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(54) **PROTECTIVE COATING FOR A PLASMA PROCESSING CHAMBER PART AND A METHOD OF USE**

(71) Applicant: **Lam Research Corporation**, Fremont, CA (US)

(72) Inventors: **Bobby Kadkhodayan**, Pleasanton, CA (US); **Jon McChesney**, Santa Clara, CA (US); **Eric Pape**, Newark, CA (US); **Rajinder Dhindsa**, San Jose, CA (US)

(73) Assignee: **Lam Research Corporation**, Fremont, CA (US)

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(57) **ABSTRACT**

A flexible polymer or elastomer coated RF return strap to be used in a plasma chamber to protect the RF strap from plasma generated radicals such as fluorine and oxygen radicals, and a method of processing a semiconductor substrate with reduced particle contamination in a plasma processing apparatus. The coated RF strap minimizes particle generation and exhibits lower erosion rates than an uncoated base component. Such a coated member having a flexible coating on a conductive flexible base component provides an RF ground return configured to allow movement of one or more electrodes in an adjustable gap capacitively coupled plasma reactor chamber.

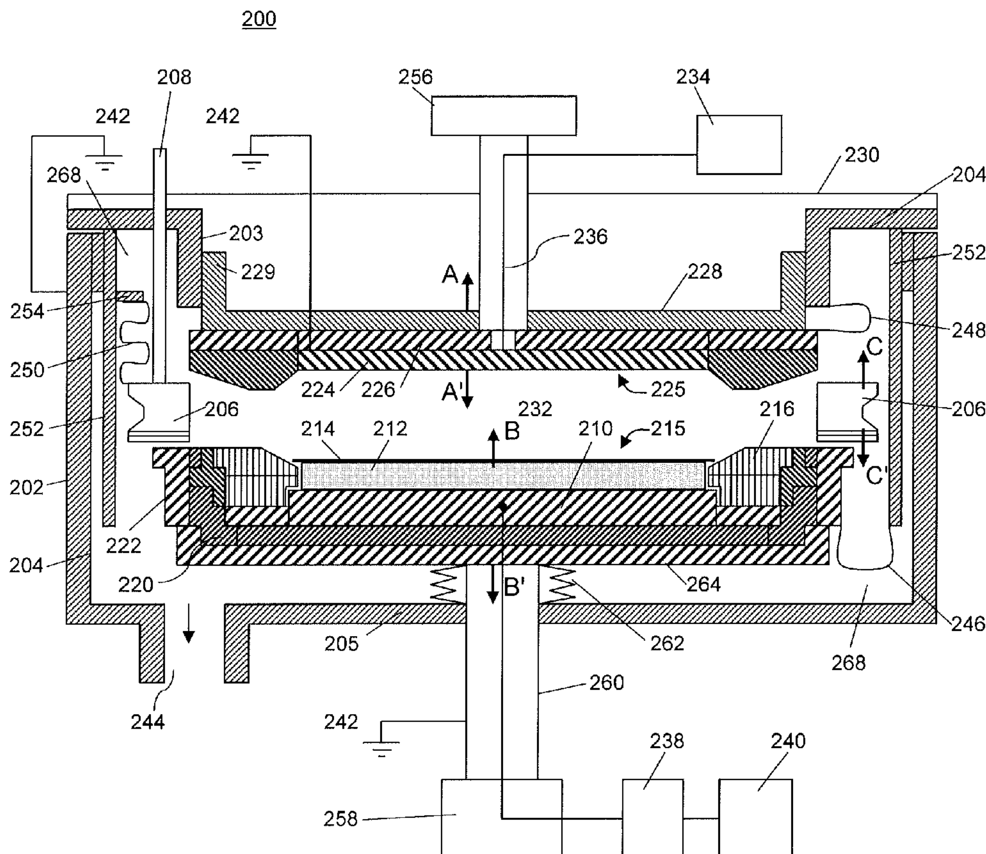


FIG. 1

FIG. 2

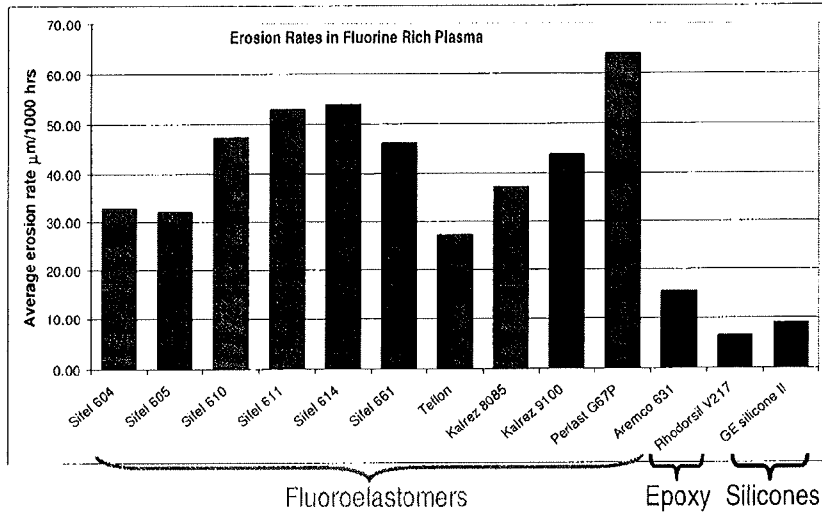
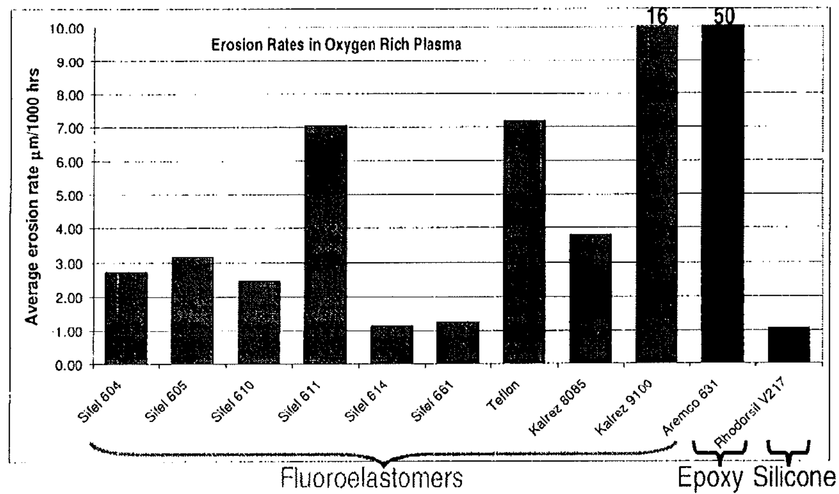


FIG. 3



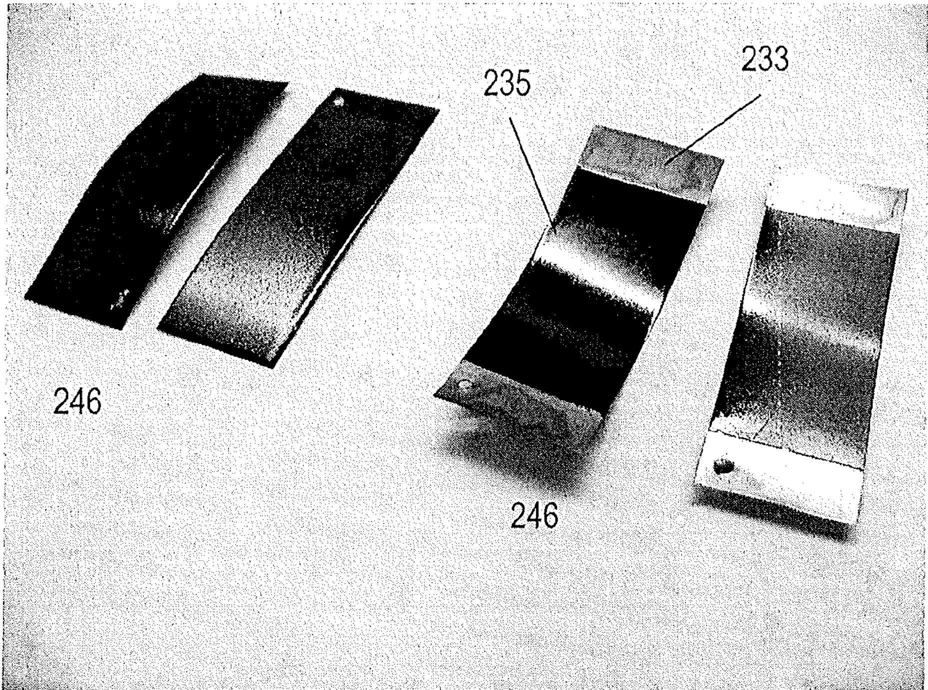


FIG. 4

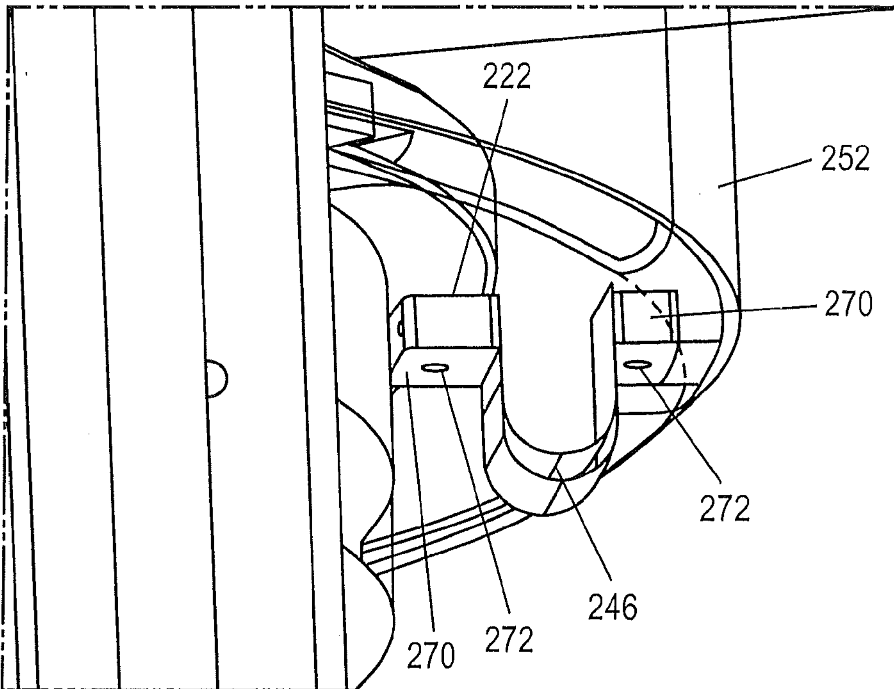


FIG. 5

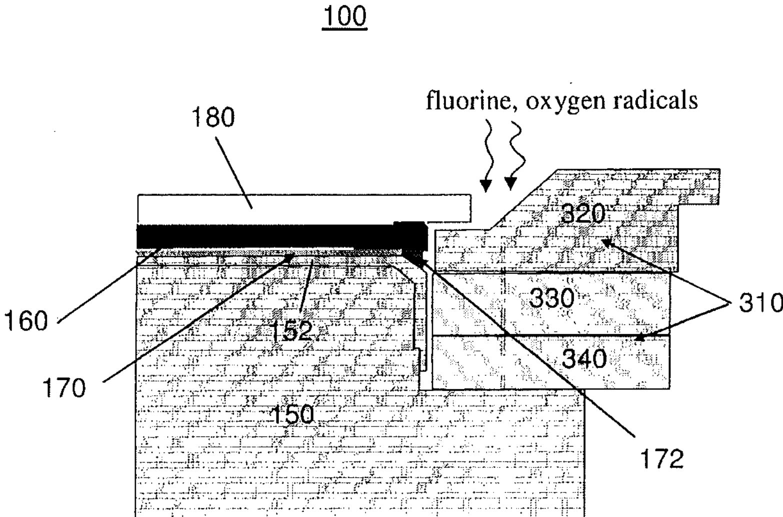


FIG. 6

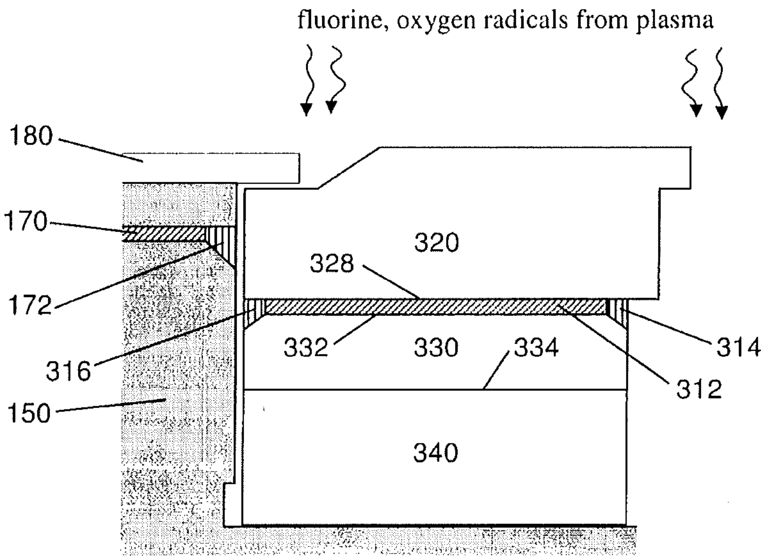


FIG. 7

PROTECTIVE COATING FOR A PLASMA PROCESSING CHAMBER PART AND A METHOD OF USE

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority under 35 U.S.C. §119 to U.S. Provisional Application No. 61/006,983 entitled A PROTECTIVE COATING FOR A PLASMA PROCESSING CHAMBER PART AND A METHOD OF USE and filed on Feb. 8, 2008, the entire content of which is hereby incorporated by reference.

BACKGROUND

[0002] Plasma processing apparatuses are used to process substrates by techniques including etching, physical vapor deposition (PVD), chemical vapor deposition (CVD), ion implantation, and resist removal. One type of plasma processing apparatus used in plasma processing includes a reaction chamber containing upper and lower electrodes. An electric field is established between the electrodes to excite a process gas into the plasma state to process substrates in the reaction chamber.

SUMMARY

[0003] In an embodiment, a coated RF return strap includes a curved metal strip having a surface and a flexible coating bonded to the surface, the coating comprising a polymer or elastomer wherein the coating provides erosion resistance in an atmosphere of plasma generated radicals and protects the metal strip from the radicals.

[0004] In a second embodiment, a plasma processing apparatus is provided which comprises a vacuum chamber for plasma processing of a semiconductor substrate therein, and a plasma processing assembly for use in the vacuum chamber. The assembly comprises a first member bonded to a second member by an elastomer bond and a silicone base elastomeric material having improved erosion resistance to plasma generated radicals, the silicone base elastomeric material surrounding the elastomer bond and sealing a mating surface of the first member to a mating surface of the second member to protect the elastomer bond from plasma generated radicals.

[0005] A third embodiment provides a method of processing a semiconductor substrate in a plasma processing apparatus wherein a substrate is placed on a substrate support in a reaction chamber of a plasma processing apparatus beneath an upper electrode assembly. A process gas is introduced into the reaction chamber and plasma is generated from the process gas in the reaction chamber between the upper electrode assembly and the substrate. The substrate is processed with the plasma while the coated RF return strap transmits RF power between parts of the chamber exposed to plasma generated radicals.

[0006] In still another embodiment, a method of processing a semiconductor substrate in a plasma processing apparatus includes placing a substrate on a substrate support in a reaction chamber of a plasma processing apparatus of the second embodiment. A process gas is introduced into the reaction chamber, a plasma is generated from the process gas in the reaction chamber between an upper electrode assembly and the substrate, and the substrate is processed with the plasma. The silicone base elastomeric material protects the elastomer bond from plasma generated radicals during plasma processing of the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

Drawings

[0007] FIG. **1** shows a schematic diagram of an adjustable gap capacitively-coupled plasma processing chamber including embodiments of a coated member.

[0008] FIG. **2** is a bar graph presenting experimental results of erosion rates in fluorine rich plasma of elastomer coated coupons.

[0009] FIG. **3** is a bar graph presenting experimental results of erosion rates in oxygen rich plasma of embodiments of elastomer coated coupons.

[0010] FIG. **4** is a photograph showing embodiments of coated members.

[0011] FIG. **5** illustrates an embodiment of a coated member.

[0012] FIG. **6** shows a cross sectional view of a portion of a vacuum processing chamber where an embodiment of a silicone base elastomeric material surrounds an elastomer bond between a lower surface of an electrostatic chucking device and an upper surface of a lower electrode.

[0013] FIG. **7** shows a cross sectional view of a wafer edge region of a parallel plate plasma apparatus where an embodiment of a silicone base elastomeric material surrounds an elastomer bond between a lower surface of an upper hot edge ring and an upper surface of a ceramic intermediate ring in a temperature controlled hot edge ring assembly.

DETAILED DESCRIPTION

[0014] Control of particulate contamination on the surfaces of substrates such as flat panel displays and semiconductor wafers during the fabrication of integrated circuits is essential in achieving reliable devices and obtaining a high yield. Processing equipment, such as plasma processing apparatuses, can be a source of particulate contamination. For example, the presence of particles on the wafer surface can locally disrupt pattern transfer during photolithography and etching steps. As a result, these particles can introduce defects into critical features, including gate structures, intermetal dielectric layers or metallic interconnect lines, resulting in the malfunction or failure of the integrated circuit component.

[0015] Reactor parts with relatively short lifetimes are commonly referred to as "consumables," for example, silicon electrodes. If the consumable part's lifetime is short, then the cost of ownership is high. Silicon electrode assemblies used in dielectric etch tools deteriorate after a large number of RF hours (time in hours during which radio frequency power is used to generate the plasma). Erosion of consumables and other parts generates particulate contamination in plasma processing chambers. Erosion can occur on parts directly exposed to plasma or on parts outside the confined plasma region of the chamber due to exposure to a high density of radicals such as fluorine and/or oxygen radicals generated by the plasma of process gas.

[0016] FIG. **1** shows an exemplary embodiment of an adjustable gap capacitively-coupled plasma (CCP) processing chamber **200** of a plasma processing apparatus. The chamber **200** allows accurate control of an electrode gap **232** between a lower surface of an upper electrode **224** of an upper

electrode assembly **225** and an upper surface of a substrate **214** supported on a lower electrode assembly **215**. During multistep processing of wafers, the gap height may be changed one or more times to optimize wafer processing conditions.

[0017] The chamber **200** comprises chamber housing **202**; the upper electrode assembly **225** mounted to a ceiling **228** of the chamber housing **202**; the lower electrode assembly **215** mounted to a floor **205** of the chamber housing **202**, spaced apart from and substantially parallel to the lower surface of the upper electrode assembly **225**; a confinement ring assembly **206** surrounding the gap **232** between the upper electrode assembly **225** and the lower electrode assembly **215**; an upper chamber wall **204**; and a chamber top **230** enclosing the top portion of the upper electrode assembly **225**. The upper electrode assembly **225** comprises the upper electrode **224**; and one or more baffles **226** including gas passages for distributing process gas into the gap **232** defined between the upper electrode **224** and the lower electrode assembly **215**. For brevity, the upper electrode assembly **225** is shown to have three components. However, the upper electrode assembly **225** can include additional components. The chamber housing **202** has a gate (not shown) through which a substrate **214**, is unloaded/loaded into the chamber **200**. For example, the substrate **214** can enter the chamber through a load lock as described in commonly-assigned U.S. Pat. No. 6,899,109, which is hereby incorporated by reference in its entirety.

[0018] In some exemplary embodiments, the upper electrode assembly **225** is adjustable in up and down directions (arrows A and A' in FIG. **1**) to adjust the gap **232** between the upper and lower electrode assemblies **225/215**. An upper assembly lift actuator **256** raises or lowers the upper electrode assembly **225**. In the illustration, annular extension **229** extending vertically from the chamber ceiling **228** is adjustably positioned along cylindrical bore **203** of the upper chamber wall **204**. A sealing arrangement (not shown) may be used to provide a vacuum seal between **229/203**, while allowing the upper electrode assembly **225** to move relative to the upper chamber wall **204** and lower electrode assembly **215**. An upper flexible coated member **248** electrically couples the upper electrode assembly **225** and the upper chamber wall **204**. The upper flexible coated member **248** comprises a conductive and flexible metal strap (**233** in FIG. **4**) which is coated with a flexible coating (**235** in FIG. **4**) bonded to the outer surface of the metal strap **233**. The flexible coating **235** protects the metal strap from deterioration due to plasma radicals by preventing the metal strap from coming into contact with active species (radicals) generated by the plasma of process gas.

[0019] In one embodiment, the flexible coated member **248** base component is an RF strap comprised of beryllium copper (BeCu). However, other flexible, conductive materials may also be utilized. In an embodiment, the flexible coating **235** is comprised of an elastomer or polymer. Preferably, the flexible coating **235** is cross linked siloxane (silicone rubber) which does not include conductive filler particles such as particles of Si, SiC, Al or the like. The upper flexible coated member **248** provides a conductive return path between the upper electrode assembly **225** and the upper chamber wall **204** to allow the electrode assembly **225** to move vertically within the chamber **200**. The strap includes two planar ends connected by a curved section. The curved section accommodates movement of the upper electrode assembly **225** relative to the upper chamber wall **204**. Depending on factors such as the chamber size, a plurality (2, 4, 6, 8 or 10) RF return straps can be arranged at circumferentially spaced positions around the electrode assembly **225**.

[0020] For brevity, only one gas line **236** connected to gas source **234** is shown in FIG. **1**. Additional gas lines can be coupled to the upper electrode assembly **225**, and the gas can be supplied through other portions of the upper chamber wall **204** and/or the chamber top **230**.

[0021] In other exemplary embodiments, the lower electrode assembly **215** may move up and down (arrows B and B' in FIG. **1**) to adjust the gap **232**, while the upper electrode assembly **225** may be stationary or movable. FIG. **1** illustrates a lower assembly lift actuator **258** connected to a shaft **260** extending through the floor (bottom wall) **205** of the chamber housing **202** to a lower conducting member **264** supporting the lower electrode assembly **215**. According to the embodiment illustrated in FIG. **1**, a bellows **262** forms part of a sealing arrangement to provide a vacuum seal between the shaft **260** and the floor **205** of the chamber housing **202**, while allowing the lower electrode assembly **215** to move relative to the upper chamber wall **204** and upper electrode assembly **225** when the shaft **260** is raised and lowered by the lower assembly lift actuator **258**. If desired, the lower electrode assembly **215** can be raised and lowered by other arrangements. For example, another embodiment of an adjustable gap capacitively coupled plasma processing chamber which raises and lowers the lower electrode assembly **215** by a cantilever beam is disclosed in commonly-assigned co-pending U.S. Patent Application Publication No. 2008/0171444, which is hereby incorporated by reference in its entirety.

[0022] If desired, the movable lower electrode assembly **215** can be grounded to a wall of the chamber by at least one lower flexible coated member **246** which electrically couples an outer conductor ring (ground ring) **222** to an electrically conductive part, such as a chamber wall liner **252**. The lower flexible coated member **246** comprises a conductive and flexible metal strap and flexible coating bonded to the surface of the flexible metal strap as described above with respect to the upper flexible coated member **248**. The flexible coating protects the metal strap from deterioration due to plasma radicals by preventing the metal strap from coming into contact with active species (radicals) generated by the plasma of process gas. The lower flexible coated member **246** electrically couples the outer conductor ring (ground ring) **222** to the upper chamber wall **204** and provides a short RF return path for plasma, while allowing the lower electrode assembly **215** to move vertically within the chamber **200** such as during multistep plasma processing wherein the gap is set to different heights. Preferably, the metal strap is a flexible conductive strap such as a polymer coated BeCu strip.

[0023] FIG. **1** further shows an embodiment of a confinement ring assembly **206** to confine a plasma volume proximate the substrate **214** and minimize surface areas with which the plasma interacts. In an embodiment, the confinement ring assembly **206** is connected to a lift actuator **208** such that the confinement ring assembly **206** is moveable in a vertical direction (arrows C-C'), meaning the confinement ring assembly **206** can be manually or automatically raised or lowered with respect to the upper and lower electrode assemblies **225/215** and the chamber **200**. The confinement ring assembly is not particularly limited and details of suitable confinement ring assemblies **206** are described in commonly-

assigned U.S. Pat. No. 6,019,060 and U.S. Pat. Application Pub. No. 2006/0027328, which are hereby incorporated by reference in their entireties.

[0024] The confinement ring assembly **206** can be grounded to a wall of the chamber by at least one flexible coated member **250** which electrically couples the confinement ring assembly **206** to an electrically conductive part such as upper chamber wall **204**. FIG. **1** shows a conductive chamber wall liner **252** supported via a horizontal extension **254**. The coated flexible member **250** preferably comprises a plurality of metal straps which provide a short RF return path by electrically coupling the confinement ring assembly **206** to the upper chamber wall **204**. The coated RF return strap comprises a flexible and conductive metal strip and a protective and flexible coating as described above with reference to the upper flexible coated member **248**. The flexible coated members **250** can provide conductive paths between the confinement ring assembly **206** and the upper chamber wall **204** at various vertical positions of the confinement ring assembly **206** within the chamber **200**.

[0025] In the embodiment shown in FIG. **1**, the lower conducting member **264** is electrically connected to an outer conductor ring (ground ring) **222** which surrounds dielectric coupling ring **220** which electrically insulates the outer conductor ring **222** from the lower electrode assembly **215**. The lower electrode assembly **215** includes chuck **212**, focus ring assembly **216**, and a lower electrode **210**. However, the lower electrode assembly **215** can include additional components, such as a lift pin mechanism for lifting the substrate, optical sensors, and a cooling mechanism for cooling the lower electrode assembly **215** attached to or forming portions of the lower electrode assembly **215**. The chuck **212** clamps a substrate **214** in place on the top surface of the lower electrode assembly **215** during operation. The chuck **212** can be an electrostatic, vacuum, or mechanical chuck.

[0026] The lower electrode **210** is typically supplied with RF power from one or more RF power supplies **240** coupled to the lower electrode **210** through an impedance matching network **238**. The RF power can be supplied at one or more frequencies of, for example, 2 MHz, 27 MHz and 60 MHz. The RF power excites the process gas to produce plasma in the gap **232**. In some embodiments the upper electrode **224** and chamber housing **202** are electrically coupled to ground. In other embodiments the upper electrode **224** is insulated from the chamber housing **202** and supplied RF power from an RF supply through an impedance matching network.

[0027] The bottom of the upper chamber wall **204** is coupled to a vacuum pump unit **244** for exhausting gas from the chamber **200**. Preferably, the confinement ring assembly **206** substantially terminates the electric fields formed within the gap **232** and prevents the electric fields from penetrating an outer chamber volume **268**.

[0028] Process gas injected into the gap **232** is energized to produce plasma to process the substrate **214**, passes through the confinement ring assembly **206**, and into outer chamber volume **268** until exhausted by the vacuum pump unit **244**. Since reactor chamber parts in the outer chamber volume **268** can be exposed to reactive process gas (radicals, active species) during operation, they are preferably formed of material, such as stainless steel, that can withstand the process gas or have protective coatings. Likewise, bellows **262** is preferably formed of a material that can withstand the process gas chemistry, such as stainless steel.

[0029] In an embodiment where the RF power supply **240** supplies RF power to the lower electrode assembly **215** during operation, the RF power supply **240** delivers RF energy via shaft **260** to the lower electrode **210**. The process gas in the gap **232** is electrically excited to produce plasma by the RF power delivered to the lower electrode **210**.

[0030] In the chamber **200**, the flexible coated members **246/248/250** can be RF return straps to provide secure electrical connections as described above between the chamber wall liner **252** or the upper chamber wall **204** and the outer conductor ring (ground ring) **222**, the confinement ring assembly **206** and/or the upper electrode assembly **225**. During wafer processing, the gap **232** between the upper and lower electrodes **225/215** may be adjusted and the RF return straps undergo bending during such gap adjustment. These coated members create an alternative and shorter RF return path for the plasma when compared to the RF return path that comprises upper chamber wall **204** of the chamber **200**. For example, the outer conductor ring **222** is formed of conducting material and electrically insulated from the lower electrode assembly **215** by the dielectric coupling ring **220**. The return path is through the upper electrode assembly **225**, the flexible coated member **248**, upper chamber wall **204**, flexible coated member **246**, outer conductor ring **222**, wall or shield of the shaft **260**, to match network **238**. The bellows **262** is preferably not part of the return path. The return path can also pass through one or more flexible coated members (not shown in FIG. **1**) extending from lower conducting member **264** to floor (bottom wall) **205**; and/or pass through one or more flexible coated members (not shown in FIG. **1**) extending from floor (bottom wall) **205** to shaft **260**.

[0031] Preferably, the outer conductor ring **222** is electrically connected to the chamber wall liner **252** by three to twelve flexible coated members **246**. More preferably, eight polymer coated RF straps electrically connect the outer conductor ring **222** to the chamber wall liner **252**.

[0032] As the outer conductor ring **222** moves relative to the upper chamber wall **204** during gap control to facilitate wafer processing or substrate loading/unloading, the flexible coated member **246** is sufficiently flexible to accommodate the relative motion. The flexible coated member **246** is preferably formed from a metal alloy, such as semiconductor grade beryllium copper (BeCu). Preferably, the coating on the flexible coated member **246** is resistant to reactive process gases. The curved section of the flexible coated member **246/248/250** is stretched or compressed due to the relative motion between the upper chamber wall **204** or wall liner **252** and the conductor ring **222**/upper electrode assembly **225**/ confinement ring assembly **206**, respectively. The flexible coated members **246/248/250** may have one or more curved sections to accommodate the gap adjustment.

[0033] Exposing uncoated conductive flexible metal straps to process gases and/or plasma generated radicals in the chamber housing **202** can create contamination from erosion of the exposed metal of the flexible straps. Plasma generated radicals can also erode supports and components in the outer chamber volume **268** from radicals moving through the confinement ring assembly **206** as well. In addition to the particle and/or metal contamination due to erosion of the straps, the uncoated straps in the vacuum chamber may need to be replaced sooner than scheduled chamber maintenance. Polymer or elastomer coating of metal components such as conductive flexible straps which are exposed to plasma generated

radicals significantly increases the component lifetime and reduces unwanted particles and/or metal contamination in the plasma chamber.

[0034] To test various coatings, elastomer and polymer coated coupons were exposed to plasma generated fluorine radicals in a plasma chamber such as a plasma etch chamber like the Lam Research 2300 Exelan™ Flex plasma processing system supplied by Lam Research Corporation (www.lamrc.com). The results of these experiments are shown in FIG. **2** as a bar chart and are presented in Table 1. To test resistance to oxygen radicals, elastomer and polymer coatings on coupons were exposed to plasma generated oxygen radicals in a similar manner as described for the coupons exposed to the fluorine radicals. The results of these experiments in oxygen radicals are shown in FIG. **3** as a bar chart and presented in Table 1.

TABLE 1

Experimental test results of erosion of elastomer and polymer flexible coatings in fluorine or oxygen active species (radicals)

sample no.	material type	trade name (TM)	average erosion rate (μm/1000 hr) F radicals	O radicals
1	perfluoroelastomer	Sifel 604	32.9	2.7
2	perfluoroelastomer	Sifel 605	32.5	3.2
3	perfluoroelastomer	Sifel 610	47.7	2.5
4	1 part perfluoroelastomer	Sifel 611	52.8	7.1
5	perfluoroelastomer	Sifel 614	54.2	1.2
6	perfluoroelastomer	Sifel 661	46.3	1.3
7	PTFE	Teflon	27.7	7.2
8	organic filled perfluoroelastomer	DuPont Kalrez 8085	37.4	3.8
9	silicate filled perfluoroelastomer	DuPont Kalrez 9100	44.1	16
10	organic filled perfluoroelastomer	Perlast G67P	64.2	—
11	two part epoxy	Aremco 631	15.7	50
12	two part unfilled silicone	Rhodorsil V217	6.7	1.1
13	filled silicone	GE silicone II	9.4	—

[0035] The elastomer and polymer coatings on the test coupons were eroded when brought into contact with active species (radicals) generated by the plasma of process gas. FIG. **2** shows the average erosion rate in μm/1000 hr measured after exposure to plasma containing fluorine (F) radicals. The coatings of Samples 1-10 comprised fluoroelastomers. These fluoroelastomers exhibited F radical erosion rates from about 27 μm/1000 hr for sample 7 (PTFE) to about 64 μm/1000 hr for sample 10 (organic filled perfluoroelastomer). Sample 11 was a two part epoxy which exhibited significantly improved erosion resistance to the fluorine radical chemistry of about 16 μm compared to the perfluoroelastomers. Surprisingly, samples 12 and 13 comprised of silicone-type material exhibited far superior erosion resistance to the fluorine radicals than any of the other samples tested. The two part unfilled silicone sample exhibited an average erosion rate of about 7 μm/1000 hr and the filled silicone sample exhibited an average of about 9 μm/1000 hr.

[0036] FIG. **3** shows the average erosion rate in μm/1000 hr measured after exposure of elastomer and polymer coated coupons to plasma containing oxygen (O) radicals. In this environment, the fluoroelastomers exhibited erosion rates from about 1.2 μm/1000 hr for sample 5 (Sifel 614™) to about 16 μm/1000 hr for sample 9 (silicate filled perfluoroelastomer). Sample 11, the two part epoxy, exhibited significantly more erosion when exposed to the oxygen radicals than any of the other samples tested, where the erosion rate was about 50 μm/1000 hr. Surprisingly, sample 12 which was comprised of the two part unfilled silicone material exhibited far superior erosion resistance to the oxygen radicals than any of the other samples tested. The two part unfilled silicone sample exhibited an average erosion rate of about 1.1 μm/1000 hr.

[0037] As shown by viewing the results in Table 1 and FIGS. **2** and **3**, the silicone coatings exhibited significantly better erosion resistance compared to the other materials tested in both fluorine and oxygen radical environments. The Rhodorosil V217™ silicone exposed to fluorine rich plasma had a very low erosion rate compared to the other material types tested with the next most erosion resistant material type having an average erosion rate of nearly twice the Rhodorsil V217™. As shown in FIG. **3**, the silicone base material also had a very low erosion rate in an oxygen rich plasma. This result is also surprising since many of the material types tested performed well in only one environment.

[0038] The flexible coated members **246/248/250** generally are outside the confined plasma region of the chamber, but under some process conditions, high densities of fluorine and oxygen radicals can exist outside of the confined plasma region. Exposed base metal of the flexible coated members **246/248/250**, such as BeCu, can create metal contamination of the processed wafers in the vacuum environment of the processing chamber. Thus the coating on the flexible coated members **246/248/250** is preferably elastic so as to withstand bending while being exposed to fluorine and oxygen rich radical chemistry to provide a markedly improved lifetime of the flexible coated members **246/248/250**.

[0039] FIG. **4** is a photograph showing an embodiment of the lower flexible coated member **248**. The surface of the conductive and flexible metal strap **233** which is exposed to the radical environment was coated with a silicone elastomer material as flexible coating **235**.

[0040] To coat the flexible components, the flexible metal straps **233** are preferably cleaned prior to applying the coating. For example, a surface of BeCu flexible metal strap can be roughened by sandblasting, primed with a primer compatible with the coating to be applied and dip coated or spray coated with silicone elastomer material after the primer is dry. However, the surface can be coated directly with the silicone elastomer material, that is, without the primer if desired. The coating is preferably cured by any suitable technique. For example, the coating can be heated or subjected to other curing methods to cure the silicone material.

[0041] In an embodiment, an elastomer or polymer material provides a flexible coating to a flexible conductive metal component to adhere to the surface of the metal component and protect the metal component from radicals of the process gas. Preferably, the coating is an in-situ cured elastomer or polymer resistant to erosion from radicals in a vacuum environment and resistant to degradation at high temperatures such as above 200° C. Polymeric materials which can be used in plasma environments above 160° C. include polyimide, polyketone, polyetherketone, polyether sulfone, polyethylene terephthalate, fluoroethylene propylene copolymers, cellulose, triacetates, silicone, and rubber.

[0042] More preferably, the coating is an in-situ room temperature vulcanized (RTV) unfilled siloxane exhibiting appropriate pre-cure and post-cure properties such as adhe-

sion strength, elastic modulus, erosion rate, temperature resistance and the like. For example, an in-situ curable silicone can be a two-part or one-part curing resin using platinum, peroxide or heat. Preferably, the silicone elastomer material has a Si—O backbone with methyl groups (siloxane). However, carbon or carbon-fluorine backbones can also be used. Most preferably, the silicone material cures in-situ for protection of the base component forming an unfilled, cross-linked silicone rubber. An especially preferred elastomer is a polydimethylsiloxane containing elastomer such as a catalyst cured, e.g. Pt-cured, elastomer available from Rhodia as Rhodorsil V217™, an elastomer which is stable at temperatures of 250° C. and higher.

[0043] FIG. **5** illustrates an embodiment of a flexible and conductive coated member **246** electrically connecting the outer conductor ring **222** to a conductive chamber sidewall liner **252** in an adjustable gap capacitively-coupled plasma reactor chamber **200**. FIG. **5** shows electrically conductive connecting members **270** such as stainless steel, copper, aluminum or gold plated metal blocks adapted to electrically connect the conductive and flexible metal strap **233** at uncoated areas (see FIG. **4**). The flexible coated member **246** can be 0.002 to 0.020 inch thick, 0.25 to 1 inch wide and 2 to 10 inches long. The flexible metal strap **233** connected to the connecting members **270** is completely protected from radicals by the flexible polymer or elastomer coating **235**. One connecting member **270** is a planar section connected to the chamber wall liner **252** on one side and connected to a first end of the flexible coated member **246** on another side. A second end of the coated member **246** is a planar section connected to another connecting member **270** which is connected to the outer conductor ring **222**. Fastener holes **272** may be provided in the connecting members **270** adapted to accept fasteners such as screws, rivets, pins and the like to complete the connections. To protect the fasteners from exposure to the oxygen and/or fluorine radicals, the coating can also be provided on exposed surfaces of the fasteners.

[0044] Referring to FIG. **2**, process gas is introduced into the gap **232** through the upper electrode assembly **225**, which may include one or more baffles **226** so that the process gas flows in the gap **232** with a showerhead effect. In the gap **232**, the process gas is excited to produce plasma to process a substrate **214** mounted on the top support surface of the lower electrode assembly **215**. For example, the substrate **214** can be plasma etched with the process gas.

[0045] The gap **232**, which is coaxial with the central axis of the substrate **214**, is spaced from the upper chamber wall **204** by virtue of the region including the confinement ring assembly **206** and includes the outer chamber volume **268** and the chamber wall liner **252**. As the confinement ring lift actuator **208** operates, the confinement ring assembly **206** moves downward or as the lower electrode assembly **215** moves upward, a bottom ring of the confinement ring assembly **206** comes into contact with the shoulder of the outer conductor ring **222**. Rings of the confinement ring assembly **206** are preferably formed of a material having high electrical conductivity, such as silicon or silicon carbide having a high electrical conductivity of about 2000 Ω-cm and able to withstand the harsh operational environment of the plasma in the gap **232**. The rings may be formed of other suitable conductive materials, such as aluminum or graphite. A post of the confinement ring lift actuator **208** may be formed of metal.

[0046] The confinement ring assembly **206** assists in confining the plasma to the space surrounded by the upper and lower electrode assemblies **225**, **215** and by the rings, while allowing neutral gas constituents in the gap **232** to pass through gaps in the confinement ring assembly **206** in a generally horizontal direction. Then, neutral gas constituents flow into the outer chamber volume **268** surrounded by the inner surface of the chamber wall **204**. The pressure in the outer chamber volume **268** is controlled by the vacuum pump unit **244** attached to the bottom of the chamber wall **204**. As such, the confinement ring assembly **206** separates the gap or plasma excitation region **232** from the outer chamber volume **268**. In general, the volume of the gap region **232** is small compared to that of the outer chamber volume **268**. Because the etch rate of the substrate **214** is directly affected by the plasma in the gap **232**, the confinement ring assembly **206** enables a small volume pressure control and plasma confinement over the entire range of the gap **232** without major physical change to the chamber hardware. Also, as the volume of the gap **232** is small, the plasma conditions can be controlled quickly and accurately.

[0047] Upon repeated use of the upper electrode assembly **225** and lower electrode assembly **215**, the electrode surfaces facing the plasma are gradually eroded by the plasma. The gap **232** can be adjusted to compensate for wear of bottom electrode **210** and upper electrode **224** so that the process repeatability is maintained, and thereby the lifetime of the electrode is extended and cost of consumables is lowered.

[0048] FIG. **6** shows a cross section of a substrate (wafer) edge region of a parallel plate plasma apparatus **100** having an elastomer bond **170** joining a chuck **160** to a lower electrode assembly **150** according to one embodiment. The chuck **160** has an upper surface adapted to accept a substrate **180** for plasma processing. A lower surface of the chuck is bonded to an upper surface of the lower electrode assembly **150** by an elastomer bond **170**. Details of suitable elastomers are described in U.S. Pat. No. 6,073,577, which is hereby incorporated by reference in its entirety. The lower electrode assembly **150** can optionally include an upper member **152**. The elastomer bond **170** is vulnerable to erosion by plasma generated radicals, such as oxygen and fluorine radicals. A silicone base material **172** having improved erosion resistance under plasma generated radical environments is adapted to surround the elastomer bond **170** and seal the upper surface of the lower electrode assembly **150** to the lower surface of the chuck **160**. The silicone base material **172** is preferably an in-situ cured unfilled, cross-linked silicone rubber. An especially preferred elastomer is a polydimethylsiloxane containing elastomer such as a catalyst cured, e.g. Pt-cured, elastomer available from Rhodia as Rhodorsil V217™, an elastomer stable at temperatures of 250° C. and higher.

[0049] FIG. **7** shows a temperature-controlled hot edge ring assembly **310** adapted to surround the substrate support according to another embodiment. The edge ring assembly **310** includes an upper ring **320**, a ceramic intermediate ring **330**, and a conductive lower ring **340**. The intermediate ring **330** has an upper surface **332** and a lower surface **334**, wherein the lower surface **334** of the intermediate ring **330** is thermally coupled to the radio frequency (RF) electrode of lower electrode assembly **150** via the lower ring **340**. Details of such a hot edge ring assembly **310** can be found in commonly-owned U.S. Pat. No. 7,244,336, which is hereby incorporated by reference in its entirety.

[0050] The upper ring **320** is preferably made of a thermally and electrically conductive material such as silicon,

carbon (e.g., graphite), silicon carbide and the like. As shown in FIG. **7**, a lower surface **328** of the upper ring **320** is preferably bonded to an upper surface **332** of the intermediate ring **330** by a thermally conductive elastomer. According to an embodiment, silicone base material **314**, **316** having improved erosion resistance under plasma generated radical environments is adapted to surround the elastomer bond **312** and seal the upper surface **332** of the intermediate ring **330** to the lower surface **328** of the upper ring **320**.

[0051] Embodiments of silicone material shaped in O-rings to surround and protect elastomeric bonds as described above are easily replaceable. The O-rings can have cross section shapes to fit and seal gaps between components or have circular cross sections. The silicone material O-rings can be formed in place or preformed and inserted in grooves.

[0052] While the invention has been described in detail with reference to specific embodiments thereof, it will be apparent to those skilled in the art that various changes and modifications can be made, and equivalents employed, without departing from the scope of the appended claims.

1. (canceled)

2. (canceled)

3. (canceled)

4. (canceled)

5. (canceled)

6. (canceled)

7. (canceled)

8. A plasma processing apparatus, comprising:

a vacuum chamber for plasma processing a semiconductor substrate therein;

a plasma processing assembly for use in the vacuum chamber comprising a first member bonded to a second member by an elastomer bond and a silicone base elastomeric material having improved erosion resistance to plasma generated radicals, the silicone base elastomeric material surrounding the elastomer bond and sealing a mating surface of the first member to a mating surface of the second member to protect the elastomer bond from plasma generated radicals.

9. The plasma processing apparatus of claim **8**, wherein

the plasma processing assembly comprises a temperature-controlled hot edge ring assembly surrounding a substrate support located in a lower portion of the vacuum chamber;

the first member comprises a ceramic intermediate ring overlying a lower ring, the intermediate ring attached via the lower ring to a RF electrode incorporated in the substrate support;

the second member comprises an upper ring overlying the intermediate ring, wherein the upper ring has an upper surface exposed to an interior of the vacuum chamber and a lower surface bonded to an upper surface of the intermediate ring via the elastomer bond; and

the silicone base elastomeric material surrounding the elastomer bond and sealing the upper surface of the intermediate ring to the lower surface of the upper ring to protect the elastomer bond from plasma generated radicals.

10. The plasma processing apparatus of claim **8**, wherein

the plasma processing assembly comprises a substrate support located in a lower portion of the vacuum chamber;

the first member comprises a lower electrode assembly coupled to a radio frequency (RF) power supply;

the second member comprises an electrostatic chucking member located on an upper surface of the lower electrode assembly, the electrostatic chucking member having an upper surface which receives a substrate and a lower surface bonded to the upper surface of the lower electrode assembly by the elastomer bond; and

the silicone base elastomeric material surrounding the elastomer bond and sealing the upper surface of the lower electrode to the lower surface of the electrostatic chucking member to protect the elastomer bond from plasma generated radicals.

11. The plasma processing apparatus of claim **10**, wherein the silicone base elastomeric material is O-ring shaped.

12. The plasma processing apparatus of claim **11**, wherein the O-ring shaped silicone base elastomeric material has a polygonal cross sectional shape.

13. (canceled)

14. (canceled)

15. (canceled)

16. (canceled)

17. (canceled)

18. A method of processing a semiconductor substrate in a plasma processing apparatus, the method comprising:

placing a substrate on a substrate support in a reaction chamber of a plasma processing apparatus of claim **8**;

introducing a process gas into the reaction chamber;

generating a plasma from the process gas in the reaction chamber between a top electrode assembly and the substrate;

processing the substrate with the plasma.

19. The method of claim **18**, wherein the processing comprises etching the substrate.

20. The method of claim **18**, wherein the processing includes a first step using plasma containing fluorine radicals and a second step using plasma containing oxygen radicals.

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