

COATED SUBSTRATE SUPPORT ASSEMBLY FOR SUBSTRATE PROCESSING

FIELD

[0001] Embodiments of the present disclosure generally relate to an apparatus for supporting a substrate during processing in an electronic device fabrication process. More particularly, embodiments disclosed herein relate to a substrate support having a two-part surface coating which reduces defect formation and back side metal contamination during substrate processing, and methods of forming the coating.

BACKGROUND

[0002] Integrated circuits are formed in and on silicon and other semiconductor substrates. In the case of single crystal silicon, substrates are made by growing an ingot from a bath of molten silicon, and then sawing the solidified ingot into multiple substrates. An epitaxial silicon layer may then be formed on the monocrystalline silicon substrate to form a defect free silicon layer that may be doped or undoped. Semiconductor devices, such as transistors, may be manufactured from the epitaxial silicon layer. The electrical properties of the formed epitaxial silicon layer are generally better than the properties of the monocrystalline silicon substrate.

[0003] Surfaces of the monocrystalline silicon and the epitaxial silicon layer are susceptible to contamination when exposed to typical substrate fabrication facility ambient conditions. For example, a native oxide layer may form on the monocrystalline silicon surface prior to deposition of the epitaxial layer due to handling of the substrates and/or exposure to ambient environment in the substrate processing facility. Additionally, foreign contaminants such as carbon and oxygen species present in the ambient environment may deposit on the monocrystalline surface. The presence of an oxide layer or contaminants on the monocrystalline silicon surface negatively affects the quality of an epitaxial layer subsequently formed on the monocrystalline surface. Therefore, a precleaning process may be performed to remove an oxide layer or contaminants from the monocrystalline surface. However, conventional preclean processes involve exposure of the substrate to process gases which may cause surface corrosion of the substrate

support. In some examples, material byproducts resulting from corrosion of the substrate support may contact the substrate causing defect formation and back side metal contamination on the substrate.

[0004] Therefore, there is a need in the art to provide an improved substrate support which resists the corrosive effects of preclean process gases that minimizes substrate defect formation and back side metal contamination.

SUMMARY

[0005] The present disclosure describes a support body for supporting a substrate in a processing chamber. In some embodiments, a support body includes a body having an upper surface and a two-part coating disposed over the upper surface of the body. The two-part coating includes a first coating layer extending a first radial distance from a center of the body. The first coating layer includes at least one of a metal-containing material or alloy. The two-part coating includes a second coating layer disposed over the first coating layer. The second coating layer extends a second radial distance from the center of the body. The first radial distance is greater than the second radial distance. The second coating layer is non-metal.

[0006] In some embodiments, a system includes a processing chamber configured to clean a substrate. The processing chamber includes a chamber body, a lid assembly disposed at an upper end of the chamber body, and a substrate support assembly at least partially disposed within the chamber body and configured to support the substrate in the processing chamber. The lid assembly includes a dual channel showerhead having a first set of channels providing fluid communication above and below a plane of the showerhead and a second set of channels providing fluid communication with a side port of the chamber body. The substrate support assembly includes a support body having an upper surface, the upper surface extending a first radial distance from a center of the support body. The substrate support assembly includes a stem coupled to the support body and a coating disposed over the support body. The coating includes a first coating layer disposed over an entirety of the upper surface of the support body, the first coating layer comprising electroless nickel plating. The coating includes a second coating layer

disposed over the first coating layer, the second coating layer extending a second radial distance from the center of the support body, the second radial distance less than the first radial distance, and the second coating layer comprising silicon carbide.

[0007] In some embodiments, a method of forming a surface coating on a support body of a processing chamber includes depositing a first material over an entire upper surface of the support body, thereby forming a first coating layer, the first material including at least one of a metal-containing material or alloy. The method includes depositing a second material over the first coating layer only over a portion of the upper surface of the support body, thereby forming a second coating layer, wherein the second material is non-metal.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] Embodiments of the present disclosure, briefly summarized above and discussed in greater detail below, can be understood by reference to the illustrative embodiments of the disclosure depicted in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this disclosure and are therefore not to be considered limiting of its scope, for the disclosure may admit to other equally effective embodiments.

[0009] Figure 1A is a cross-sectional view of a processing chamber, according to certain embodiments.

[0010] Figure 1B is an isolated, isometric view of a support body of a substrate support assembly of Figure 1A, according to certain embodiments.

[0011] Figure 1C is an enlarged cross-sectional view of a portion of the stem of Figure 1A illustrating an exemplary surface coating disposed thereon, according to certain embodiments.

[0012] Figure 1D is an enlarged cross-sectional view of a portion of the support body of Figure 1B illustrating an exemplary surface coating disposed thereon, according to certain embodiments.

[0013] Figure 2 is a diagram illustrating a method of forming the exemplary surface coating of Figure 1C, according to certain embodiments.

[0014] Figure 3 is a diagram illustrating a method of forming the exemplary surface coating of Figure 1D, according to certain embodiments.

[0015] Figure 4 is an enlarged cross-sectional view of a portion of a support body which is configured to be used in the processing chamber of Figure 1A illustrating another exemplary surface coating disposed thereon, according to certain embodiments.

[0016] To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures. The figures are not drawn to scale and may be simplified for clarity. It is contemplated that elements and features of one embodiment may be beneficially incorporated in other embodiments without further recitation.

DETAILED DESCRIPTION

[0017] Embodiments disclosed herein relate to a substrate support having a two-part surface coating which reduces defect formation and back side metal contamination during substrate processing, and methods of forming the coating.

[0018] Certain embodiments disclosed herein provide a substrate support assembly (also referred to as a “pedestal”) having a two-part surface coating, in contrast to conventional one-part coatings. A first coating, which is able to fill even the smallest feature sizes and intricate structures, is applied to the entire substrate support assembly to reduce overall surface corrosion of the substrate support assembly. A second coating, which is free of metal contaminants, is applied to a top portion (e.g., support body) of the substrate support assembly to reduce substrate back side metal contamination. Thus, the coating performance is improved compared to conventional one-part coatings.

[0019] In some examples, a substrate may include a silicon-containing material, and the surface may include a material, such as silicon (Si), germanium (Ge) or silicon germanium alloys (SiGe). In some examples, the Si, Ge, or SiGe surface may have an oxide layer, such as a native oxide layer, and contaminants disposed thereon. Due to the sensitivity of epitaxial deposition processes to oxides and contaminants, such as carbon-containing contaminants, surface contamination

resulting from exposure to cleanroom environments for a few hours can become significant enough for the accumulated oxides and contaminants to affect the quality of a subsequently formed epitaxial layer. Therefore, a precleaning process may be performed to remove an oxide layer or contaminants from the surface. As used herein, the term “precleaning” refers to a process involving exposure of a substrate (e.g., a semiconductor substrate) to one or more process gases to remove an oxide layer or contaminants from the substrate surface. Herein, “precleaning” may also be referred to as “etching.”

[0020] In some examples, the substrate surface may be cleaned by performing an oxide removal process and a contaminant removal process. In one example, the oxides may be removed from the surface of the substrate using a precleaning process, and the contaminants, such as carbon-containing contaminants, may be removed from the surface of the substrate using a reducing process.

[0021] In some examples, the process gas may include a reactive gas such as a fluorine- or chlorine-containing gas. In some examples, the process gas may further include a vapor. In some examples, the process gas may further include one or more purge gases or carrier gases (e.g., hydrogen, helium, and/or argon). In some examples, the reactive gas may include hydrogen fluoride (e.g., HF), anhydrous hydrogen fluoride (which may be referred to as “AHF”), diatomic fluorine (F_2), nitrogen fluoride (e.g., nitrogen trifluoride (NF_3)), carbon fluoride (e.g., carbon tetrafluoride (CF_4), hexafluoroethane (C_2F_6), trifluoromethane (CHF_3), difluoromethane (CH_2F_2), octofluoropropane (C_3F_8), octofluorocyclobutane (C_4F_8), octofluoro[1-]butane (C_4F_8), octofluoro[2-]butane (C_4F_8), or octofluoroisobutylene (C_4F_8)), sulfur fluoride (e.g., sulfur hexafluoride (SF_6)), ammonia (NH_3), or combinations thereof.

[0022] In some examples, a flow rate of the reactive gas may be about 50 sccm to about 500 sccm for a 300 mm substrate. In some examples, a concentration of the reactive gas within the processing chamber (e.g., in contact with the substrate surface) may be about 5% wt/wt to about 75% wt/wt of the total process gas mixture including any other components (e.g., vapor, carrier or purge gases).

[0023] In some examples, a vapor may include water (e.g., distilled water), a primary alcohol (e.g., methyl alcohol, ethyl alcohol, propyl alcohol, butyl alcohol, or isobutyl alcohol), a secondary alcohol (e.g., isopropyl alcohol or sec-butyl alcohol), a tertiary alcohol (e.g., *tert*-butyl alcohol), a cyclic alcohol (e.g., cyclohexyl alcohol), a complex alcohol (e.g., 4-ethyl-3-hexanol), a C1 alcohol, a C2 alcohol, a C3 alcohol, a C1-C2 alcohol, a C1-C3 alcohol, a C1-C4 alcohol, an organic acid, or combinations thereof. In some examples, the vapor may increase a rate of reaction between the reactive gas and surface oxides. In some examples, lower carbon number alcohols may increase the reaction rate to a greater degree compared to higher carbon number alcohols (e.g., a relative rate of reaction may be C1 alcohol>C2 alcohol>C3 alcohol). In some examples, a flow rate of the vapor may be about 5 sccm to about 500 sccm for a 300 mm substrate. In some examples, a flow ratio of the reactive gas to the vapor may be about 10:1 to about 1:10. In some examples, a concentration of the vapor may be about 5 wt/wt to about 75 wt/wt of the total process gas mixture including any other components (e.g., reactive, carrier or purge gases).

[0024] In operation, the reactive gas and vapor may be provided to the process chamber through different pathways (i.e., separately) and mixed after arrival to the process chamber and before contacting the substrate. In some other examples, the reactive gas may be mixed with the vapor for charging to the process chamber. Mixing of the gases may be spatially separated from a processing region in which the substrate is disposed. The term “spatially separated” described herein may refer to a mixing region that is separated from a substrate processing region by one or more chamber components, or even a conduit between a mixing chamber and a substrate processing chamber. In some examples, a processing temperature, which may refer to a temperature of the mixed process gas within the processing chamber (e.g., a temperature of the mixed process gas in contact with the substrate surface), may be about 0 °C or less, such as about -50 °C to about 40 °C. In some examples a pressure in the processing chamber may be within a range of about 0.5 Torr to about 20 Torr.

[0025] The preclean process may be largely conformal and selective for oxide layers, and thus does not readily etch silicon (e.g., low-k spacers or other dielectric materials), germanium, or nitride layers regardless of whether the layers are

amorphous, crystalline or polycrystalline. In some examples, selectivity of the process gas for oxide compared to silicon or germanium may be at least about 3:1, such as about 5:1 or greater, such as about 10:1 or greater. The process gas may also be highly selective of oxide compared to nitride. In some examples, the selectivity of the process gas for oxide compared to nitride may be at least about 3:1, such as about 5:1 or greater, such as about 10:1 or greater, such as about 20:1 or greater, such as about 50:1 or greater, such as about 80:1 or greater, such as about 100:1 or greater, such as about 120:1 or greater.

[0026] In some examples, either during the preclean process or after performing the preclean process, thermal energy may be applied to the processed substrate to help remove any generated byproducts. In some examples, the thermal energy may be provided via a radiant, convective and/or conductive heat transfer process that causes the unwanted byproducts found on the substrate surface to sublime.

[0027] In some examples, an additional process may be performed to remove carbon contaminants or other contaminants from the surface of the substrate. In some examples, contaminant removal may occur before or after the precleaning process. In some examples, contaminant removal may include a plasma process performed in a plasma-cleaning chamber. The plasma process may use a plasma formed from a gas including hydrogen (H₂), helium (He), ammonia (NH₃), a fluorine-containing gas, or a combination thereof. The plasma may be inductively or capacitively coupled, the plasma may be formed by a microwave source in a processing chamber, or the plasma may be formed by a remote plasma source.

[0028] In some examples, an epitaxial layer may be formed on the surface of the substrate. If cleaned prior, as described above, the surface of the substrate is uniformly oxide and contaminant free which improves the quality of layers subsequently formed on the surface of the substrate. An exemplary processing chamber that can be used to perform the epitaxial deposition process is the Centura™ Epi chamber, which is available from Applied Materials, Inc., of Santa Clara, California. Chambers from other manufacturers may also be used.

[0029] Figure 1A is a cross-sectional view of a processing chamber 100, according to certain embodiments. The processing chamber 100 is configured to perform a precleaning process. In one example, the processing chamber 100 may be a Siconi™ or Selectra™ chamber, which are available from Applied Materials, Santa Clara, California. The processing chamber 100 generally includes a chamber body 102, a lid assembly 104, and a substrate support assembly 106. The lid assembly 104 is disposed at an upper end of the chamber body 102, and the substrate support assembly 106 is at least partially disposed within the chamber body 102. A vacuum system is used to remove gases from the processing chamber 100. The vacuum system includes a vacuum pump 108 coupled to a vacuum port 110 disposed in the chamber body 102. A pumping ring 122 is disposed within the chamber body 102. The pumping ring 122 has a plurality of exhaust ports 126 providing fluid communication between the inside of the processing chamber 100 and the vacuum port 110 for exhausting gas therethrough.

[0030] The lid assembly 104 includes a plurality of stacked components configured to provide gases to a processing region 112 within the chamber 100. The lid assembly 104 is connected to a first gas source 114 and a second gas source 116. Gases from the first gas source 114 are introduced to the lid assembly 104 through a top port 118. Gases from the second gas source 116 are introduced to the lid assembly 104 through a side port 120. In some examples, the first gas source 114 may provide at least a first part of a process gas (e.g., a reactive gas). In some examples, the second gas source 116 may provide a second part of the process gas (e.g., a vapor). In some examples, one or more purge gases or carrier gases may also be delivered to the processing region 112 from the first gas source 114, second gas source 116, or from another gas source.

[0031] The lid assembly 104 generally includes a showerhead 124 disposed above the processing region 112 through which gases from the first gas source 114 are introduced to the processing region 112. The showerhead 124 may include one or more additional plates (e.g., blocker plate, faceplate) disposed above the plate shown in Figure 1A. Each plate of the showerhead 124 may include multiple apertures formed therethrough which connect gas regions above and below each respective plate. In some examples, the showerhead 124 may be heated. In some

examples, gases may be mixed in or above the showerhead 124 during heating. In one example, the showerhead 124 may be heated to about 190 °C while a substrate to be processed is at about 10 °C.

[0032] In the example illustrated in Figure 1A, the showerhead 124 is a dual channel showerhead which has a first set of channels 128 and a second set of channels 130. The first set of channels 128 provides fluid communication above and below a plane of the showerhead 124 for gases from the top port 118 to enter the processing region 112. The second set of channels 130 provides fluid communication with the side port 120 for gases from the second gas source 116 to enter the processing region 112. The dual channel showerhead may be particularly advantageous to improve mixing of different gases coming from the first gas source 114 and second gas source 116.

[0033] The substrate support assembly 106 (also referred to as a “pedestal”) includes a support body 132 (also referred to as a “puck”) to support a substrate 101 thereon during processing and a stem 136 coupled to the support body 132. The substrate support assembly 106 includes a two-part coating which is described in more detail below with respect to Figures 1C and 1D. In some examples, the support body 132 may be modular and thus easily replaced with another coated part. Thus, replacement of the entire substrate support assembly 106 may be avoided when only the coating on the support body 132 is damaged.

[0034] The support body 132 has a flat, or a substantially flat, substrate-supporting surface 133 (also referred to as a “substrate-supporting area” or “substrate contact surface” of the support body 132). Referring to Figure 1B, the substrate-supporting surface 133 is the region underlying and/or in contact with the substrate 101 (shown in phantom in Figure 1B). In some examples, the substrate-supporting surface 133 may extend a radial distance R1 from a center C1 of the support body 132. Although as shown in Figure 1B, an outer perimeter of the substrate 101 matches the size of the substrate-supporting surface 133, in some examples, the substrate 101 may overhang the substrate-supporting surface 133. The substrate-supporting surface 133 includes multiple surface features (such as channels 135, ports 137, and recess 139 shown in Figure 1B) formed therein which, due to their small

dimensions and/or intricate structures, may be difficult to coat using conventional one-part coatings. Advantageously, two-part coatings described herein cover substantially an entire outer surface of each surface feature and, thus protect from corrosion, even the smallest feature sizes. In some examples, the two-part coatings may be capable of filling feature sizes having a critical dimension of about 30 μm or less. Advantageously, two-part coatings described herein are capable of filling high aspect ratio features with aspect ratios of about 5:1 or greater, such as about 10:1 or greater, such as about 20:1 or greater, which improves protection of high aspect ratio features from corrosion.

[0035] As shown in Figure 1A, the support body 132 includes two independent temperature control zones (referred to as “dual zone”) to control substrate temperature for center-to-edge processing uniformity and tuning. In the example illustrated in Figure 1A, the support body 132 has an inner zone 132i and an outer zone 132o surrounding the inner zone 132i. As shown in Figure 1B, the inner zone 132i and outer zone 132o are separated from each other in the radial direction by circumferential recess 139. In some other examples, the support body 132 may have more than two independent temperature control zones (referred to as “multi zone”).

[0036] The support body 132 is coupled to an actuator 134 by the stem 136 which extends through a centrally-located opening formed in a bottom of the chamber body 102. The actuator 134 is flexibly sealed to the chamber body 102 by bellows 138 that prevent vacuum leakage around the stem 136. The actuator 134 allows the support body 132 to be moved vertically within the chamber body 102 between a processing position and a loading position. The loading position is slightly below a substrate opening 140 formed in a sidewall of the chamber body 102.

[0037] The processing chamber 100 also includes an ultra-low temperature kit 142 for lowering a temperature of the substrate to be processed, which can improve selectivity for oxide removal (e.g., native oxide removal) compared to other materials, such as low-k dielectric materials and silicon nitride (e.g., SiN), among others. In some examples, the temperature of the substrate to be processed and/or

a temperature of the support body 132 may be lowered to about -30 °C to about 10 °C. The ultra-low temperature kit 142 provides a continuous flow of ultra-low temperature coolant to the support body 132 which cools the support body 132 to a desired temperature. In some examples, the ultra-low temperature coolant may include perfluorinated, inert polyether fluids (e.g., Galden® fluids). In the example illustrated in Figure 1A, the ultra-low temperature coolant is provided to the inner zone 132i and outer zone 132o of the support body 132 through inner coolant channel 144i and outer coolant channel 144o, respectively. The coolant channels are drawn schematically in Figure 1A and may have a different arrangement from what is shown. For example, each coolant channel may be in the form of a loop.

[0038] A system controller 150, such as a programmable computer, is coupled to the processing chamber 100 for controlling the processing chamber 100 or components thereof. For example, the system controller 150 may control the operation of the processing chamber 100 using a direct control of the substrate support assembly 106, vacuum pump 108, first gas source 114, second gas source 116, actuator 134, and/or ultra-low temperature kit 142 or using indirect control of other controllers associated therewith. In operation, the system controller 150 enables data collection and feedback from the respective components to coordinate processing in the processing chamber 100.

[0039] The system controller 150 includes a programmable central processing unit (CPU) 152, which is operable with a memory 154 (e.g., non-volatile memory) and support circuits 156. The support circuits 156 are conventionally coupled to the CPU 152 and comprise cache, clock circuits, input/output subsystems, power supplies, and the like, and combinations thereof coupled to the various components of the processing chamber 100.

[0040] In some embodiments, the CPU 152 is one of any form of general purpose computer processor used in an industrial setting, such as a programmable logic controller (PLC), for controlling various monitoring system component and sub-processors. The memory 154, coupled to the CPU 152, is non-transitory and is typically one or more of readily available memory such as random access memory (RAM), read only memory (ROM), floppy disk drive, hard disk, or any other form of digital storage, local or remote.

[0041] Herein, the memory 154 is in the form of a computer-readable storage media containing instructions (e.g., non-volatile memory), that when executed by the CPU 152, facilitates the operation of the processing chamber 100. The instructions in the memory 154 are in the form of a program product such as a program that implements the methods of the present disclosure (e.g., middleware application, equipment software application, etc.). The program code may conform to any one of a number of different programming languages. In one example, the disclosure may be implemented as a program product stored on computer-readable storage media for use with a computer system. The program(s) of the program product define functions of the embodiments (including the methods described herein).

[0042] Illustrative computer-readable storage media include, but are not limited to: (i) non-writable storage media (e.g., read-only memory devices within a computer such as CD-ROM disks readable by a CD-ROM drive, flash memory, ROM chips or any type of solid-state non-volatile semiconductor memory) on which information is permanently stored; and (ii) writable storage media (e.g., floppy disks within a diskette drive or hard-disk drive or any type of solid-state random-access semiconductor memory) on which alterable information is stored. Such computer-readable storage media, when carrying computer-readable instructions that direct the functions of the methods described herein, are embodiments of the present disclosure.

[0043] Figure 1C is an enlarged cross-sectional view of a portion of the stem 136 of Figure 1A illustrating an exemplary surface coating disposed thereon, according to certain embodiments. The stem 136 includes a base layer 160 having an outer surface 162. The “outer surface” may refer to a surface which is exposed before the surface coating is disposed thereon. The stem 136 includes a first coating layer 164 disposed over the outer surface 162. The first coating layer 164 has an outer surface 166. As shown, the first coating layer 164 is in direct contact with the outer surface 162. However, in some other examples, one or more additional layers may be disposed between the base layer 160 and first coating layer 164. Although only a portion of the stem 136 is shown in Figure 1C, in some examples, the first coating layer 164 may be disposed over an entirety of the substrate support assembly 106 including corresponding outer surfaces of each of the stem 136 and the support

body 132. In some examples, the first coating layer 164 may be disposed over an entirety of the support body 132 or over one or more individual surfaces or portions of the support body 132. For example, the first coating layer 164 may be disposed over one or more surfaces of support body 132 (shown in Figure 1B) such as over the substrate-supporting surface 133, over an area of the support body 132 outside the substrate-supporting surface 133 (e.g., over an upward-facing surface 141 surrounding the substrate-supporting surface 133 or around a side 143 of the support body 132), or combinations thereof. In some examples, the first coating layer 164 may be disposed over an entirety of the upper surface of the support body 132, which includes the substrate-supporting surface 133 and the upward-facing surface 141. The first coating layer 164 may extend a second radial distance R2 from the center C1 of the support body 132. The second radial distance R2 is greater than the first radial distance R1 of the substrate-supporting surface 133.

[0044] In some examples, the base layer 160 may include a metal such as aluminum, nickel alloy (e.g., Ni100 or Ni200), or other metal alloys, a ceramic such as aluminum nitride or aluminum oxide, mild steel alloys, stainless steel alloys, or combinations thereof. In some examples, the first coating layer 164 may include a metal-containing material or alloy. In one example, the first coating layer 164 includes a nickel and phosphorus alloy formed through electroless nickel plating (ENP). In some examples, the ENP coating may be either a high-phosphate or low-phosphate ENP. In some other examples, the first coating layer 164 may include an electrolytic nickel plating. In some other examples, the first coating layer 164 may be deposited using atomic layer deposition (ALD). In some examples, the first coating layer 164 may include bulk nickel, a precious metal (e.g., platinum or gold), aluminum oxide (e.g., Al₂O₃), yttrium oxide (e.g., Y₂O₃), nickel fluoride (e.g., NiF₂), magnesium fluoride (e.g., MgF₂), or combinations thereof. In some examples, the first coating layer 164 may be a conformal layer, which may generally conform to the contours of the base layer 160. The term “conformal” may refer to a coating which has a thickness within +/- 5% of the nominal coating thickness. In some examples, the first coating layer 164 may have about equal thickness over the entire outer surface 162. In some examples, during application the first coating layer 164 may have a flowability parameter which enables the coating to fill even the smallest

features formed in the outer surface 162. For example, the first coating layer 164 may be capable of filling feature sizes having a critical dimension within a range of about 30 μm to about 50 μm .

[0045] In some examples, a thickness of the first coating layer 164 may be within a range of about 0.1 μm to about 50 μm . In some examples, a surface roughness average (Ra) of the first coating layer 164 may be within a range of about 2 μin (to about 64 μin , such as about 20 μin). In some examples, the first coating layer 164 may be resistant to exposure with 50 mol% liquid hydrochloric acid (HCl) for at least 24 hours without pitting or discoloration. In some examples, the first coating layer 164 may be resistant to HCl vapor for at least 22 days without pitting or discoloration.

[0046] Figure 1D is an enlarged cross-sectional view of a portion of the support body 132 of Figure 1B illustrating an exemplary surface coating disposed thereon, according to certain embodiments. The support body 132 includes a base layer 170 having an outer surface 172. The support body 132 has a first coating layer 174 disposed over the outer surface 172. The first coating layer 174 has an outer surface 176. As shown, the first coating layer 174 is in direct contact with the outer surface 172. However, in some other examples, one or more additional layers may be disposed between the base layer 170 and first coating layer 174. In some examples, the base layer 170 may include a metal such as aluminum, stainless steel, nickel alloy, or other metal alloys, a ceramic such as aluminum nitride or aluminum oxide, or combinations thereof. In some examples, the base layer 170 may be formed from the same material as the base layer 160. In some examples, the first coating layer 174 may include one or more aspects of the first coating layer 164 described above. In some examples, the first coating layer 174 may be the same as the first coating layer 164 of Figure 1C. Although not shown in Figure 1D, the first coating layer 174 may cover substantially an entire outer surface 172 of each surface feature (such as channels 135, ports 137, and recess 139 shown in Figure 1B) formed in a substrate-supporting area of the base layer 170.

[0047] The support body 132 includes a second coating layer 178 disposed over the outer surface 176 of the first coating layer 174. The second coating layer 178 has an outer surface 180. As shown, the second coating layer 178 is in direct

contact with the outer surface 176. However, in some other examples, one or more additional layers may be disposed between the first coating layer 174 and second coating layer 178.

[0048] In some examples, the second coating layer 178 may include a material which is free of metal contaminants (also referred to as “non-metal” or “metal-free”). In some examples, non-metal materials may include materials having a metal concentration of about 2000 ppm or less. In some examples, the second coating layer 178 may be deposited using chemical vapor deposition (CVD), plasma enhanced CVD (PECVD), ALD, or plasma enhanced ALD (PEALD). In some examples, the second coating layer 178 may be an amorphous film.

[0049] In some examples, the second coating layer 178 may be or include silicon carbide (e.g., SiC). In some other examples, the second coating layer 178 may be or include silicon. In general, silicon coatings are softer than silicon carbide while having the same or better resistance to etching. For example, a hardness of the silicon coatings may be within a range of about 4,000 N/mm² (MPa) to about 6,000 N/mm² (MPa), in contrast to silicon carbide coatings, which may have a hardness within a range of about 10,000 N/mm² (MPa) to about 16,000 N/mm² (MPa). Thus, silicon may be less susceptible to scratching a back side surface of a semiconductor substrate, which may be particularly advantageous for coating surfaces in contact with a semiconductor substrate such as the substrate-supporting surface 133 (shown in Figure 1B).

[0050] In some other examples, the second coating layer 178 may be or include a perfluorinated film. In some examples, the perfluorinated film may be a self-assembled monolayer (SAM). In contrast to other coatings such as silicon carbide, perfluorinated SAMs are beneficially less porous, exhibit lower water absorption, and/or exhibit reduced outgassing. In some examples, a thickness of the perfluorinated film may be about 5 nm to about 20 nm, such as about 5 nm to about 10 nm, about 10 nm to about 15 nm, or about 15 nm to about 20 nm. In some examples, the perfluorinated film may entirely cover the underlying surface. In some examples, a perfluoride precursor of the perfluorinated film may be or include a tetrafluoroethene-based precursor (e.g., $\text{CF}_3\text{-(CF}_2)_9\text{-(CH}_2)_2\text{-SiCl}_3$), which bonds covalently to the underlying surface. When the tetrafluoroethene-based precursor is

$\text{CF}_3-(\text{CF}_2)_9-(\text{CH}_2)_2-\text{SiCl}_3$, the covalently bonded chemical structure may be $\text{CF}_3-(\text{CF}_2)_9-(\text{CH}_2)_2-\text{Si}-\text{O}-$. Other suitable perfluoride precursors may be or include perfluorooctane or tridecafluoro-1,1,2,2-tetrahydrooctyltrichlorosilane (FOTS), among others. In general, perfluorinated films described above involve short-chain molecules of polytetrafluoroethylene (PTFE). Thus, the perfluorinated films are characterized by low friction and/or low surface energy, which may be particularly advantageous for coating surfaces in contact with a semiconductor substrate such as the substrate-supporting surface 133 (shown in Figure 1B). Perfluorinated films described above may be deposited using ALD, among other techniques.

[0051] In some other examples, the second coating layer 178 may be or include yttrium oxyfluoride (YOF). In some examples, a thickness of the YOF coating may be about 100 nm to about 500 nm, such as about 100 nm to about 200 nm, about 200 nm to about 300 nm, about 300 nm to about 400 nm, or about 400 nm to about 500 nm. In some examples, the YOF coating may entirely cover the underlying surface. In some examples, an individual concentration of yttrium atoms, oxygen atoms, and fluoride atoms in the YOF coating may be within a range of about 25 atomic (at.) % to about 40 at. %. In one example, the concentration of each component may be about equal (i.e., about 33 at. % Y, 33 at. % O, and 33 at. % F). In general, YOF coatings described above are more resistant to etching (e.g., when exposed to AHF/water process chemistry) compared to other coatings such as silicon carbide. In some examples using 4 wt% to 25 wt% HF in liquid water, an etch rate of the YOF coatings may be less than about 0.5 Angstroms/minute ($\text{\AA}/\text{min}$). In some other examples, in an application specific process environment (e.g., using the processing chamber 100 described above with HF and water vapor at temperatures less than about 0 °C), an etch rate of the YOF coatings may be less than about 0.15 $\text{\AA}/\text{min}$. The YOF coatings described above may be deposited using ALD, among other techniques.

[0052] In some examples, the second coating layer 178 has a high bulk density which corresponds to low void volume. In some examples, the second coating layer 178 may have a bulk density as a fraction of volumetric mass density of the coating material of about 90% or greater, such as about 95% or greater, such as about 99% or greater, such as about 100%. In some examples, a thickness of the second

coating layer 178 may be within a range of about 100 nm to about 40 μm , such as about 100 nm to about 40 μm , such as about 1 μm to about 10 μm , such as about 10 μm to about 20 μm , such as about 20 μm to about 30 μm , such as about 30 μm to about 40 μm , such as about 30 μm . In some examples, the second coating layer 178 may be more durable with the use of a thicker coating (e.g., greater than about 1 μm) compared to the use of a thinner coating (e.g., less than about 1 μm). Thus, in at least some implementations, CVD may be a particularly advantageous process compared to ALD for forming the second coating layer 178. In some examples, a surface roughness average (Ra) of the second coating layer 178 may be within a range of about 5 μin to about 20 μin . In some examples, electrical resistivity of the second coating layer 178 may be about 10^7 Ohm-cm to about 10^8 Ohm-cm.

[0053] Advantageously, when the substrate-supporting surface 133 of the support body 132 includes a non-metal coating as shown in Figure 1D, substrate back side metal contamination is reduced or prevented compared to conventional surface materials which include metal elements such as aluminum oxide (e.g., Al_2O_3). The portion of the support body 132 shown in Figure 1D corresponds to the substrate-supporting surface 133. In some examples, the second coating layer 178 may be disposed over only the substrate-supporting surface 133. In other words, the second coating layer 178 may extend a radial distance from the center C1 of the support body 132 which is about equal to the first radial distance R1. Thus, the second coating layer 178 may extend a radial distance from the center C1 which is less than the second radial distance R2 of the first coating layer 164. In some other examples, the second coating layer 178 may be applied to areas outside the substrate-supporting surface 133. For example, the second coating layer 178 may be applied to an entirety of the upper surface of the support body 132 including the upward-facing surface 141 (shown in Figure 1B) surrounding the substrate-supporting surface 133. In some examples, the side 143 (e.g., vertical sides) of the support body 132 are free of the second coating layer 178. In some other examples, the second coating layer 178 may be applied around the side 143 (shown in Figure 1B) of the support body 132. However, portions of the second coating layer 178 disposed over vertical surfaces such as on the side 143 of the support body 132, may have reduced overall coating quality. Therefore, it may be advantageous to

avoid coating the side 143. In some examples, the second coating layer 178 may be disposed over an entirety of the support body 132. In some examples, the stem 136 may be free of the second coating layer 178. Application of the second coating layer 178 to the stem 136 may be particularly difficult. Therefore, it may be advantageous to avoid coating the stem 136.

[0054] In some examples, the coated substrate support assembly 106 (e.g., shown in Figures 1C-1D) may have increased thermal conductivity compared to corresponding uncoated supports. Coating embodiments disclosed herein may be particularly advantageous for improving thermal characteristics of supports formed from aluminum at least in part because uncoated aluminum-based supports provide limited control of substrate temperature compared to more thermally conductive materials.

[0055] Figure 2 is a diagram illustrating a method 200 of forming the exemplary surface coating of Figure 1C, according to certain embodiments. At operation 202, an optional first surface treatment is applied to the outer surface 162 of the base layer 160. In some examples, the first surface treatment may include a cleaning process which removes oxides and trace metals with uniform density. In some examples, the first surface treatment may include O₂ plasma cleaning. In some examples, the cleaning process may include the preclean process described above which may be performed in the processing chamber shown in Figure 1A. In some other examples, the cleaning process may use a milder process chemistry compared to the preclean process, in which the milder process conditions may be more suitable for cleaning unfinished surfaces (e.g., uncoated surfaces or surfaces which are only coated with a single coating layer) of the substrate support assembly.

[0056] At operation 204, a first material precursor is deposited over the base layer 160 to form the first coating layer 164. In some examples, the first material precursor may be deposited using ENP or electrolytic nickel plating, among other processes which are suitable to deposit materials forming the first coating layer 164 as described above. In some examples, the parts of the substrate support assembly 106 to be coated (e.g., the support body 132 and/or stem 136) are submerged in a bath containing the first material precursor.

[0057] At operation 206, an optional second surface treatment is applied to the outer surface 166 of the first coating layer 164. In some examples, the second surface treatment may include one or more of the cleaning processes described above with respect to operation 202.

[0058] Figure 3 is a diagram illustrating a method 300 of forming the exemplary surface coating of Figure 1D, according to certain embodiments. At operation 302, an optional first surface treatment is applied to the outer surface 172 of the base layer 170. In some examples, the first surface treatment may include one or more of the cleaning processes described above with respect to operation 202.

[0059] At operation 304, a first material precursor is deposited over the base layer 170 to form the first coating layer 174. In some examples, the first material precursor may be deposited using ENP or electrolytic nickel plating, among other processes which are suitable to deposit materials forming the first coating layer 164 as described above.

[0060] At operation 306, an optional second surface treatment is applied to the outer surface 176 of the first coating layer 174. In some examples, the second surface treatment may include one or more of the cleaning processes described above with respect to operation 202. In some examples, the second surface treatment may include reactive ion etching. In some examples, the second surface treatment may include reverse transferred arc plasma cleaning.

[0061] At operation 308, a second material precursor is deposited over the first coating layer 174 to form the second coating layer 178. In some examples, the second material precursor may be deposited using CVD, PECVD, ALD, or PEALD.

[0062] At operation 310, an optional third surface treatment is applied to the outer surface 180 of the second coating layer 178. In some examples, the third surface treatment may include one or more of the cleaning processes described above with respect to operation 202.

[0063] Figure 4 is an enlarged cross-sectional view of a portion of a support body which is configured to be used in the processing chamber 100 of Figure 1A illustrating another exemplary surface coating disposed thereon, according to certain embodiments. The surface coating shown in Figure 4 is similar to the surface

coating shown in Figure 1D, except the first coating layer 174 is omitted. In such examples, the first coating layer 174 is not needed when the support body is formed from a material which is resistant to the process environment. Instead, the second coating layer 178 is in direct contact with the outer surface 172 of the base layer 170. In some other examples, one or more additional layers may be disposed between the base layer 170 and second coating layer 178. In one example, the base layer 170 may be or include a nickel alloy (e.g., Ni100 or Ni200), and the second coating layer 178 may be or include silicon carbide (e.g., SiC), silicon, a perfluorinated film, YOF, or combinations thereof.

[0064] The portion of the support body shown in Figure 4 corresponds to the substrate-supporting surface 133. However, in some examples, the second coating layer 178 may be applied directly to the base layer 170 in areas outside the substrate-supporting surface 133 as described above with respect to Figure 1D.

[0065] Benefits of the present disclosure include improved coatings for a substrate support assembly of a processing chamber. Certain embodiments provide a two-part surface coating, in contrast to conventional one-part coatings. The two-part coating includes a first coating which reduces overall surface corrosion of the substrate support assembly and a second coating, free of metal contaminants, which reduces substrate back side metal contamination.

[0066] While the foregoing is directed to embodiments of the present disclosure, other and further embodiments of the disclosure may be devised without departing from the basic scope thereof.

Claims:

1. A support body for supporting a substrate in a processing chamber, comprising:
 - a body having an upper surface; and
 - a two-part coating disposed over the upper surface of the body, the two-part coating comprising:
 - a first coating layer extending a first radial distance from a center of the body, the first coating layer including at least one of a metal-containing material or alloy; and
 - a second coating layer disposed over the first coating layer, the second coating layer extending a second radial distance from the center of the body, the first radial distance greater than the second radial distance, wherein the second coating layer is non-metal.
2. The support body of claim 1, wherein the first coating layer is disposed over an entirety of the upper surface of the body.
3. The support body of claim 1, wherein the first coating layer is disposed over an entirety of the body, and wherein vertical sides of the body are free of the second coating layer.
4. The support body of claim 1, wherein the first coating layer is disposed over a substrate contact surface of the body and over an area of the body outside the substrate contact surface, and wherein the second coating layer is disposed over only the substrate contact surface of the body.
5. The support body of claim 1, wherein the second coating layer comprises a perfluorinated film.
6. The support body of claim 5, wherein the perfluorinated film comprises a self-assembled monolayer.

7. The support body of claim 1, wherein the first coating layer comprises electroless nickel plating, and wherein the second coating layer comprises silicon carbide.
8. The support body of claim 1, wherein the first coating layer comprises electroless nickel plating, and wherein the second coating layer comprises silicon.
9. The support body of claim 1, wherein the second coating layer comprises yttrium oxyfluoride.
10. A system comprising:
- a processing chamber configured to clean a substrate, the processing chamber comprising:
 - a chamber body;
 - a lid assembly disposed at an upper end of the chamber body, the lid assembly comprising:
 - a dual channel showerhead having a first set of channels providing fluid communication above and below a plane of the showerhead; and
 - a second set of channels providing fluid communication with a side port of the chamber body; and
 - a substrate support assembly at least partially disposed within the chamber body, the substrate support assembly configured to support the substrate in the processing chamber, the substrate support assembly comprising:
 - a support body having an upper surface, the upper surface extending a first radial distance from a center of the support body;
 - a stem coupled to the support body; and
 - a coating disposed over the support body, the coating comprising:
 - a first coating layer disposed over an entirety of the upper surface of the support body, the first coating layer comprising electroless nickel plating; and

a second coating layer disposed over the first coating layer, the second coating layer extending a second radial distance from the center of the support body, the second radial distance less than the first radial distance, and the second coating layer comprising silicon carbide.

11. The system of claim 10, wherein the first coating layer is further disposed over vertical sides of the support body and over the stem, and wherein the vertical sides of the support body and the stem are free of the second coating layer.

12. The system of claim 10, further comprising an epitaxy chamber to grow an epitaxial layer on the substrate after the substrate is cleaned by the processing chamber.

13. The system of claim 10, wherein the second coating layer is disposed over only a substrate contact surface of the support body.

14. The system of claim 10, wherein the second coating layer comprises a perfluorinated film.

15. The system of claim 14, wherein the perfluorinated film comprises a self-assembled monolayer.

16. The system of claim 10, wherein the second coating layer comprises yttrium oxyfluoride, wherein an individual concentration of yttrium atoms, oxygen atoms, and fluoride atoms in the yttrium oxyfluoride coating is within a range of about 25 atomic % to about 40 atomic %.

17. A method of forming a surface coating on a support body of a processing chamber, comprising:

depositing a first material over an entire upper surface of the support body, thereby forming a first coating layer, the first material including at least one of a metal-containing material or alloy; and

depositing a second material over the first coating layer only over a portion of the upper surface of the support body, thereby forming a second coating layer, wherein the second material is non-metal.

18. The method of claim 17, wherein the upper surface extends a first radial distance from a center of the support body, and wherein the second coating layer extends a second radial distance less than the first radial distance from the center of the support body.

19. The method of claim 17, further comprising depositing the first material over an entirety of the support body.

20. The method of claim 17, wherein the first coating layer comprises electroless nickel plating, and wherein the second coating layer comprises silicon carbide.