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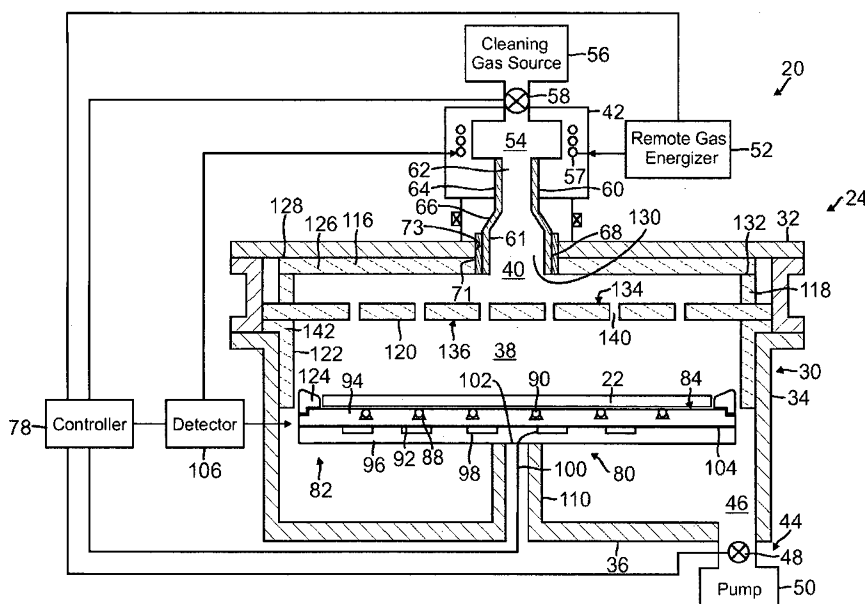

FIG. 1

(57) **Abstract:** A substrate cleaning chamber comprises various components, such as for example, a consumable ceramic liner, substrate heating pedestal, and process kit. The consumable ceramic liner is provided for connecting a gas outlet channel of a remote gas energizer to a gas inlet channel of a substrate cleaning chamber. The substrate heating pedestal comprises an annular plate having a substrate receiving surface with a plurality of ceramic balls positioned in an array of recesses. A process kit comprises a top plate, top liner, gas distributor plate, bottom liner, and focus ring.

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SUBSTRATE CLEANING CHAMBER AND COMPONENTS

BACKGROUND

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In the processing of substrates such as semiconductors and displays, layers are formed on the substrate, and then etched to form features such as electrically conducting interconnects, contacts, vias, gates and barriers. For example, a pattern of electrical interconnect lines can be made by depositing a metal-containing conductor on the substrate, 10 forming a patterned etch resistant material on the conductor, etching the conductor to form the interconnect lines, removing remnant resist, and depositing dielectric over the etched features. The dielectric layer can be further etched to form contact holes or vias that expose the underlying metal-containing conductor material or other substrate layers. Electrically conducting material is then deposited into the etched holes or trenches to electrically contact 15 the underlying conductor. For example, in the formation of copper-containing interconnects, the dielectric layer can be etched to form contact holes that expose an underlying copper conductor material. A thin seed layer of copper can be deposited over the exposed conductor and contact hole to facilitate subsequent copper electroplating processes to fill the contact holes.

20 However, contaminants and undesirable surface material on the metal-containing conductor require cleaning of the exposed conductor surfaces before subsequent process steps are performed. For example, a native oxide film often forms on a conductor exposed to oxygen species during an intermediate process step, for example, during a resist stripping process in which an oxygen-containing gas plasma is used to strip resist, or when 25 transferring the substrate between different chambers. The oxide films increase the electrical resistance at the contact interface between conductor surfaces. The surface material can also have residual process deposits from previous processes, such as for example carbon-containing, silicon-containing, fluorine-containing, and nitrogen-containing process residues. These process deposits can cause voids or other irregularities to form at the interface between 30 the exposed and deposited materials.

Substrate cleaning chambers, also known as pre-clean chambers, are used to clean oxide films and other undesirable process deposits from the substrate surface prior to processing and in between processing steps. During the cleaning process, the substrate is 35 supported in the cleaning chamber and an energized cleaning gas is formed in a remote gas chamber and introduced into the chamber. The cleaning gas reacts with and removes the surface residues. In some processes, the substrate heating pedestal includes a heating element to control the temperature of the substrate during cleaning.

However, one problem with the use of an energized cleaning gas in such cleaning processes is that it is difficult to control the energy of the radical and ionic species of the excited cleaning gas. Higher energy collisions between the cleaning gas and the substrate surface can cause damage to the underlying substrate. Lighter ions in the cleaning gas, such as for example H^+, can also be detrimental when they penetrate the surface of the substrate to damage underlying dielectric layers. Thus, it is desirable to control the energy of, and type of energized species introduced into the process chamber.

Another problem is that the cleaning gas often etches away and erodes the remote chamber wall surrounding the excitation region of the remote within a gas energizer, and can even etch and erode components inside the cleaning chamber. Such erosion damages these components, and if the component is an integral part of the chamber, the chamber must be shut down to allow the component to be refurbished or replaced after a predetermined number of process cycles, which is undesirable. Conventional stainless steel walls and liners are particularly susceptible to erosion and require frequent replacement or refurbishment.

Yet another problem occurs when the substrate heating pedestal in the cleaning chamber that contacts the substrate, transfers contaminants and process residues deposits to the backside of the substrate or even scratches the substrate during the substrate transferring process. Substrate heating pedestals containing heating elements can also provide non-uniform heating across the surface of the substrate. Substrate heating pedestals having a substrate receiving surface made up of raised mesas and grooves allow flow of a heat transfer gas behind the substrate to improve temperature uniformity but still transfer undesirable amounts of process residues and deposits to the substrate.

Thus, it is desirable to have a cleaning chamber and gas energizer that can selectively filter energized gas species, for example, to filter out certain ionic species from the cleaning gas. It is also desirable to have chamber components that can be easily replaced or refurbished. It is further desirable to have a substrate heating pedestal that minimizes contamination of the substrate by the transfer of process deposits to the backside surface of the substrate. It is also desirable to have a substrate heating pedestal that allows a more uniform heating of the substrate.

SUMMARY

A consumable ceramic liner for connecting a gas outlet channel of a remote chamber to a gas inlet channel of a substrate cleaning chamber is provided. The liner

comprises: an inlet cylinder having an outer diameter sized to fit in the gas outlet channel of the remote chamber; an outlet cylinder connected to the gas inlet channel of the substrate cleaning chamber; and a conical flare joining the inlet cylinder to the outlet cylinder.

5 Several embodiments of the consumable ceramic liner are provided. In one embodiment the conical flare of the liner comprises a conical surface that is inclined from a vertical axis at an angle of from about 10 to about 60 degrees. In one embodiment, the ratio of the length of the conical flare to the length of the outlet cylinder is from about 1:2 to about 1:8. In one embodiment the inlet cylinder of the liner comprises a first diameter and the outlet
10 cylinder of the liner comprises a second diameter that is at least 1.5 times larger that the first diameter. In a further embodiment, the first diameter is from about 1 to about 4 cm and the second diameter is from about 2 to about 8 cm. In one embodiment the liner comprises a ceramic material that is capable of scavenging an ion species from the energized gas generated in the remote gas energizer. In one embodiment the liner is be composed of quartz,
15 aluminum oxide or aluminum nitride and can even have a thickness of from about 2 mm to about 6 mm. The liner can further comprise a liner locking cylinder that is sized to fit around the outer diameter of the outlet cylinder.

A method of inserting a ceramic liner into a upper chamber wall for connecting a
20 gas outlet channel of a remote chamber to a gas inlet channel of a substrate cleaning chamber, the ceramic liner comprising an inlet cylinder sized to fit in the gas outlet channel of the remote chamber, an outlet cylinder connected to the gas inlet channel of the substrate cleaning chamber, and a conical flare joining the inlet to the outlet cylinder, is provided. The method has steps of: (a) placing a liner locking cylinder over the outlet cylinder of the ceramic liner; (b)
25 sliding a liner holding tool into the outlet cylinder of the ceramic liner, the outer diameter of the liner holding tool being sized to grip the inner diameter of the outlet cylinder; and (c) grasping the liner holding tool and inserting the inlet cylinder of the ceramic liner into the gas outlet channel of the remote chamber.

30 In one embodiment the method further comprises: (d) twisting the liner holding tool to lock an annular flange of the locking cylinder into a matching annular lip of the upper chamber wall.

A substrate heating pedestal for a substrate cleaning chamber is provided. The
35 substrate heating pedestal comprises: (a) an annular plate comprising a first disk having a substrate receiving surface with an array of recesses, a second disk having a channel shaped to receive the heating element, and a brazed bond joining the first and second disks; (b) a plurality of ceramic balls that are each positioned in a recess on the substrate receiving surface;

and (c) a heating element embedded in the annular plate.

The brazed bond of the substrate heating pedestal can comprise an aluminum brazing compound. The first and second disks of the pedestal can comprise aluminum. The ceramic balls of the pedestal can be composed of alumina oxide, quartz, sapphire, silicon nitride, synthetic corundum, zirconium oxide, Al_2O_3, or mixtures thereof. In one embodiment the ceramic balls of the pedestal comprise a diameter of from about 1 to about 3 mm and can even have a diameter that is sufficiently large to maintain the substrate receiving surface higher than the top surface of the annular plate by from about 0.01 mm to about 0.5 mm.

A gas distributor plate for a substrate process chamber is provided. The gas distributor plate has: a first ring of first holes that each have a diameter d; a second ring of second holes that each have a diameter 2d, the second ring being radially outward of the first ring; a third ring of third holes that each have a diameter 3d, the third ring being radially outward of the second ring; and a fourth ring of fourth holes that each have a diameter 4d, the fourth ring being radially outward of the third ring.

In one embodiment of the gas distributor plate, the diameter d is from about 1 to about 5 mm. The gas distributor plate can be composed of a ceramic and can even comprise aluminum oxide or silicon oxide.

A process kit for a substrate cleaning chamber having a chamber lid holding a gas distributor plate which faces a substrate heating pedestal is provided. The process kit has: (a) a top plate for contacting the chamber lid, the quartz top plate having an orifice for passing process gas therethrough, and having a perimeter edge; (b) a top liner contacting the perimeter edge of the quartz top plate and being above the gas distributor plate; (c) a bottom liner below the gas distributor plate; and (d) a focus ring resting on a peripheral edge of the substrate heating pedestal.

In one embodiment of the process kit the top plate, top liner, bottom liner and focus ring all comprise quartz. The top plate of the process kit can comprise an annular disk having an outer peripheral edge and an orifice for passing process gas therethrough. The top plate can have a thickness of from about 1 mm to about 5 mm. In one embodiment the gas distributor plate of the process kit is composed of a ceramic and can even comprise aluminum oxide or silicon oxide. The top and bottom liners of the process kit can comprise cylinders. The focus ring of the process kit can have an inner flange which rests on the peripheral edge of the substrate heating pedestal, the flange comprising a sloped upper surface that joins to a vertical

surface at the substrate periphery. In a further embodiment the sloped upper surface of the process kit comprises an angle of between about 85 to about 100°.

DRAWINGS

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These features, aspects, and advantages of the present invention will become better understood with regard to the following description, appended claims, and accompanying drawings, which illustrate examples of the invention. However, it is to be understood that each of the features can be used in the invention in general, not merely in the context of particular
10 drawings, and the invention includes any combination of these features, where:

FIG. 1 is a sectional side view of an embodiment of a substrate processing apparatus comprising a substrate cleaning chamber;

15 FIG. 2A is an exploded perspective view of a consumable ceramic liner being fitted into a top plate of the cleaning chamber using a liner locking cylinder and liner holding tool;

FIG. 2B is a schematic side view of the ceramic liner and liner locking cylinder
20 fitted into the top plate of the cleaning chamber;

FIG. 3A is a perspective view of a substrate heating pedestal having ceramic balls embedded in the substrate receiving surface;

25 FIG. 3B is a cross sectional schematic view of the substrate heating pedestal of FIG. 3A having first and second discs with a brazed bond, and an embedded heating element;

FIG. 4A is an exploded perspective view of a process kit and gas distributor plate;

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FIG. 4B is a schematic partial sectional view of the process kit, gas distributor plate and substrate heating pedestal in a cleaning chamber;

FIG. 4C is a top view of the gas distributor plate; and

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FIG. 5 is a schematic view of a substrate processing apparatus comprising a substrate cleaning chamber.

DESCRIPTION

An embodiment of an substrate apparatus 20 comprising a cleaning chamber 24
5 suitable for cleaning a substrate 22, is shown in its FIG. 1. The cleaning chamber 24, as shown, is suitable for cleaning substrates 22 such as semiconductor wafers; however, the cleaning chamber 24 can be adapted by those of ordinary skill to clean other substrates 22, such as flat panel displays, polymer panels, or other electrical circuit receiving structures. Thus, the scope of the present invention should not be limited to the illustrative embodiments of
10 the cleaning chamber shown herein. Generally, the cleaning chamber 24 comprises one or more enclosure walls 30, which can include an upper wall 32, sidewalls 34, and a bottom wall 36, and which enclose a process zone 38. Energized cleaning gas is provided to a gas inlet channel 40 of the cleaning chamber 24 from a remote chamber 42. The cleaning gas reacts with the substrate 22 and other surfaces within the chamber 24. Spent gas and byproducts are
15 exhausted from the chamber 24 through an exhaust system 44 which may include an exhaust port 46 that receives gas from the process zone 38, and can also include a throttle valve 48 to control the pressure of gas in the chamber 24, and one or more exhaust pumps 50, such as a turbo-molecular exhaust pump. The exhaust system 44 can be capable of maintaining a sub-atmospheric pressure in the chamber 24.
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A remote chamber 42 suitable for remotely energizing the cleaning gas comprises a remote gas energizer 52 which couples energy to a gas energizer zone 54. A cleaning gas source 56 provides a cleaning gas to the gas energizer zone 54. A flow valve 58 can be provided to control a flow rate of the cleaning gas into the remote chamber 42. The gas
25 energizer 52 couples energy to the cleaning gas in the gas energizer zone 54 to form an energized cleaning gas comprising ionic and radical species. The gas energizer 52 can couple, for example, RF or microwave energy to the cleaning gas. In one version, the remote gas energizer 52 comprises an inductor antenna 57 that inductively couples RF energy to the cleaning gas in the gas energizer zone 54 at a power level of, for example, from about 100
30 Watts to about 10 kWatts. The gas energizer 52 can also be a toroidal gas energizer to couple energy to the cleaning gas in the remote zone 54, as for example described in U.S. Patent No. 6,150,628 to Smith et al., which is incorporated by reference herein and in its entirety. A suitable RF power level applied by the toroidal gas energizer may be from about 1000 Watts to about 10,000 Watts. A remote gas energizer 52 comprising a microwave gas activator
35 providing a microwave power level of from about 300 Watts to about 5 kW, can also be used.

A consumable ceramic liner 60 connects a gas outlet channel 62 of the remote gas energizer 52 to a gas inlet channel 40 of the chamber 24, as shown in FIGS. 2A and 2B.

The liner 60 serves to protect the channels 40, 62 by covering their inner surfaces with at least a portion of the surface of the liner 60, such that the inner surface 61 of the liner 60 is exposed to the energized gas species. The liner 60 comprises an inlet cylinder 64 having an outer diameter sized to fit in the gas outlet channel 62 of the remote gas energizer. In one version, the inlet cylinder 64 has a length L that is sufficiently long to extend out from the remote chamber 42 by a distance of at least about 50 mm. The length L is sufficiently short to terminate at least about 1 mm before the end of the gas inlet 40 of the chamber 24. In one version, the inlet cylinder 64 has a length L of from about 100 to about 110 mm, and a diameter of between about 1 cm to about 4 cm.

A conical flare 66 joins the inlet cylinder 64 to an outlet cylinder 68. The conical flare 66 comprises a tube having a diameter that increases along a conical surface over the length of the flare 66. The conical flare 66 has an upper end 70 and a lower end 72. The outer diameter of the upper end 70 of the conical flare 66 is sized to correspond to the outer diameter of the inlet cylinder 64 at the junction between the conical flare 66 and the inlet cylinder 64. The outer diameter of the lower end 72 of the conical flare 66 is sized to correspond to the outer diameter of the outlet cylinder 68 at the junction between the conical flare 66 and the outlet cylinder 68. The diameter of the lower end 72 of the conical flare 66 is larger than the diameter of the upper end 70 of the conical flare 66 by at least a factor of 1.5.. In one version the inlet cylinder 64, the conical flare 66 and the outlet cylinder 68 are integrally connected.

The conical flare 66 serves to gradually increase the diameter of the inner volume of the liner 60 between the upper and lower ends 70, 72 to provide a more uniform distribution of energized gas species entering the process chamber. An abrupt change in diameter was believed to result in non-uniform gas distribution from the outlet of the liner. The conical flare 66 gradually tapers the diameter from the first diameter of the inlet cylinder 64 to the second diameter of the outlet cylinder 68 to provide a gradual increase in volume along the flow path of the dissociated gas species. In one version,
the conical flare 66 comprises a conical surface that is angled relative to a vertical axis passing through the centerline of the conical flare, at an angle of from about 10 degrees to about 60 degrees. Also, the ratio of the length of the conical flare 66 to the length of the outlet cylinder 68 is from about 1:2 to about 1.8. Spacing the increase in volume across a length of the conical flare 66 provides better distribution of gas species at the outlet end 72 of the conical flare 66.

The liner 60 also has an outlet cylinder 68 that is connected to the gas inlet channel 40 of the substrate cleaning chamber 24. In one version, the outlet cylinder 68 has an outer diameter sized to fit in the gas inlet channel 40 of the substrate cleaning chamber 24.

The outlet cylinder 68 has a length L that is sufficiently short to terminate before a process zone of the cleaning chamber 24 to avoid erosion in the chamber environment. When the inlet cylinder 64 has a first diameter, the outlet cylinder 68 comprises a second diameter that is at least 1.5 times larger that the first diameter. In one version, the outlet cylinder 68 has a
5 diameter of from about 2 cm to about 8 cm or more typically about 4 cm. The outlet cylinder 68 protects the inner surfaces of the gas inlet 40 of the chamber from erosion by the energized gas species, while also increasing the diameter of the liner to reduce collisions between the energized gas species formed in the remote zone 54.

10 The consumable liner 60 comprises a ceramic material capable of scavenging an ion species from the energized gas generated in the remote gas energizer. For example, the liner 60 can comprise quartz, aluminum oxide or aluminum nitride. In one version, the liner 60 comprises quartz and is capable of scavenging hydrogen ions from the energized gas by adsorbing some of the hydrogen ions onto its inner surface 74. The quartz inner surface 74 is
15 believed to act as an ion filter 76 to reduce the recombination of the radicals by providing a surface to which hydrogen-containing species can adsorb. It is also believed that hydrogen-containing species that impinge on the quartz surface 74 release an adsorbed hydrogen-containing radical into the energized gas thereby regenerating free hydrogen radicals. However, hydrogen ions are not regenerated by the quartz surfaces 74, and thus, the hydrogen
20 ions impinging on the quartz surface recombine to form electrically neutral, non-ionic species. Thus, passing the activated or energized cleaning gas over the quartz surface 74, causes ionic species to be filtered out from the energized cleaning gas while hydrogen radicals are preserved.

25 The thickness of the consumable liner 60 is selected depending upon the number of process cycles the liner must withstand before replacement. The energized gas is capable of etching and eroding the liner 60, thus, the liner 60 must be replaced after a predetermined number of process cycles. Also, the adsorption properties of the liner 60 degrade as more and more ions are adsorbed onto the surface of the ceramic liner. The
30 number of cycles that the liner 60 can withstand is related to the thickness of the liner 60. In one version, the liner 60 is sufficiently thick to scavenge ion species for at least about 30,000 process cycles, and has a thickness of from about 2 mm to about 6 mm.

The liner 60 can be made by molding a ceramic powder into the desired shape,
35 for example, by cold isostatic pressing. For example, ceramic powder is combined with a liquid binding agent such as the organic binding agent polyvinyl alcohol. The mixture is placed in a rubber bag of an isostatic pressing device and a pressure is uniformly applied on the walls of the bag to compact the mixture to form a ceramic structure having the desired tubular shape.

The pressure can be applied, for example, by immersing the flexible container in water or by other pressurizing methods. The molded ceramic preform can be made cylindrical or ring-like using a hollow tube mold, and the resultant molded ceramic preform can be further shaped by machining. The shaped ceramic preform is then sintered to form a sintered ceramic. For example, aluminum oxide can be sintered at a temperature of from about 1300°C to about 1800°C for about 48 to about 96 hours, typically at a pressure of about 1 atm. The sintered ceramic material can be further shaped, for example, by machining, polishing, laser drilling, or using other methods, to provide the desired ceramic structure.

The liner 60 is held in place in the chamber by a liner locking cylinder 71. The liner locking cylinder 71 is sized to slide over the outer diameter of the outlet cylinder 68 of the liner 60 and it rests against an annular lip 69 of the outlet cylinder 68. as shown in FIGS. 2A and 2B. The liner locking cylinder 71 fits in between the outer cylinder 68 of the liner 60 and the aperture wall 73 to form a gas tight seal as shown in FIG. 1, and can b made from a metal or ceramic material.

Advantageously, the liner locking cylinder 71 facilitates placement into the upper chamber wall 32, and also facilitates removal of the liner 60 after it is exposed to plasma for a preset number of process cycles, for refurbishment or replacement. The liner locking cylinder 71 comprises a circular flange 73 which extends out from one end of the locking cylinder 71. The circular flange 73 has a flat key 75 which is inserted into a matching flat key portion 77 on an annular lip 79 extending out from the upper chamber wall 32, as shown in FIG. 2B. Twisting the liner locking cylinder 71 rotates the circular flange 73 so that it slides behind the annular lip 79 of the upper chamber wall 32 to lock the circular flange behind the same. A locking blocker (not shown) such as a locking pin can be inserted into the pathway of the rotating circular flange 73 to block and stop the flange from further rotation.

A method of inserting the liner 60 into a chamber lid for connecting a gas outlet channel 62 of a remote chamber 42 to a gas inlet channel 40 of a cleaning chamber 24 is also demonstrated in FIG. 2B. In this method, the liner locking cylinder 71 is first placed over the outlet cylinder 68 of the ceramic liner 60. Then, a liner holding tool 81 is passed into the outlet cylinder 68 of the ceramic liner 60 so that the outer diameter of the liner holding tool 81 grips the inner diameter of the outlet cylinder 68. A user grasps the liner holding tool 81 and then inserts the inlet cylinder 64 of the ceramic liner 60 into the gas outlet channel 62 of the remote chamber 42. The liner holding tool 81 is then twisted to lock the circular flange 73 of the liner locking cylinder 71 into a matching annular lip 79 of the upper chamber wall 32 as described.

The chamber 24 may also optionally comprise a chamber gas energizer (not shown) that couples energy to the gas in the process zone 38 of the chamber 24. For example, the chamber gas energizer can comprise one or more of electrodes and an inductor antenna to couple RF energy.

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A substrate heating pedestal 80 is provided to hold the substrate 22 in the process zone 38 of the substrate cleaning chamber 24 as shown in FIGS. 1, 3A, 3B and 4B. The pedestal 80 comprises an annular plate 82 having a substrate receiving surface 84 with an array of recesses 88 and a heating element 92 embedded in the annular plate 82. The heating
10 element 92 is controlled by a controller 78. The controller 78 is able to supply a variable power level to the heating element 92 in response to at least one of: input from one or more detectors 106 that monitor the conditions in the cleaning chamber 24 or the remote chamber 42, or input from a user of the apparatus 20. The pedestal 80 can optionally comprise an electrode (not shown) that can be electrically biased to hold the substrate 22 to the pedestal 80 or affect the
15 characteristics of the process, such as the degree of ion bombardment of the substrate 22. The bias applied to the electrode is also controlled by the controller 78.

A plurality of ceramic balls 90 are each positioned in a recess 88 on the substrate receiving surface 84 as shown in FIG. 3A. The ceramic balls 90 are embedded in the
20 surface 84 of the pedestal 80 such that a portion of the surface of each ball 90 is situated above the plane of the pedestal surface 84. As such, a top region 144 of the balls 90 make up a raised substrate receiving surface 86 consisting of N discrete regions, where N is the number of balls 90 embedded in the surface 84 of the pedestal 80. The raised substrate receiving surface 86 is vertically separated from the pedestal surface 84. That is, the raised substrate receiving
25 surface 86 is higher than the surface of the annular plate 82 by from about 0.01 mm to about 0.5 mm. Supporting the substrate 22 by a series of discrete points, and at a vertical distance from the surface of the annular plate 82 of the heating pedestal 80 allows for gas in the chamber 24 to transfer heat between the substrate 22 and the surface of the annular plate 82 during heating. Suspension of the substrate 22 above the surface of the annular plate 82
30 allows for a more uniform heating of the substrate 22, as compared to contacting the substrate 22 to the surface of the annular plate 82, because the thermal contact is not directly affected by local variations in the thermal conductivity and surface contact characteristics of the plate 82.

In one version, the ceramic balls 90 are spherical in shape and the diameter of
35 the balls 90 is sufficiently high to maintain the substrate receiving surface higher than the top surface of the annular plate by from about 0.01 mm to about 0.5 mm. Typically, the balls 90 comprise a diameter of between about 1 mm and about 3 mm. In one version, the spherical bodies have a diameter of about 2 mm and protrude from the upper surface of the annular plate

82 by about 0.04 mm. The ceramic balls 90 comprise at least one of silicon nitride, zirconium oxide, sapphire, synthetic corundum, and alumina oxide and in one version comprise alumina oxide.

5 The annular plate 82 is constructed from two disks 94, 96 which are bonded together with a brazed bond. In one version, as shown in FIGS. 3A and 3B, the annular plate 82 comprises a first disk 94 having the raised substrate receiving surface 86. The first disk 94 comprises a thickness of from about 10mm to about 30mm and diameter of from about 10cm to about 70cm. The diameter of the disk 94 is dependant on the dimensions of the substrate to be 10 processed. The receiving surface of the disk 94 comprises a plurality of recesses 88 each having a diameter and a depth sufficient to receive a ceramic ball 90. The recesses 88 can be formed by machining and preferably comprise sides which are sloped inward by between about 2 and about 20 degrees such that the diameter of the recess 88 at the surface of the first disk is slightly less than the diameter of the ceramic ball 90. Recesses 88 machined in this manner 15 are capable of confining the inserted ceramic balls 90 to the surface of the annular plate 82 after insertion.

A second disk 96 is provided having a diameter to match the diameter of the first disk 94 and a thickness of between about 6 mm and about 15 mm. The second disk 96 20 comprises a channel 98 shaped to receive the heating element 92 and is made of at least one of aluminum, copper, titanium, molybdenum or stainless steel, or combinations thereof. In one version, the second disk comprises aluminum, and the brazing bond material comprises an aluminum brazing material. The heating element 92 comprises a resistor assembly having sufficient electrical resistance to maintain the surface 84 of the annular plate 82 at temperatures 25 of from about room temperature to about 400°C. The heating element 92 is powered via terminal posts 100 which extend through the second disk 96 about the center 102 of the disk.

The annular plate 82 with embedded heating element 92 may be formed by machining a first disk 94 from an aluminum sheet having a thickness of about 5mm. Recesses 30 88 having a depth of about 2 mm from the surface 84 of the first disk 94 are drilled into the surface 84 of the disk 94 corresponding to the desired placement of the countersunk ceramic balls 90. A second disk 96 is machined to have the same diameter as the first disk 94 from an aluminum sheet having a thickness of from about 11.5 mm to about 12.5 mm. A serpentine channel 98 is machined in the disk 96, the channel 98 having a width and depth corresponding 35 to the dimensions of the heating element 92. At least one pair of holes (not shown) are drilled about the center 102 of the second disk 96. The drilled holes have a diameter of at least 10% greater than the diameter of the terminals 100 of the heating element 92. The heating element 92 is applied to the grooved side of the second disk 96 by pressing it into the channel 98 and

threading the terminals 100 through the drilled holes. A brazing foil or brazing compound is placed onto the grooved surface of the second disk 96 such that it covers the surface of the second disk 96. The non-pitted side of the first disk 94 is held onto the brazing surface and the assembly is aligned such that the circumferences of the first and second disks 94, 96 overlap
5 with each other. The assembly is bonded together by placing the assembly in a furnace, heating the assembly to above the melting point of the brazing material and applying pressure, such as in a hot press. The assembly is then cooled to form a brazed bond 104.

The backside surface of the annular plate 82 is mounted to a support post 110
10 used for supporting the annular plate 82. The support post 110 comprises a rod having a receiving surface adapted to receive the backside surface of the annular plate 82. The rod may comprise a metal such as stainless steel or aluminum and may be a solid or a hollow structure. In one version, the support post 110 also comprises a bellows and a lift mechanism (not shown) that is adapted to raise and lower the pedestal 80 into position for receiving a substrate 22,
15 treating the substrate 22 and removing the substrate 22 from the chamber 24. The method of fastening the annular plate 82 to the support post 110 can comprise welding the support post 110 to the bottom surface of the annular plate 82, welding a threaded adapter to the bottom surface of the annular plate 82 and then screwing the annular plate 82 to the support post 110 or by welding a hollowed tube onto the bottom surface of the annular plate 82 and then
20 clamping the hollowed tube to the support post 110.

A process kit 114 comprising several components 112 is provided to contain the energized gas into the cleaning chamber 24 and distribute the gas across the substrate surface as shown in FIG. 4A and 4B. The components 112 of the process kit 114 can include, for
25 example, a top plate 116, a top liner 118, a gas distributor plate 120, a bottom liner 122, and a focus ring 124. The components 112 of the process kit 114 can be easily removed from the chamber 24, for example, to replace or repair eroded components, or to adapt the cleaning chamber 24 for processing substrates 22 of different sizes. The process kit 114 components can be made from quartz because quartz is effective at reducing the recombination rate of
30 process gas radicals such as hydrogen radicals.

The top plate 116 comprises an annular disk 126 having an outer peripheral edge 128 and an orifice 130 for passing process gas therethrough as illustrated in FIG. 4A. The top plate 116 is sized to fit into the substrate cleaning chamber 24 and the orifice 130 has a
35 diameter of between about 40 mm and about 45 mm and is located about the center of the top plate 116 such that the orifice 130 substantially overlaps with the gas inlet channel 40 of the upper chamber wall 32. The top plate 116 contacts the upper wall 32 of the chamber 24. The

top plate 116 contacts and is supported by the top liner 118. The top plate 116 comprises a thickness of from about 1 mm to about 10 mm.

The top liner 118 contacts the outer peripheral edge 128 of the top plate 116.
5 The top liner 118 comprises a cylinder that serves to confine the energized process gas and to protect the walls 30 of the cleaning chamber 24 from the energized process gas. The liner 118 comprises a thickness of from about 0.60 cm to about 0.70 cm. In one version, the outer peripheral edge 128 of the top plate 116 rests on the upper edge 132 of the top liner 118.

10 A gas distributor plate 120 has a top surface 134 contacting the top liner 118, a bottom surface 136, and a plurality of holes 140 therethrough for distributing process gas in the chamber 24. The holes 140 are shaped, sized, and distributed in a spaced apart relationship across the surface of the plate 120 to promote uniform delivery of the process gas to the surface of the substrate 22. In one version, the plurality of holes 140 comprises four rings
15 139a-d of holes 140a-d that are each sized with different diameters as shown in FIG. 4C. In one version, the innermost first ring 139a of first holes 140a that are sized with a diameter d. A second ring 139b of second holes 140b that each have a diameter 2d, are located radially outward of the first ring 139a. A third ring 139c of third holes 140c that each have a diameter 3d are radially outward of the second ring 139b. A fourth ring 139d of fourth holes 140d that
20 each have a diameter 4d are being radially outward of the third ring 139c. Such a distribution of holes 140a-d provides more uniform delivery of the process gas to the surface of the substrate 22. In one version, the first holes 140a have a diameter d which is from about 1 to about 5 mm, and the other holes 140b-d are sized accordingly. As one example, the first ring of holes 140a each have a diameter of from about 1 to about 5 mm; the second ring of holes 140b each have
25 a diameter of from about 2 to about 10 mm; the third ring of holes 140c each have a diameter of from about 3 to about 15 mm; and the fourth ring of holes 140a each have a diameter of from about 4 to about 20 mm. In one version, the different diameter holes 140a-d are also spaced apart to include a larger number of holes on the fourth ring 139d, and progressive smaller numbers of holes for the third ring 139c, second ring 139b, and first ring 139a. The gas
30 distributor plate 120 can be composed of a ceramic, such as for example, aluminum oxide or silicon oxide, and the silicon oxide can be quartz.

A bottom liner 122 contacts the bottom surface 136 of the gas distributor plate 120 as shown in FIGS. 4A and 4B. The bottom liner 122 also comprises a cylinder having an
35 annular peripheral edge 142 that extends outward from the cylinder. The peripheral edge 142 contacts the bottom surface 136 of the gas distributor plate 120 and the sidewall 34 of the cleaning chamber 24.

A focus ring 124 is provided to focus the energized process gas onto the substrate 22. The focus ring 124 comprises an inner flange 148 which rests on the peripheral edge of the support pedestal 80 and which has a sloped upper surface 150 joining a vertical surface 151 at the substrate periphery, as shown in FIGS. 3B and 4B. The sloped upper
5 surface 150 comprises an angle of between about 85 to about 100°, for example about 95°. The focus ring 124 also has a foot 152 which is elevated about a outer ledge 154 of the substrate heating pedestal 80.

The process kit 114 components described above can comprise a filtering
10 material, such as for example quartz, to adsorb ionic species from the energized gas to filter out the ionic species from the energized gas. In one version, at least a portion of the surfaces of the top plate 116, top liner 118, gas distributor plate 120, bottom liner 122 and focus ring 124 comprises quartz, for example a coating of quartz. The quartz can be deposited onto the surfaces of these process kit 114 components by physical vapor deposition or by hydrothermal
15 deposition. A suitable thickness for a layer of quartz on these surfaces is from about 0.01 mm to about 4 mm. In one version, the process kit 114 components 112 are composed of quartz.

The quartz surfaces 74 can be arranged to provide optimal filtering of the hydrogen ion species from the energized cleaning gas. In one version, the quartz surfaces 74
20 comprise the interior surface of a portion of the ceramic liner 60 that connects the gas energizer zone 54 and the cleaning chamber 24. For example, the ceramic liner 60 can comprise a quartz tube. In another version, the quartz surface 74 comprises one or more surfaces of a gas distributor, such as for example the upper surface of the gas distributor plate 120. The quartz surfaces may also comprise a wire grid situated between the remote zone and the substrate,
25 for example above the process zone, to further filter the activated cleaning gas.

In one cleaning process performed in the cleaning chamber 24 of apparatus 20, the temperature of the substrate 22 is set to provide optimum conditions for the reduction of oxides in the deposits, and can even be set to accelerate the chemical reaction between the
30 hydrogen-containing radicals and the deposits. For example, the temperature of the substrate 22 may be maintained at from about 0 to about 500°C, such as from about 150°C to about 450°C, and even from about 25°C to about 350°C, such as from about 150°C to about 350°C. In one version, a bias power level applied to the substrate 22 during the cleaning process may be desirably low, as a high bias power level can increase the bombardment of the substrate 22
35 by ions in the energized cleaning gas. A suitable bias power level may be less than about 100 Watts such as, for example, from about to about 0 to about 10 Watts, and even from about 1 to about 10 Watts, and may even be substantially zero. In another version, a higher bias power

level may be applied to increase the rate of cleaning, such as a bias power level of greater than 100 Watts, and even from about 100 Watts to about 200 Watts.

It has further been discovered that cleaning of the substrate 22 can be improved by performing a heat treatment or annealing step to remove deposits from the substrate 22. In the heat treatment step, the substrate 22 is heated to a temperature that is sufficiently high to vaporize material from the substrate 22. A flow of a reducing gas may also be provided during the heat treatment step to inhibit the formation of oxides on the substrate 22. A suitable reducing gas may comprise a hydrogen-containing gas, such as for example H_2. The heat treatment step can be performed without substantially energizing the reducing gas, for example without substantially coupling RF or microwave energy to the reducing gas, to provide a relatively gentle initial clean of the substrate 22 prior to the energized hydrogen radical cleaning step.

In one version of a suitable cleaning process, a cleaning gas comprising from about 50 to about 1000 sccm of H_2, such as 300 sccm of H_2, and from about 0 to about 10 sccm H_2O, such as 3 sccm H_2O is activated in the chamber 42 of the remote gas energizer 52 by applying a power level of from about 300 Watts to about 3000 Watts, such as 1050 Watts. The remote chamber 42 pressure is maintained at less than about 10 Torr, such as about 1 Torr. A bias power level of from about 0 to about 100 Watts, such as 50 Watts is applied to bias the substrate 22, and the temperature of the substrate 22 is maintained at from about 150 to about 450°C, such as 250°C. The cleaning process substantially removes the deposits to provide a cleaned surface.

After the cleaning process has been completed, the pressure in the chamber 24 is reduced to a pressure of less than about 10 mTorr, to evacuate spent cleaning gas and cleaning by-products and to reduce the likelihood of contamination of the multi-chamber apparatus 26 by the cleaning chamber 24. The substrate 22 can then be transferred under vacuum via a substrate transfer chamber having a transfer robot 119 to a deposition chamber 24b to deposit a second metal-containing conductor 21, such as at least one of copper, aluminum, tantalum, tungsten, tantalum nitride and tungsten nitride, on the freshly cleaned metal-containing conductor surface.

A multi-chamber apparatus 20 suitable for processing substrates 22 comprises one or more process chambers 28a-d which can include the cleaning chamber 24, as shown in FIG. 5. The chambers are mounted on a platform that provides electrical, plumbing, and other support functions. The platform typically supports a load lock 156 to receive a cassette 158 of substrates 22 to be processed and a substrate transfer chamber 154 containing a robot 162 to

transfer substrates 22 from the cassette 158 to the different chambers 28a-d for processing and return them after processing. The different chambers 28a-d may include, for example, a cleaning chamber 24, a deposition chamber 28b for depositing materials on wafers, optionally, a heat treatment chamber 28c, and other processing chambers. For example, in one version, 5 one of the chambers comprises the cleaning chamber 24 for removing deposits formed on a metal-containing conductor on the substrate 22. After the cleaning process is finished, the substrate 22 can be transferred by the robot 162 to a deposition chamber 28d to deposit material such as a metal-containing conductor on the cleaned substrate 22. The substrate 22 can also be transferred by the robot 162 to a second deposition chamber 28c capable of 10 depositing another material, such as another metal-containing conductor, over the first material deposited in the first chamber 28b. The chambers 28a-d are interconnected to form a continuous vacuum environment within the walls 164 of the substrate transfer chamber 154 to provide as process which may proceed uninterrupted and reducing contamination of substrates 22. The transfer chamber 154 comprises a wall 160 having an exhaust port 164 to exhaust 15 gases and to maintain a low pressure environment, such as a pressure of less than about 10 mTorr, in order to reduce contamination of the chambers.

The multi-chamber apparatus 26 can be operated by a controller 170 via a hardware interface. The controller 170 comprises a computer (not shown) having a central 20 processor unit (CPU) that is coupled to a memory and peripheral computer components. Preferably, the memory may include a removable storage media, such as for example a CD or floppy drive, a non-removable storage media, such as for example a hard drive, and random access memory. The controller 170 may further comprise a plurality of interface cards including, for example, analog and digital input and output boards, interface boards, and motor 25 controller boards. In one version, the controller 170 comprises a computer-readable program may be stored in the memory, for example on the non-removable storage media or on the removable storage media. The computer readable program generally comprises process control software comprising program code to operate the chambers 28a-d and their components, the transfer chamber 154 and robot 162, process monitoring software to monitor 30 the processes being performed in the chambers, safety systems software, and other control software, as for example. The computer-readable program may be written in any conventional computer-readable programming language.

Although exemplary embodiments of the present invention are shown and 35 described, those of ordinary skill in the art may devise other embodiments which incorporate the present invention, and which are also within the scope of the present invention. For example, the chamber 24 may comprise components other than those specifically described, as would be apparent to those of ordinary skill in the art. Furthermore, the terms below, above,

bottom, top, up, down, first and second and other relative or positional terms are shown with respect to the exemplary embodiments in the figures and are interchangeable. Therefore, the appended claims should not be limited to the descriptions of the preferred versions, materials, or spatial arrangements described herein to illustrate the invention.

What is claimed is:

1. A consumable ceramic liner for connecting a gas outlet channel of a remote chamber to a gas inlet channel of a substrate cleaning chamber, the ceramic liner comprising:

(a) an inlet cylinder having an outer diameter sized to fit in the gas outlet channel of the remote chamber;

(b) an outlet cylinder connected to the gas inlet channel of the substrate cleaning chamber; and

(c) a conical flare joining the inlet cylinder to the outlet cylinder.

2. A liner according to claim 1 wherein the ratio of the length of the conical flare to the length of the outlet cylinder is from about 1:2 to about 1:8.

3. A liner according to claim 1 comprising a ceramic material capable of scavenging an ion species from the energized gas generated in the remote gas energizer.

4. A method of inserting a ceramic liner into a upper chamber wall for connecting a gas outlet channel of a remote chamber to a gas inlet channel of a substrate cleaning chamber, the ceramic liner comprising an inlet cylinder sized to fit in the gas outlet channel of the remote chamber, an outlet cylinder connected to the gas inlet channel of the substrate cleaning chamber, and a conical flare joining the inlet to the outlet cylinder, the method comprising:

(a) placing a liner locking cylinder over the outlet cylinder of the ceramic liner;

(b) sliding a liner holding tool into the outlet cylinder of the ceramic liner, the outer diameter of the liner holding tool being sized to grip the inner diameter of the outlet cylinder; and

(c) grasping the liner holding tool and inserting the inlet cylinder of the ceramic liner into the gas outlet channel of the remote chamber.

5. A method according to claim 4 further comprising:

(d) twisting the liner holding tool to lock an annular flange of the locking cylinder into a matching annular lip of the upper chamber wall.

6. A substrate heating pedestal for a substrate cleaning chamber, the substrate heating pedestal comprising:

(a) an annular plate comprising a first disk having a substrate receiving surface with an array of recesses, a second disk having a channel shaped to receive the heating element, and a brazed bond joining the first and second disks;

(b) a plurality of ceramic balls that are each positioned in a recess on the substrate receiving surface; and

(c) a heating element embedded in the annular plate.

7. A pedestal according to claim 6 wherein the ceramic balls are composed of alumina oxide, quartz, sapphire, silicon nitride, synthetic corundum, zirconium oxide, Al_2O_3, or mixtures thereof.

8. A pedestal according to claim 6 wherein the ceramic balls comprise a diameter of from about 1 to about 3 mm.

9. A pedestal according to claim 8 wherein the diameter of the ceramic balls is sufficiently large to maintain the substrate receiving surface higher than the top surface of the annular plate by from about 0.01 mm to about 0.5 mm

10. A gas distributor plate for a substrate process chamber, the gas distributor plate comprising:

(a) a first ring of first holes that each have a diameter d;

(b) a second ring of second holes that each have a diameter 2d, the second ring being radially outward of the first ring;

(c) a third ring of third holes that each have a diameter 3d, the third ring being radially outward of the second ring; and

(d) a fourth ring of fourth holes that each have a diameter 4d, the fourth ring being radially outward of the third ring.

11. A gas distributor plate according to claim 10 wherein the diameter d is from about 1 to about 5 mm.

12. A gas distributor plate according to claim 10 composed of a ceramic.

13. A process kit for a substrate cleaning chamber having a chamber lid holding a gas distributor plate which faces a substrate heating pedestal, the process kit comprising:

(a) a top plate for contacting the chamber lid, the quartz top plate having an orifice for passing process gas therethrough, and having a perimeter edge;

(b) a top liner contacting the perimeter edge of the quartz top plate and being above the gas distributor plate;

(c) a bottom liner below the gas distributor plate; and

(d) a focus ring resting on a peripheral edge of the substrate heating pedestal.

14. A process kit according to claim 13 wherein a top plate, top liner bottom liner, and focus ring, all comprise quartz.

15. A process kit according to claim 13 wherein the focus ring comprises an inner flange which rests on the peripheral edge of the substrate heating pedestal, the flange comprising a sloped upper surface that joins to a vertical surface at the substrate periphery.

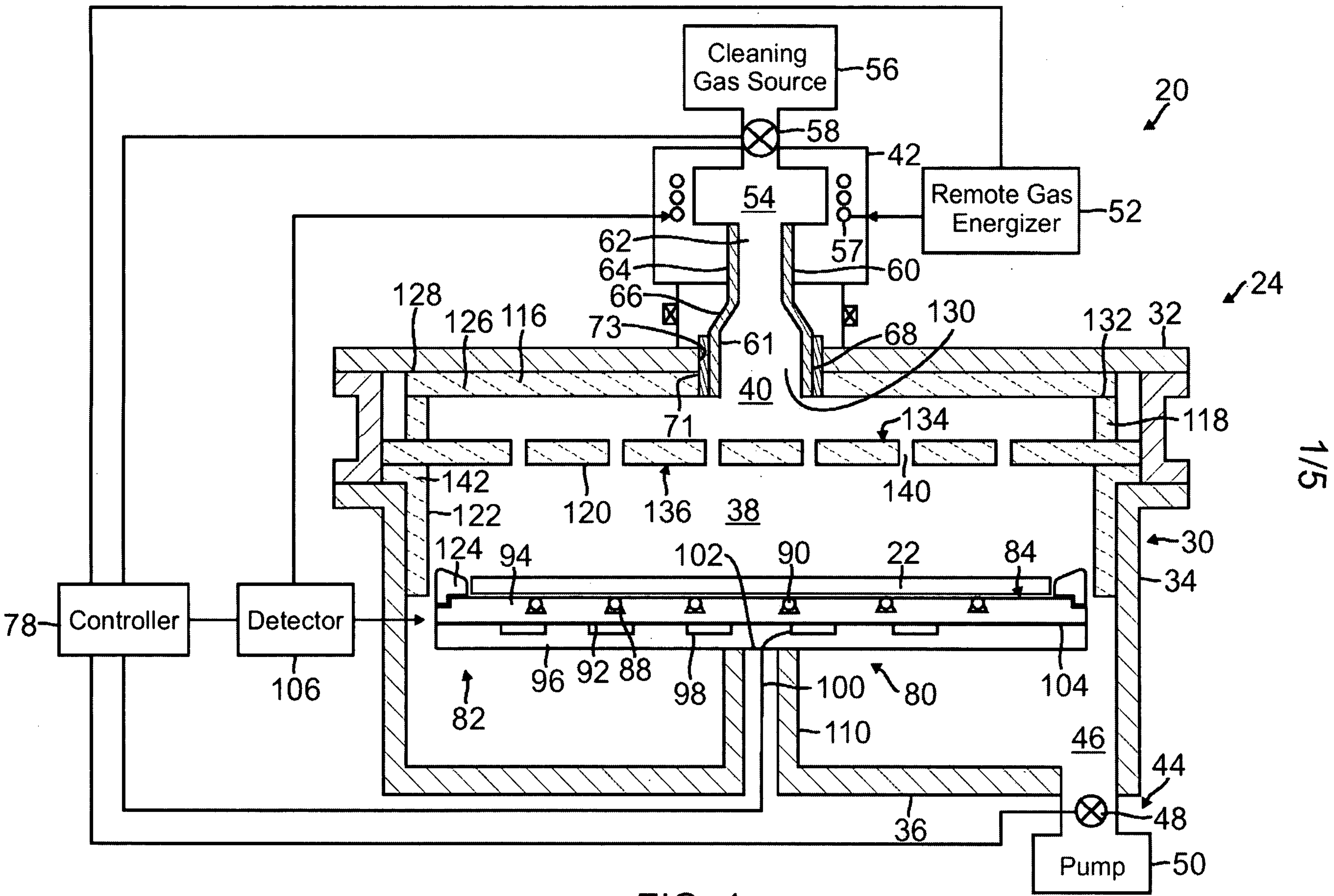

FIG. 1

FIG. 2A

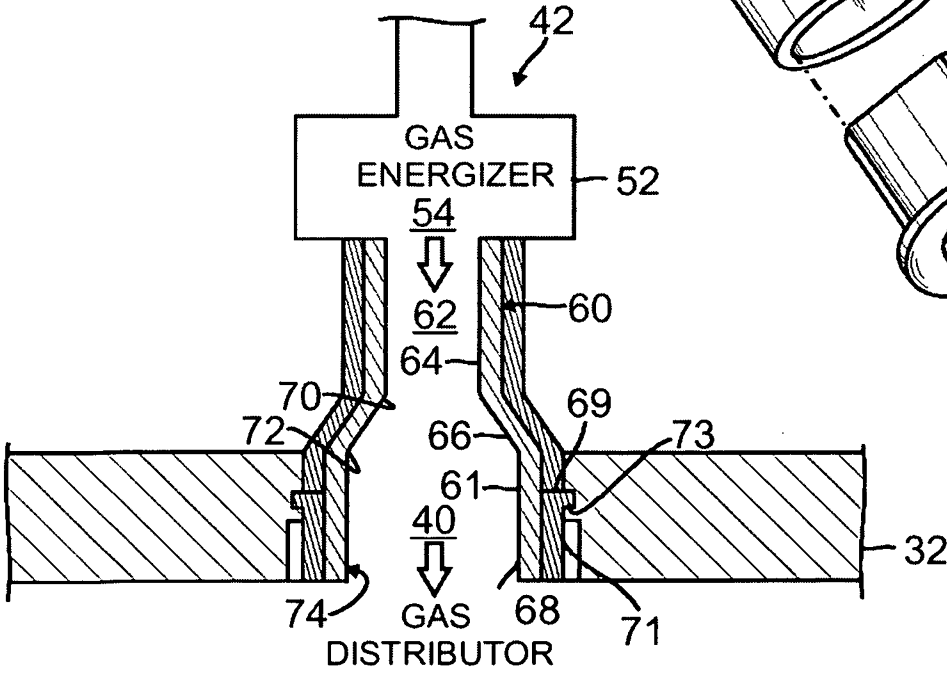

FIG. 2B

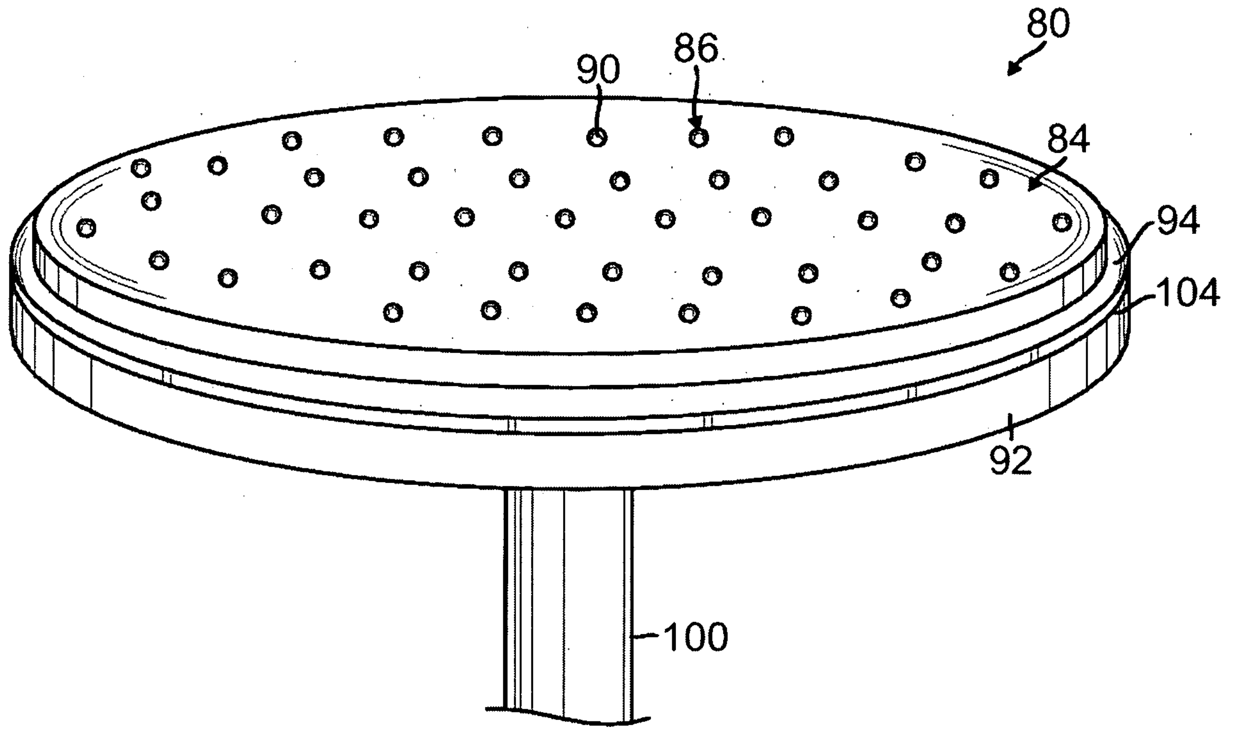

FIG. 3A

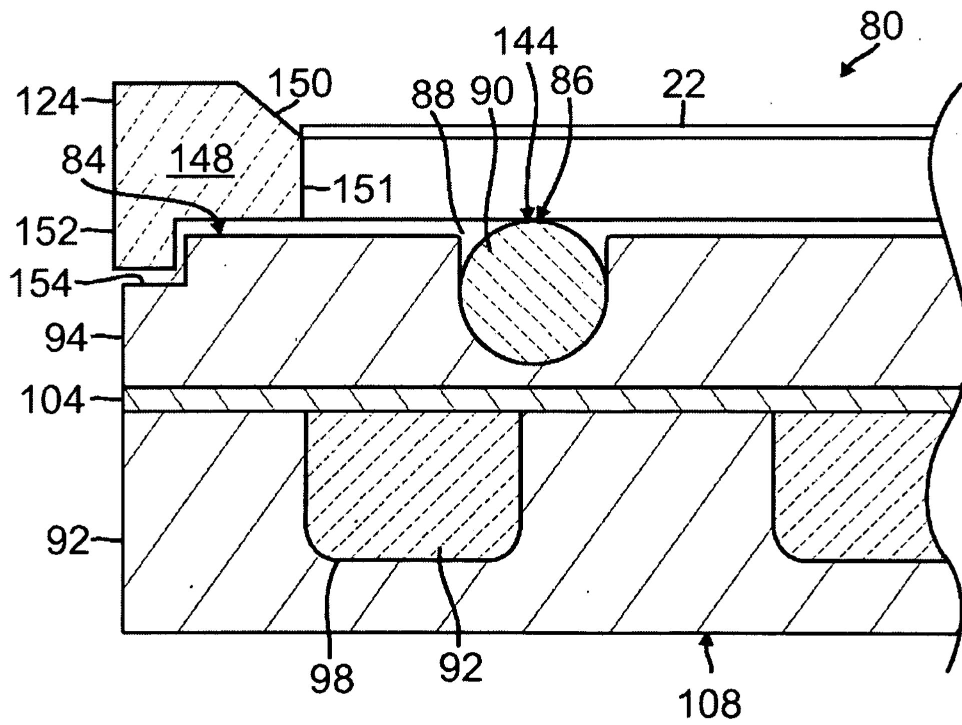

FIG. 3B

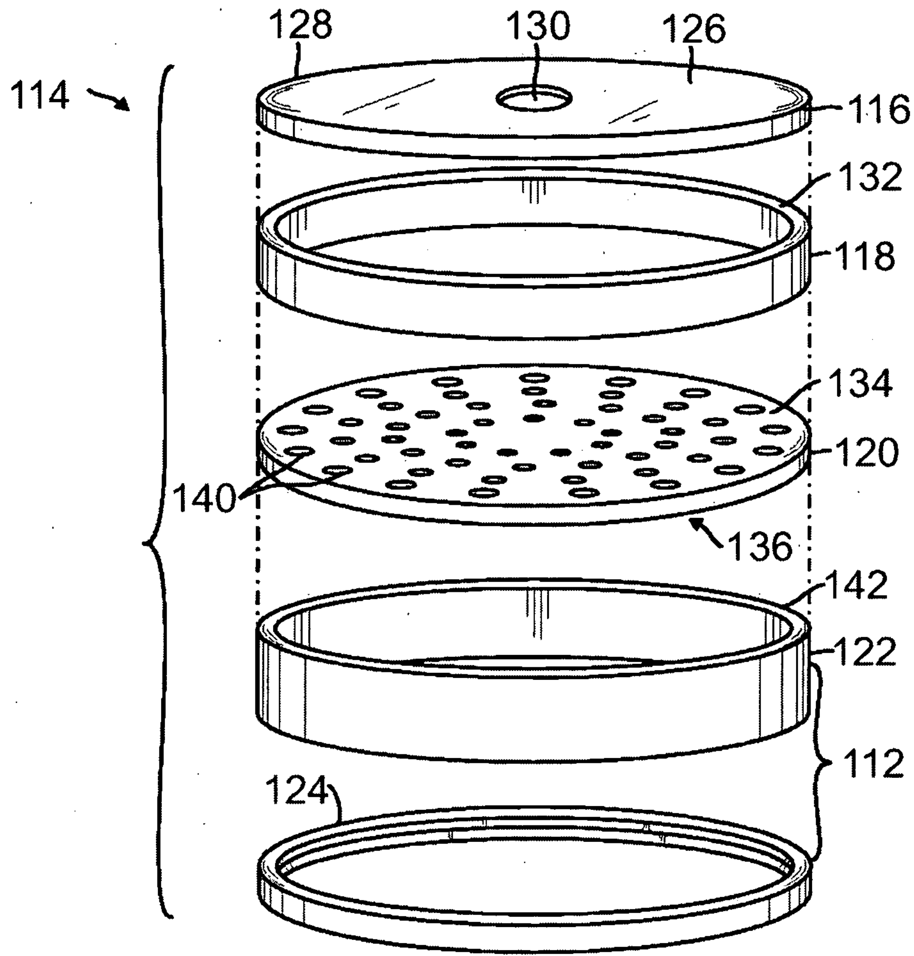

FIG. 4A

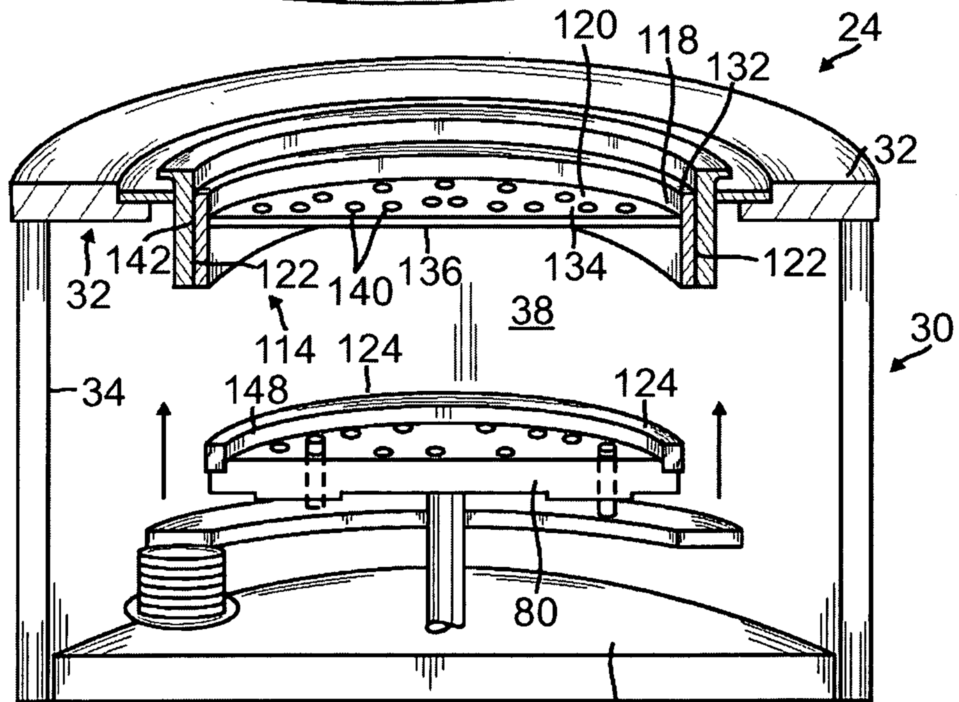

FIG. 4B

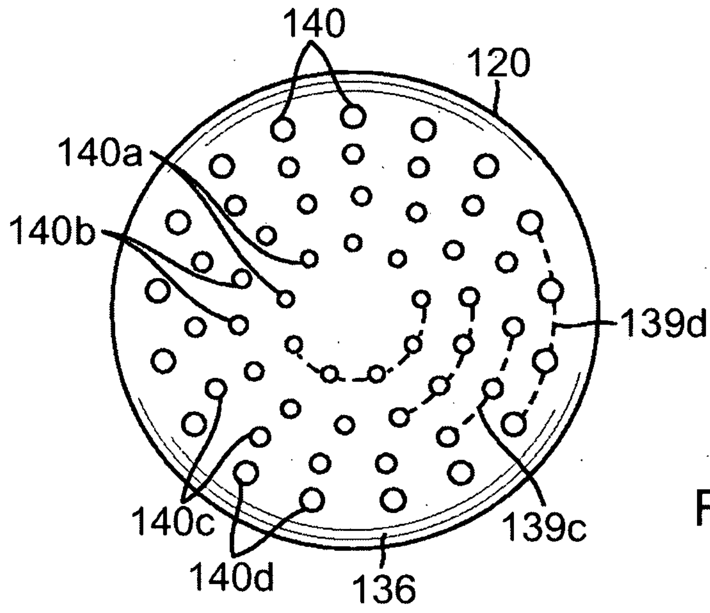

FIG. 4C

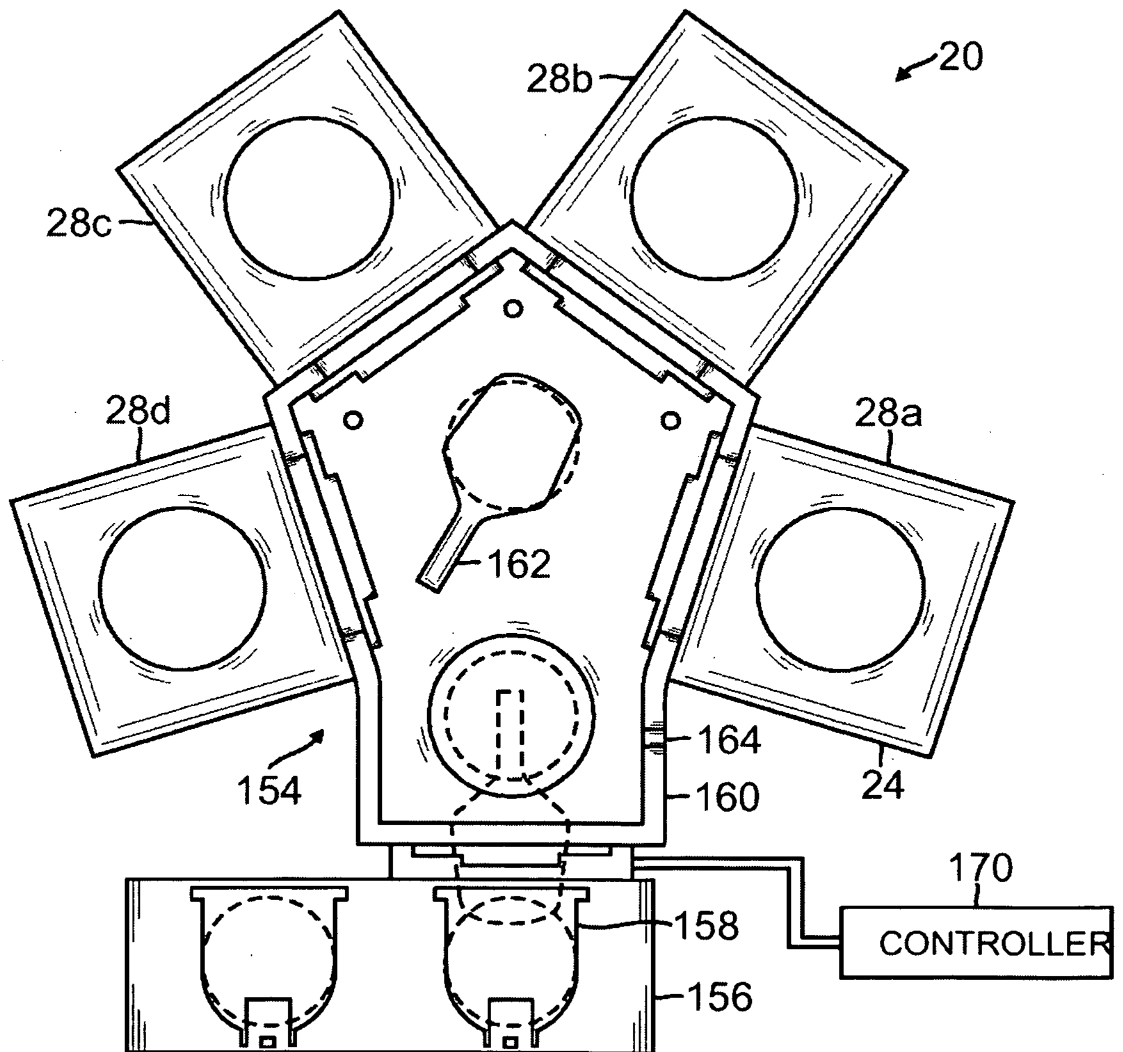

FIG. 5