposition system, comprising:

a first electromagnetic wave applicator comprising a first closed loop antenna array coupled to a first dedicated radio frequency generator, and

a second electromagnetic wave applicator comprising a second closed loop antenna array disposed adjacent the first closed loop antenna array and coupled to a second dedicated radio frequency generator, wherein each of the first closed loop antenna array and the second closed loop antenna array comprises a pair of linear plasma tubes.

2. The deposition system of claim 1, wherein each of the pair of linear plasma tubes are electrically coupled by a coaxial conduit at one end and a cross-member at another end.

3. The deposition system of claim 2, wherein the cross-member includes an electrical isolator.

4. The deposition system of claim 2, wherein one or both of the coaxial conduit and one of the linear plasma tubes includes a tuner device.

5. The deposition system of claim 4, wherein the tuner device comprises a reflector.

6. The deposition system of claim 2, wherein the coaxial conduit intersects with one of the linear plasma tubes.

7. The deposition system of claim 6, wherein one of the coaxial conduit and the one of the linear plasma tubes includes a bent portion.

8. The deposition system of claim 1, wherein the first closed loop antenna array and the second closed loop antenna array are coplanar.

9. A deposition system for a chemical vapor deposition process, the system, comprising:

a gas distribution system comprising one or more gas distribution conduits; and

a first closed loop antenna array coupled to a first dedicated radio frequency generator; and

a second closed loop antenna array coupled to a second dedicated radio frequency generator, the second closed loop antenna array disposed adjacent to the first closed loop antenna array.

10. The deposition system of claim 9, wherein the first closed loop antenna array and the second closed loop antenna array are coplanar.

11. The deposition system of claim 9, wherein the first closed loop antenna array and the second closed loop antenna array are intermeshed.

12. The deposition system of claim 9, wherein each of the first closed loop antenna array and the second closed loop antenna array comprises a pair of linear plasma tubes.

13. The deposition system of claim 12, wherein each of the pair of linear plasma tubes are electrically coupled by a coaxial conduit at one end and a cross-member at another end.

14. The deposition system of claim 13, wherein the cross-member includes an electrical isolator.

15. The deposition system of claim 13, wherein the coaxial conduit includes a tuner device.

16. The deposition system of claim 15, wherein the tuner device comprises a reflector.

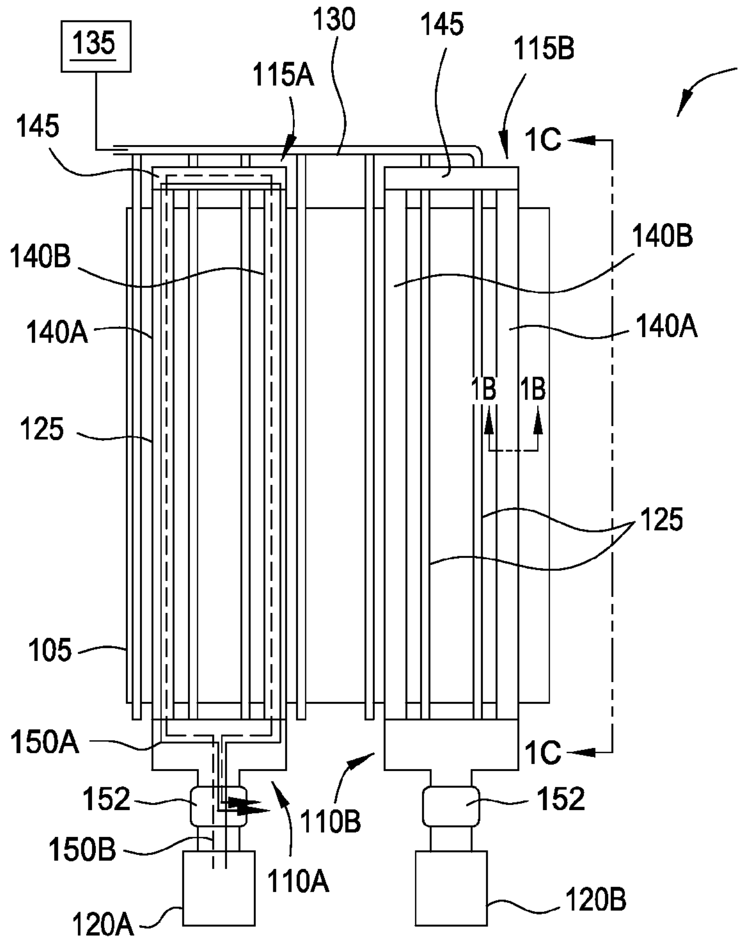

FIG. 1A

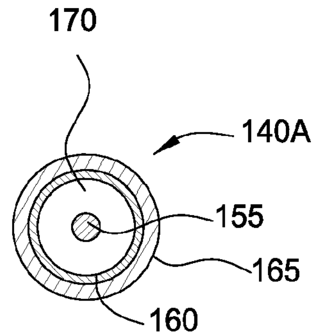

FIG. 1B

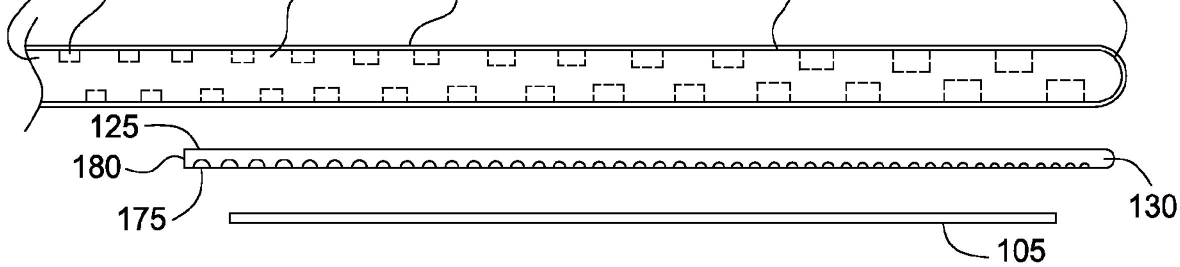

FIG. 1C

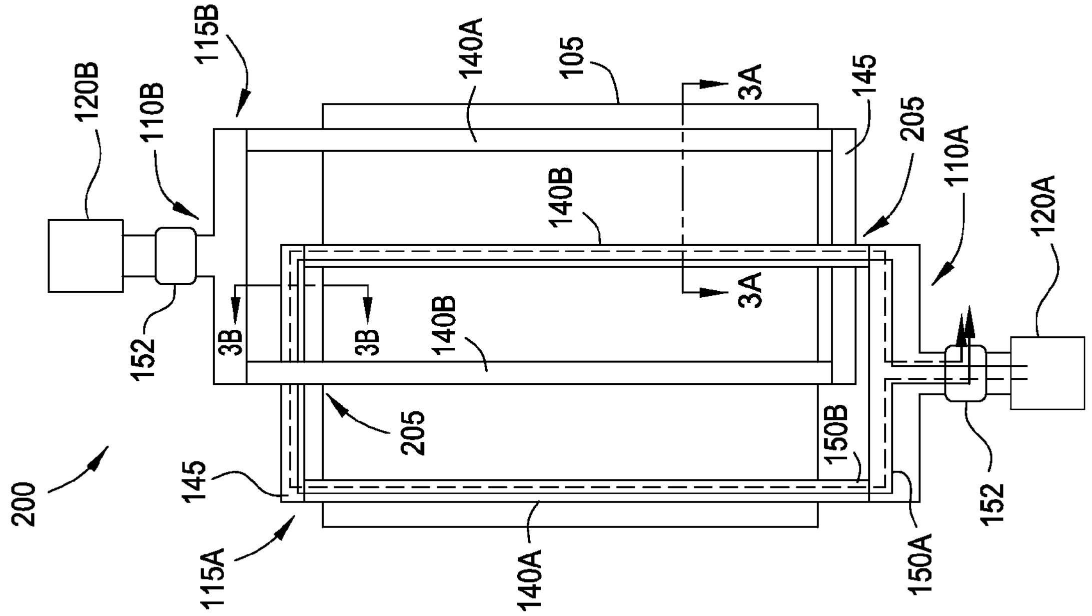

FIG. 2

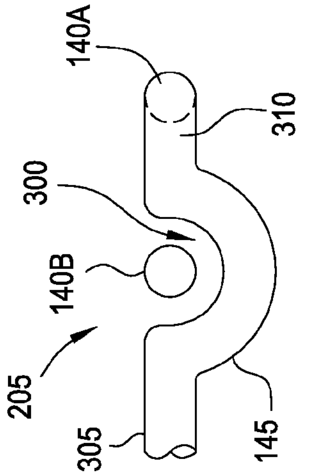

FIG. 3A

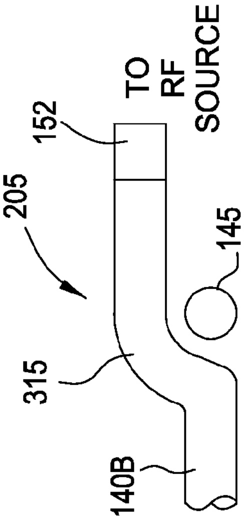

FIG. 3B

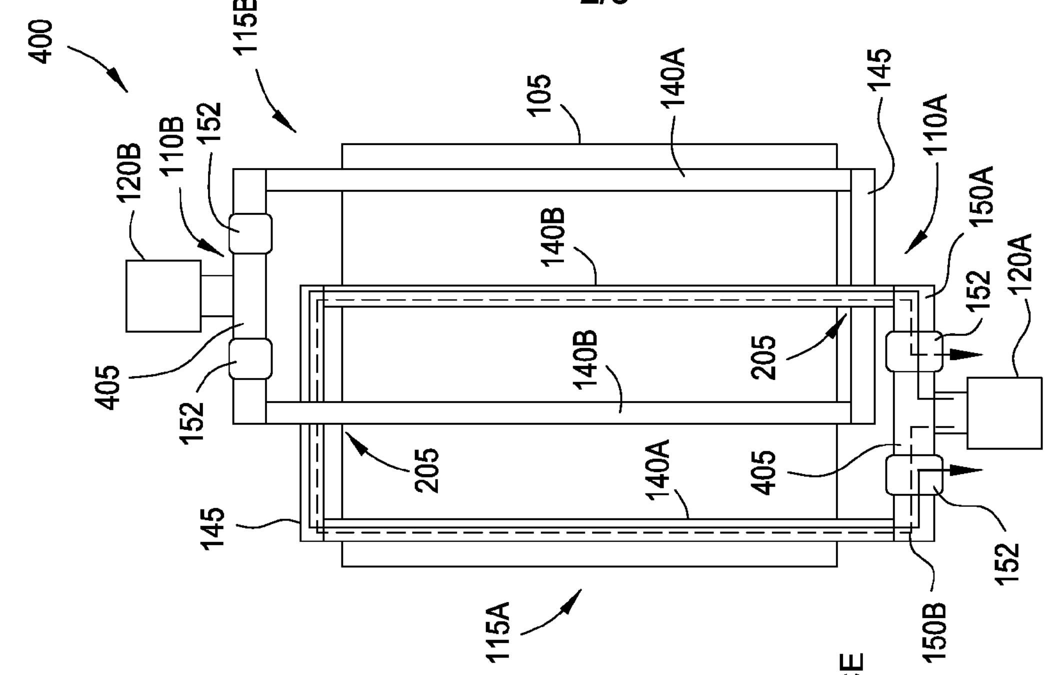

FIG. 4

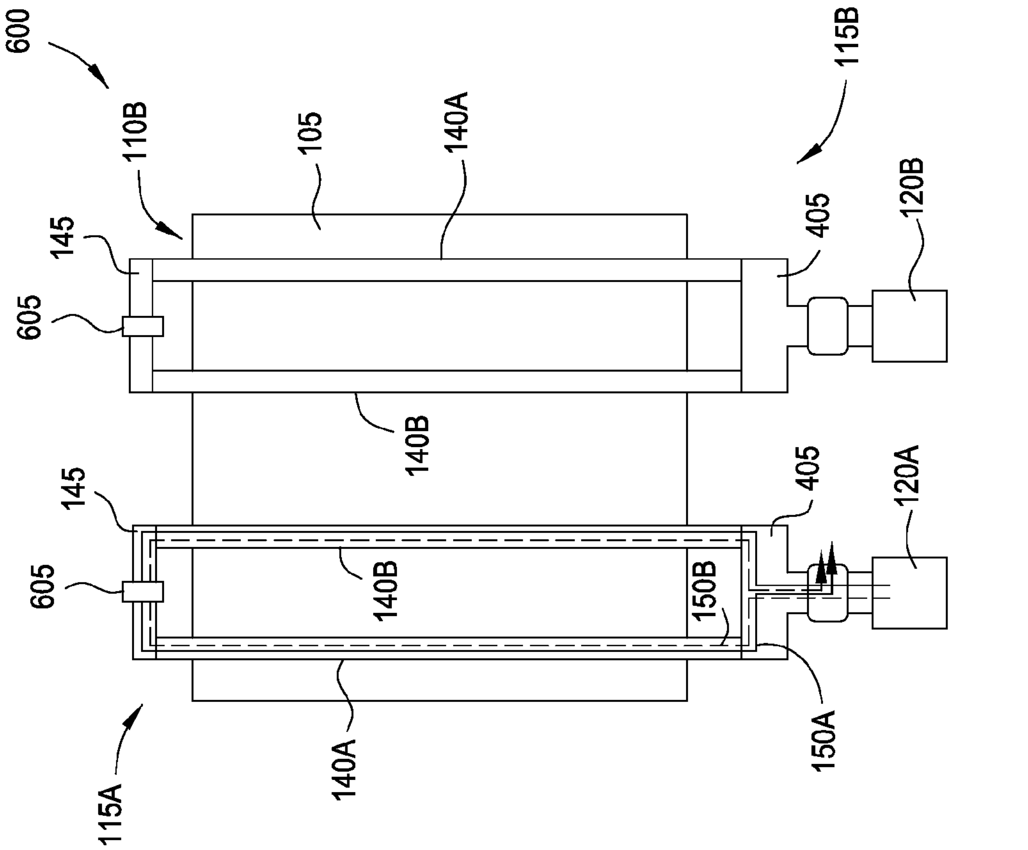
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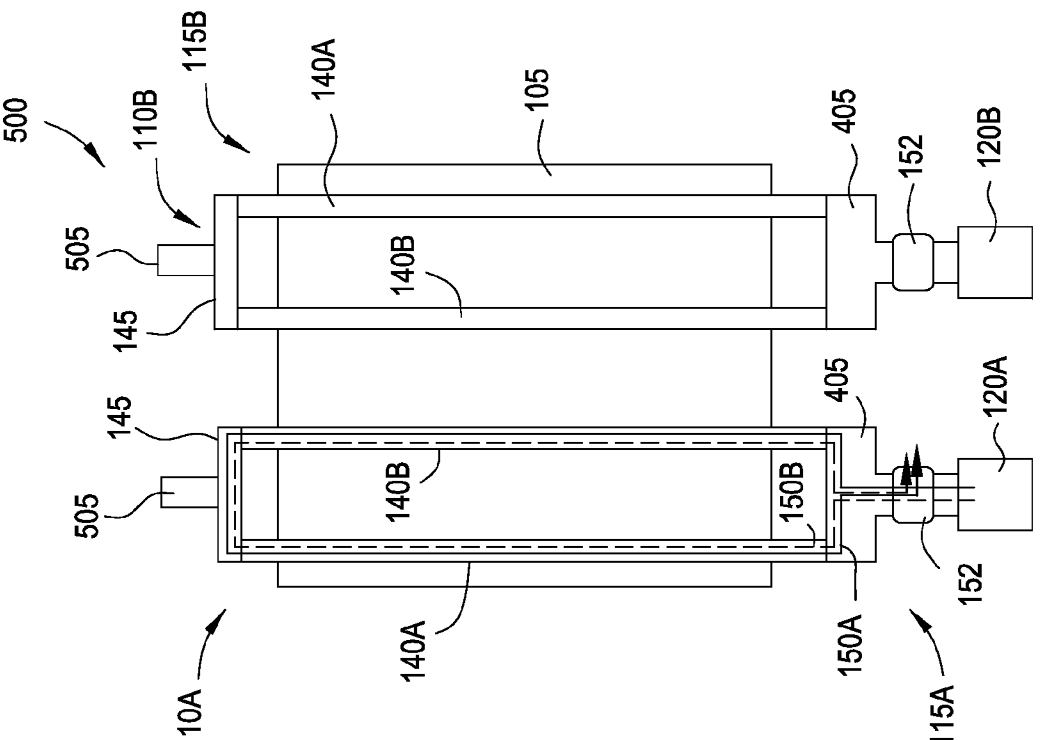
FIG. 6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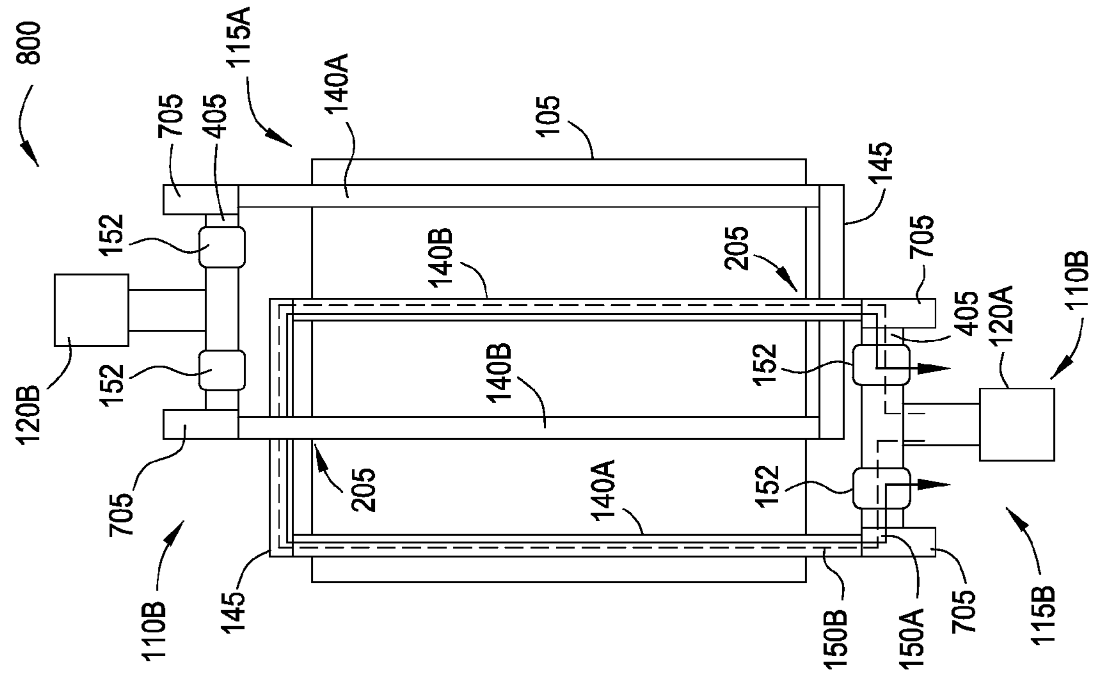
115A

FIG. 5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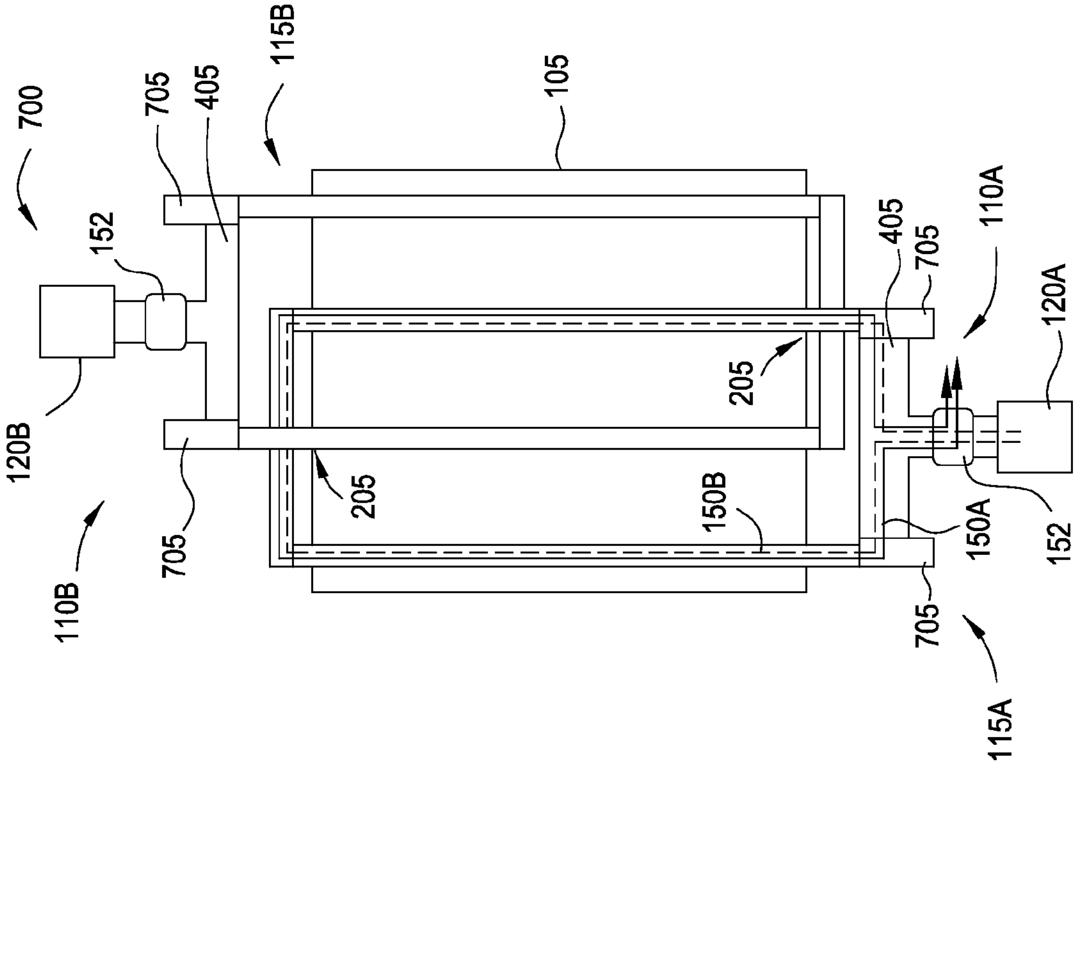
115B

FIG. 8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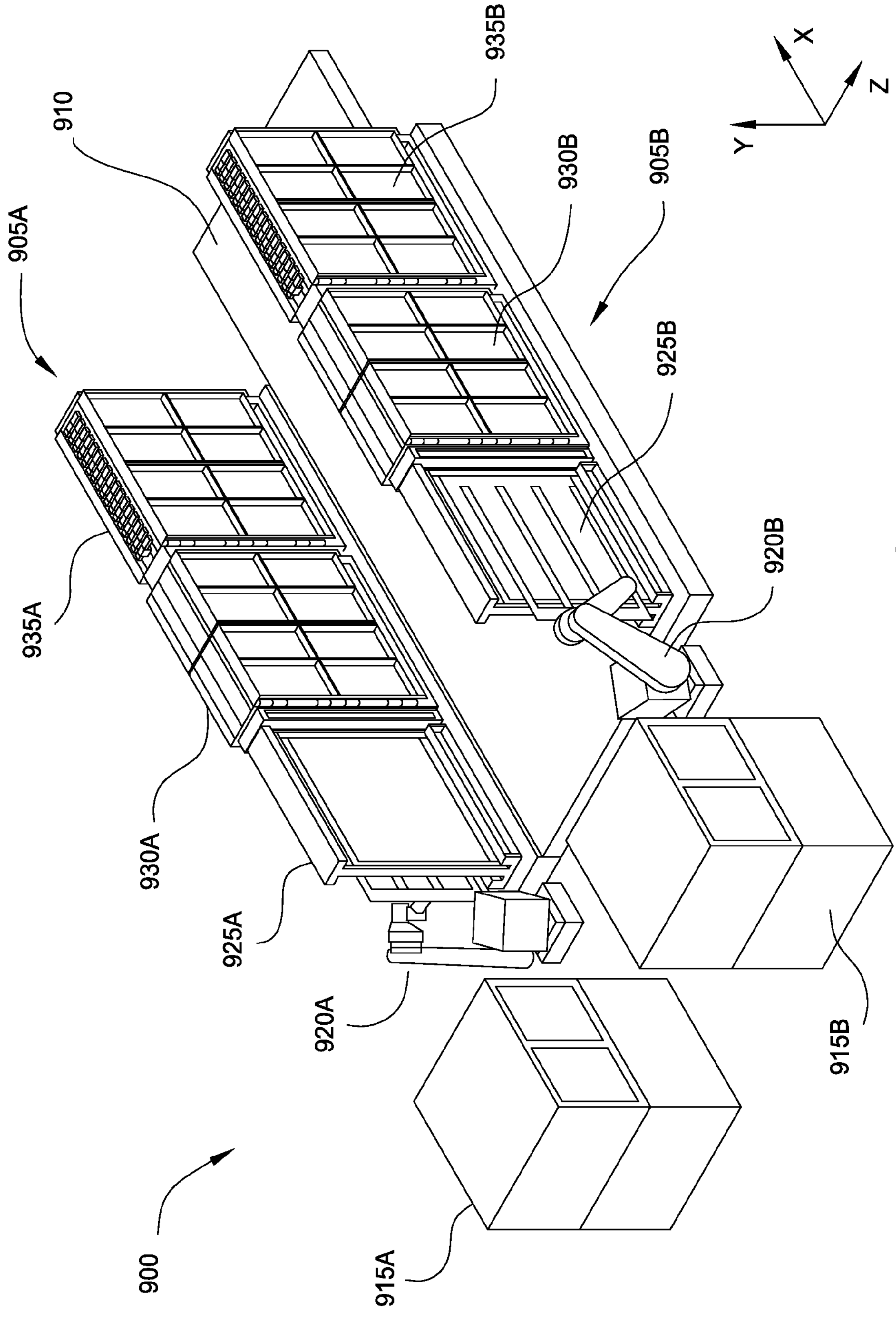
115A

FIG. 7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925A
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935A
935B
X
Y
Z

FIG. 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/034144

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/205(2006.01)i, H05H 1/46(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 21/205; H01P 3/12; H05H 1/46; C23C 16/52; G21B 1/00; B05C 9/00; C23C 16/50; H01J 37/32; H05H 1/00; C23C 16/00; C23C 16/511

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: plasma, antenna, loop, gas

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2004-0221814 A1 (GEUN-YOUNG YEOM et al.) 11 November 2004 See abstract, paragraphs [0020]-[0028] and figure 2.	1-16
A	US 2012-0148761 A1 (MICHAEL W. STOWELL et al.) 14 June 2012 See abstract, paragraphs [0024]-[0054] and figures 1-5.	1-16
A	EP 0489407 A2 (APPLIED MATERIALS INC.) 10 June 1992 See abstract, page 5, line 39 - page 8, line 13 and figures 1-2.	1-16
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A	US 5795429 A (NOBUO ISHII et al.) 18 August 1998 See abstract, column 9, line 51 - column 10, line 27 and figure 8.	1-16
A	US 2004-0223579 A1 (YOUNG-KWAN LEE et al.) 11 November 2004 See abstract, paragraphs [0033]-[0036] and figures 3-4.	1-16

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

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"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
18 August 2014 (18.08.2014)	**18 August 2014 (18.08.2014)**

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Information on patent family members

International application No.

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