THERMAL INTERFACE COMPONENT FOR A PLASMA PROCESSING TOOL

BACKGROUND

[0001] Thermal interface components can be used to transport heat between components in a processing tool. As examples, thermal interface components can be used at an interface between an electrode and a gas distribution plate, at an interface between an electrostatic chuck and a thermal control element, and/or an interface between the electrostatic chuck and a conductive baseplate of a processing chamber. Thermal interface components at these locations can help to prevent temperature drift during substrate processing, and thus can help to achieve suitably uniform substrate processing over time.

SUMMARY

[0002] This Summary is provided to introduce a selection of concepts in a simplified form that are further described below in the Detailed Description. This Summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject matter. Furthermore, the claimed subject matter is not limited to implementations that solve any or all disadvantages noted in any part of this disclosure.

[0003] Examples are disclosed that relate to a thermal interface component for a plasma processing tool, and a plasma processing tool with a thermal interface component. In one example, a plasma processing tool comprises an outer electrode surrounding an inner electrode, and a gas distribution plate. The plasma processing tool further comprises a thermal interface component situated between the gas distribution plate and one or more of the inner electrode and the outer electrode. The thermal interface component comprises a non-silicone polymeric elastomer as a continuous phase and thermally conductive particles as a dispersed phase.

[0004] In some such examples, the gas distribution plate comprises a plurality of gas distribution openings, and the thermal interface component comprises a plurality of holes positioned complementary to the gas distribution openings.

[0005] Additionally or alternatively, in some such examples, the plasma processing tool comprises an edge ring, and further comprises a second thermal interface component situated between the edge ring and a substrate holder.

[0006] Additionally or alternatively, in some such examples, the non-silicone polymeric elastomer comprises one or more of an epoxy-based matrix or a fluorocarbon-based matrix.

[0007] Additionally or alternatively, in some such examples, the thermal interface component has a thickness of > 0.4 mm.

[0008] Additionally or alternatively, in some such examples, the thermal interface component has an alternating current (AC) breakdown voltage of >4.0 kV.

[0009] Additionally or alternatively, in some such examples, the thermal interface component has a thermal conductivity in a range of 2.0-40 W/mK.

[0010] Additionally or alternatively, in some such examples, the thermal interface component has a relative permittivity in a range of 2-4.

[0011] Additionally or alternatively, in some such examples, the thermal interface component comprises a core layer sandwiched between a first thermal interface component layer and a second thermal interface component layer.

[0012] Additionally or alternatively, in some such examples, the thermally conductive particles are electrically insulating.

[0013] Additionally or alternatively, in some such examples, the thermally conductive particles comprise boron nitride.

[0014] Additionally or alternatively, in some such examples, the thermally conductive particles are electrically conductive.

[0015] Additionally or alternatively, in some such examples, the thermally conductive particles comprise carbon fiber.

[0016] In another example, a thermal interface component is provided for an electrode assembly of a plasma processing tool. The thermal interface component comprises a non-silicone polymeric elastomer as a continuous phase; and thermally conductive particles as a dispersed phase.

[0017] In some such examples, the non-silicone polymeric elastomer comprises one or more of an epoxy-based matrix or a fluorocarbon-based matrix.

[0018] Additionally or alternatively, in some such examples, the thermally conductive particles comprise one or more of boron nitride, carbon fiber, graphite, aluminum oxide, or aluminum nitride.

[0019] Additionally or alternatively, in some such examples, the thermally conductive particles are electrically insulating.

[0020] Additionally or alternatively, in some such examples, the thermally conductive particles are electrically conductive.

[0021] Additionally or alternatively, in some such examples, the thermal interface component is configured to be situated between a gas distribution plate and one or more of an inner electrode and an outer electrode of the electrode assembly, wherein the gas distribution plate comprises a plurality of gas distribution openings, and wherein the one or more thermal interface components comprises a plurality of holes positioned complementary to the gas distribution openings.

[0022] Additionally or alternatively, in some such examples, the thermal interface component comprises a core layer sandwiched between a first thermal interface component layer and a second thermal interface component layer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 shows a schematic diagram of an example processing tool comprising a thermal interface component.

[0024] FIG. 2 shows a top-down view of an example thermal interface component suitable for use with the processing tool of FIG. 1.

[0025] FIG. 3 shows a cross-sectional view of the thermal interface component of FIG. 2.

DETAILED DESCRIPTION

[0026] The term “additive” generally represents a second material added to a continuous phase of a composite material during a manufacturing process. The additive can alter one or more properties of the continuous phase, such as viscosity, compliance, electrical conductivity, or thermal conductivity.

[0027] The term “breakdown voltage” generally represents a minimum voltage that causes an insulating material to experience electric breakdown and become electrically conductive.

[0028] The term “continuous phase” generally represents a phase of a composite material within which solid or fluid particles of a dispersed phase, such as an additive or filler material, are dispersed.

[0029] The term "dispersed phase" generally represents a solid that is suspended within a continuous phase of a composite material.

[0030] The term "edge ring" generally represents a component of a processing tool configured to encircle a substrate positioned on a substrate holder.

[0031] The term "elastomer" generally represents a material that regains its original shape after being stretched or compressed.

[0032] The terms "electrical conductor" and variants thereof generally represent a material in which electrical current can flow without having to apply a voltage that exceeds a bandgap in the material.

[0033] The terms "electrical insulator" and "electrically insulating" generally represent a material with a resistivity higher than a resistivity of a semiconductor. A resistivity of an electrical insulator can be 10^8 ohms-cm or greater.

[0034] The term "electrode" generally represents an electrical conductor positioned at the terminals of an electrically conducting medium and used to make contact with a non-metal portion of an electric circuit.

[0035] The term "epoxy-based matrix" generally represents a polymer matrix comprising an epoxy resin. An epoxy-based matrix may contain fibers and/or particles of one or more dispersed phase materials.

[0036] The term "fluorocarbon-based matrix" generally represents a polymer matrix comprising one or more compounds having carbon-fluorine bonds. A fluorocarbon-based matrix may contain fibers or particles and/or particles of one or more dispersed phase materials.

[0037] The term "gas distribution plate" generally represents a component of an electrode assembly that receives processing gas flows from a processing gas inlet and distributes the processing gas through one or more gas distribution openings.

[0038] The term "gasket" generally represents a shaped material configured to seal an interface between two or more components of an apparatus.

[0039] The term "ligand" generally represents a chemical moiety that is bonded to a particle to functionalize a surface of the particle.

[0040] The term "plasma processing tool" generally represents a machine including a processing chamber and other hardware configured to enable plasma processing to be carried out in the processing chamber.

[0041] The term "relative permittivity" generally represents a ratio of an electrical permittivity of a material with an electrical permittivity of a vacuum.

[0042] The term "silicone polymer" generally represents a polymer comprising a backbone having silicon-oxygen bonds. The term "non-silicone polymer" generally represents a polymer having a backbone without silicon-oxygen bonds.

[0043] The term "substrate" may generally represent any object on which a film can be deposited.

[0044] The term "substrate holder" generally represents any structure configured to support a substrate in a processing chamber.

[0045] The term "thermal conductor" generally represents a material that permits heat to travel through the material at a rate of at least 1 W/(mK).

[0046] The term "thermally conductive particle" generally represents a particle of a dispersed phase in a composite material that has a higher thermal conductivity than a material of a continuous phase of the composite material. The "thermally conductive particle" contains or is made of a "thermal conductor".

[0047] The term "thermal interface material" generally represents a material that is configured to conduct heat between two or more other components. The term "thermal interface component" generally represents a gasket or other component made at least partially of a thermal interface material.

[0048] As introduced above, thermal interface materials (TIMs) are thermally conductive components that can be placed between components of a processing tool to help transfer heat between the components. As an example, a thermal interface component can be positioned between an electrode and a gas distribution plate in an etching or deposition tool. The gas distribution plate can be thermally coupled with other components to conduct heat away from the electrode. The thermal interface component between the gas distribution plate and the electrode can be selected, for example, to conduct heat at a sufficiently high rate to avoid unsuitable levels of thermal drift of the electrode during substrate processing. Such a thermal interface component can be electrically insulating, which can help to control the impedance on the electrode in segments. This can help to provide tunability at the substrate in terms of plasma density as a function of the distance from the center to the edge of the electrode.

[0049] Some processing tools utilize silicone-based composite materials in thermal interface components. A silicone-based composite material comprises a silicone polymer ("silicone") as a continuous phase, and a thermally conductive particle as a dispersed phase. The silicone polymer is an elastomer, and thus can deform to conform to the surfaces of components (for example, a gas distribution plate and

electrode) when placed between these components. This helps to ensure good thermal contact between these components and the thermal interface component. Silicone is a durable material that possesses a glass transition temperature suitable for use in a plasma processing tool. The thermally conductive particle is selected to have a higher thermal conductivity than the silicone polymer. The thermal conductivity of such a composite thermal interface component can be controlled by tailoring a size and/or a concentration of particles in the dispersed phase.

[0050] However, the use of silicone as a continuous phase can pose issues in some use environments. For example, silicone can be degraded by hydrogen fluoride (HF), which can be used as an etching agent in some etching processes. This can result in premature degradation of the thermal interface component. Degradation can impact thermal conductivity and mechanical robustness of a thermal interface component. As such, thermal interface component degradation can lead to an unsuitably short lifespan that requires more frequent replacement than other related components, such as electrodes. Such replacement involves tool downtime, which impacts tool throughput effectively. Silicone polymers also present other risks, including silicone oil leeching, which can contaminate a processing tool and/or substrates processed in the processing tool.

[0051] Accordingly, examples are disclosed that relate to thermal interface components that utilize a thermal interface material comprising a non-silicone polymeric elastomer as a continuous phase and thermally conductive particles as a dispersed phase. Non-silicone polymeric elastomers can be more resistant to HF than silicone. Accordingly, the use of the non-silicone polymeric elastomer can prevent premature degradation of the thermal interface component and other issues associated with silicone-based thermal interface components when used in a processing environment containing HF. A non-silicone polymeric elastomer also may be more resistant to degradation in other processing chemical environments than an HF environment.

[0052] Prior to discussing these examples in more detail, FIG. 1 schematically shows an example processing tool 100 in the form of a plasma etching tool. FIG. 1 is illustrative. In other examples, a processing tool can include any other components suitable for performing a plasma process. Further, in some examples, processing tool 100 can omit one or more components illustrated. While discussed herein in the context of a plasma etching tool, other processing tools can include a thermal interface

component according to the disclosed examples. Other examples of processing tools include plasma-enhanced atomic layer deposition (PEALD) and plasma-enhanced chemical vapor deposition (PECVD) tools.

[0053] Processing tool 100 includes a processing chamber 102. Processing tool 100 further includes a substrate holder 104 positioned within the processing chamber 102. During operation, a substrate 106 is arranged on the substrate holder 104. In some examples, the substrate holder 104 includes a pedestal, an electrostatic chuck, and/or any other suitable components for supporting the substrate 106.

[0054] The processing tool 100 further comprises an inner electrode 108 and an outer electrode 110. The use of separate components for inner electrode 108 and outer electrode 110 instead of a unitary, larger electrode allows inner electrode 108 and outer electrode 110 to be replaced at different frequencies, for example.

[0055] Inner electrode 108 and outer electrode 110 are positioned beneath a processing gas inlet 112 and a gas distribution plate 114 in the example of FIG. 1. Substrate holder 104 is configured to support substrate 106 adjacent to gas distribution plate 114. The gas distribution plate 114 receives processing gas flows from the processing gas inlet 112. The processing gas flows are distributed through one or more processing gas flow channels (not shown) within an interior of gas distribution plate 114. Gas distribution plate 114 also comprises a plurality of gas distribution openings (not shown) that lead from the interior of gas distribution plate 114 to a corresponding plurality of holes (not shown) formed in the inner electrode 108 and the outer electrode 110. This allows processing gases to reach the substrate 106.

[0056] A first thermal interface component 170 is situated between the gas distribution plate 114 and the inner and outer electrodes 108, 110. The first thermal interface component 170 is configured to help conduct heat away from the inner electrode 108 and/or the outer electrode 110 during substrate processing. This can, for example, help to prevent unsuitable magnitudes of temperature drift from occurring during substrate processing. The thermal interface component 170 includes a plurality of holes (not shown in FIG. 1) that are positioned complementary to the gas distribution openings of gas distribution plate 114 and that act as a conduit between the plurality of gas distribution openings of gas distribution plate 114 and the plurality of holes of inner electrode 108 and outer electrode 110. An example implementation of the thermal interface component 170 is described in more detail below.

[0057] The substrate holder 104 includes a conductive baseplate 116 that acts as a lower electrode. In some examples, such as systems for performing etching of conductive materials, the conductive baseplate 116 supports a substrate heater 120. When included, the substrate heater 120 can take the form of a ceramic multi-zone heating plate. In other examples, such as systems for performing etching of dielectric materials, a substrate heater can be omitted, as the plasma heat can be so high that cooling is used to maintain a substrate temperature. A thermal resistance layer 122 is arranged between the substrate heater 120 and the conductive baseplate 116. Conductive baseplate 116 includes one or more coolant channels 124 for flowing coolant through conductive baseplate 116. The substrate holder 104 further includes an edge ring 126 configured to encircle the substrate 106.

[0058] The processing tool 100 further comprises a plasma generator 128 configured to generate a plasma in the processing chamber 102. The plasma generator 128 generates and outputs a radio frequency (RF) voltage to the inner electrode 108 and the outer electrode 110. In some examples, the RF voltage oscillates around a bias voltage. The conductive baseplate 116 can be direct current (DC) grounded, alternating current (AC) grounded, or floating. The plasma generator 128 includes an RF voltage generator 130 configured to generate the RF voltage. The RF voltage is supplied using an impedance matching and distribution network 132 to inner electrode 108 and outer electrode 110 to form a plasma. In other examples, the RF voltage can be sent to the conductive baseplate 116, and inner electrode 108 and outer electrode 110 can be DC grounded, AC grounded, or floating.

[0059] The processing tool 100 further comprises a processing chemical delivery system 134. The processing chemical delivery system 134 includes processing chemical sources 136A-136N (collectively processing chemical sources 136), where N indicates an arbitrary number of additional processing chemical sources that is equal to or greater than zero.

[0060] The processing tool 100 further comprises flow control hardware 138. The flow control hardware 138 is configured to control a flow of each of one or more processing chemicals into the processing chamber 102. Each of the processing chemical sources 136 is in fluid communication with the flow control hardware 138. For example, the processing chemical sources 136 are connected by valves 140A-140N (collectively valves 140) and mass flow controllers (MFCs) 142A-142N (collectively MFCs 142) to a manifold 144. An output of the manifold 144 is fed to processing

chamber 102, for example through the gas distribution plate 114 and the inner and outer electrodes 108, 110. The processing chemical delivery system 134 further can help to control a pressure of processing chamber 102.

[0061] A temperature controller 146 is connected to a plurality of thermal control elements (TCEs) 148 (e.g., heating elements) arranged in ceramic layer 118. The temperature controller 146 is used to control the TCEs 148 to control a temperature of the substrate holder 104 and the substrate 106. Further, the temperature controller 146 communicates with a coolant assembly 150 to control coolant flow through coolant channels 124. In some examples, the coolant assembly 150 can include a coolant pump and reservoir. The temperature controller 146 operates the coolant assembly 150 to selectively flow the coolant through the coolant channels 124 to cool the substrate holder 104.

[0062] A valve 152 and a pump 154 can be used to evacuate reactants from the processing chamber 102. Further, a system controller 156 is configured to control components of plasma processing tool 100. A robot 158 delivers substrates onto, and removes substrates from, substrate holder 104. For example, the robot 158 transfers substrates between the substrate holder 104 and a load lock 160. Although shown as separate controllers, the temperature controller 146 can be implemented within the system controller 156. Further, a protective seal 162 is provided around a perimeter of thermal resistance layer 122 between the ceramic layer 118 and conductive baseplate 116. In other examples, the protective seal 162 is omitted.

[0063] The processing chamber 102 further includes a plasma containment shroud 164. The plasma containment shroud 164 is arranged around the outer electrode 110 and the edge ring 126. In the depicted example, the inner electrode 108, the outer electrode 110, the plasma containment shroud 164, and the edge ring 126 confine the plasma within a plasma confinement area 166. In some examples, the plasma containment shroud 164 is electrically connected to the outer electrode 110 and the inner electrode 108. Plasma containment shroud 164 includes one or more slots 168 to provide fluid communication between the plasma confinement area 166 and an environment external to plasma containment shroud 164. In other examples, any other suitable plasma-exposed parts are used to confine a plasma within a plasma confinement area.

[0064] The processing tool 100 comprises various thermal interface components. As mentioned above, the processing tool 100 comprises a first thermal

interface component 170 positioned between the gas distribution plate 114 and the inner and outer electrodes 108, 110. In the depicted example, the processing tool 100 further comprises a second thermal interface component 172 situated between the edge ring 126 and the substrate holder 104. The thermal interface component 170 and the second thermal interface component 172 each function to remove heat generated during substrate processing. In some examples, the first thermal interface component 170 functions to maintain a suitably uniform temperature at the inner electrode 108, which helps to maintain substrate etch uniformity. The second thermal interface component 172 functions to maintain a suitably even temperature at the edge ring 126, without unsuitable temperature drift, during substrate processing. This, in turn, helps maintain etch performance at the edge of the wafer. Thermocouples (not shown) within or adjacent to inner electrode 108, outer electrode 110, and edge ring 126 can be used to monitor temperature during substrate processing. In other examples, a processing tool can include additional and/or alternative thermal interface components than first thermal interface component 170 and second thermal interface component 172. Both first thermal interface component 170 and second thermal interface component 172 can be exposed to HF during conductor substrate processing. Thus, first thermal interface component 170 and second thermal interface component 172 can be susceptible to degradation from the HF.

[0065] FIG. 2 shows a top-down schematic view of an example implementation of an example thermal interface component 200. The thermal interface component 200 is suitable for use, for example, as first thermal interface component 170 of FIG. 1. The thermal interface component 200 is configured to be situated between gas distribution plate 114 and inner and outer electrodes 108, 110 of processing tool 100 of FIG. 1. In this example, thermal interface component 200 comprises an inner gasket 202 and an outer gasket 204, although in other examples, thermal interface component 200 can comprise a single, unified gasket. As an example, inner gasket 202 may align with inner electrode 108 and outer gasket 204 may align with outer electrode 110.

[0066] The thermal interface component 200 includes a plurality of holes 206 comprising processing gas through-holes. The holes 206 are positioned to align with and be complementary to the aforementioned gas distribution openings of the gas distribution plate 114 and gas processing outlet holes of the inner and outer electrodes 108, 110. This allows processing gases to reach the processing chamber interior. In this example, holes 206 are depicted as round openings, but other shapes are possible. The

diameters of holes 206 compared to the diameter of thermal interface component 200 are merely illustrative. Thermal interface component 200 may further comprise additional mounting holes 208 that may be used to affix thermal interface component 200 to one or more of the gas distribution plate, inner electrode, and outer electrode. Additionally or alternatively, in some examples, thermal interface component 200 can be affixed in place using adhesives on one or both sides.

[0067] FIG. 3 shows a magnified cross-sectional view of a portion of the thermal interface component 200 of FIG. 2, taken along line 3-3 of magnified excerpt 210 of FIG. 2. FIGS. 2 and 3 are not to scale, but rather are drawn to arbitrary scale to clarify the example structures described. In the depicted example, the thermal interface component 200 comprises a core layer 214 sandwiched between a first thermal interface component layer 216 and a second thermal interface component layer 218. However, in other examples, the core layer may be omitted, and the thermal interface component can comprise a single layer. For example, a thermal interface component containing a dispersed phase of ceramic particles may not include a core layer. When included, core layer 214 comprises holes that align with holes 206 of thermal interface component 200. However, the process of laminating core layer 214, first thermal interface component layer 216, and a second thermal interface component layer 218 may generate some offsets between layers, such as in the range of < 1mm in some examples.

[0068] The core layer 214 is configured to reinforce the thermal interface component 200. This can provide for stronger mechanical integrity than an un-reinforced thermal interface component. Furthermore, the reinforced thermal interface component can be easier to handle and align in the processing tool during installation than the un-reinforced material. For example, core layer 214 may have a greater tensile strength and/or Young's modulus than first thermal interface component layer 216 and second thermal interface component layer 218. In some examples, core layer 214 has a tensile strength and/or Young's modulus that is at least 25% greater than that of first thermal interface component layer 216 and second thermal interface component layer 218. More specifically, in some such examples, core layer 214 has a tensile strength and/or Young's modulus that is at least 50% greater than that of first thermal interface component layer 216 and second thermal interface component layer 218.

[0069] In addition, the core layer 214 can be used to alter one or more other properties of the thermal interface component 200 (e.g., mechanical integrity, thermal conductivity, electrical conductivity, electrical insulation) while being protected from

a processing environment by a bulk material of the thermal interface. For example, core layer may be an electrically conductive foil. In some such examples, the core layer 214 comprises a metal such as aluminum (e.g., an aluminum alloy) or any other suitable metal. Other examples include as titanium and titanium alloys. In other examples, core layer 214 may be an electrically insulating material such as a polymer (e.g., polyimide). It will also be appreciated that the first thermal interface component 170 can be reinforced by any other suitable material, such as a ceramic, a polymer, or a composite material. In some examples, two or more reinforcing layers (such as core layer 214) can be used. In some such examples, the reinforcing layers may or may not be separated by a layer of the thermal interface component.

[0070] The thermal interface component 200 has a thickness 300. In some examples, the thickness 300 is in a range of 100 μm – 3 mm. In some more specific examples, the thickness 300 is in a range of 150 μm – 1 mm. In some yet more specific examples, the thickness 300 is greater than 400 μm, such as in a range of 400 μm – 750 μm. It will also be appreciated that, in other examples, the thickness 300 can have any other suitable value. For example, where thermal interface component 200 is an electrically conductive thermal interface component, the thickness 300 may be in the range of 100 μm - 400 μm, or, in some more specific examples, in the range of 200 μm to 300 μm. Other examples of suitable average thickness values include values less than 100 μm and values greater than 3 mm. In some examples, multiple thinner thermal interface components can be stacked to form a single, thicker thermal interface component. For example, 2 or 3 thermal interface components that are 0.2 mm thick can be stacked to form a thermal interface component that is 0.4 or 0.6 mm thick, respectively. In order to maintain the thermal properties of thermal interface component 200, when included, core layer 214 can be thinner first thermal interface component layer 216 and second thermal interface component layer 218. For example, core layer 214 can be in the range of 10-100 μm thick, or in some more specific examples, core layer 214 may be in the range of 20-50 μm thick. In other examples, a core layer 214 can have a thickness outside of these ranges.

[0071] A close-up view of second thermal interface component layer 218 is shown at 310. The first thermal interface component layer 216 and the second thermal interface component layer 218 of the thermal interface component 200 comprise a non-silicone polymeric elastomer 312. The non-silicone polymeric elastomer 312 is a continuous phase of the thermal interface component. In some examples, the non-

silicone polymeric elastomer 312 comprises a majority of the thermal interface component, or over 50% of the thermal interface component by volume.

[0072] In some examples, the non-silicone polymeric elastomer 312 comprises a gas permeability of less than or equal to 20,000 cm^3/m^2 per 24 hours. In some, more specific examples, the non-silicone polymeric elastomer 312 comprises a gas permeability in a range of less than or equal to 2000 cm^3/m^2 per 24 hours. This can help to slow or prevent etching agents, such as HF, from reaching and attacking internal portions of the thermal interface component, thereby avoiding premature degradation.

[0073] The non-silicone polymeric elastomer 312 can be based on a carbon-carbon backbone. In this manner, the non-silicone polymeric elastomer 312 is more resistant to attack and degradation by HF, for example, than a silicone-based backbone. In some examples, the elastomeric continuous phase comprises one or more of polyisoprene, butyl rubber, chloroprene, ethyl propylene diene, a fluorocarbon-based matrix (e.g., fluoroelastomer (FKM), perfluoroelastomer (FFKM), nitrile butadiene, saturated nitrile, styrene butadiene, polyurethane, an acrylic, or a polyimide. In other examples, any other suitable polymer can be used. Other examples of suitable polymers include natural rubber, polyolefins, epoxy-based matrices (e.g., with or without additives to enable elastomeric behavior), and derivatives of polymers disclosed herein.

[0074] The thermal interface component 200 further comprises a dispersed phase comprising a thermal conductor. In the example of FIG. 3, the dispersed phase comprises a plurality of thermally conductive particles 314. In some examples, the thermal interface component 200 comprises up to 50% of the dispersed phase by weight. In some more specific examples, the thermal interface component 200 comprises 10-49% of the dispersed phase by weight. In further, more specific examples, the thermal interface component 200 comprises 30-49% of the dispersed phase by weight. It will be appreciated that the amount of the dispersed phase can be chosen as a function of a desired thermal conductivity, which is proportional to the concentration of the dispersed phase in the thermal interface part. The amount of dispersed phase can additionally or alternatively be chosen as a function of one or more properties of the thermal interface component, such as viscosity of the continuous phase, dispersion of the coated particles, and length of polymer chains in the continuous phase.

[0075] In some examples, thermally conductive particles 314 are electrically insulating particles. For example, thermally conductive particles 314 can comprise materials such as oxides (e.g., aluminum oxide), nitrides (e.g., boron nitride, aluminum

nitride), or other ceramics. In other examples, thermally conductive particles 314 are electrically conductive particles. For example, in some plasma processing tools the upper electrode is grounded, and it may be desirable for the thermal interface component to be electrically conductive but still HF resistant. In such examples, thermally conductive particles 314 can comprise metals, carbon (such as carbon fibers, graphite flakes), etc.. In some examples, thermally conductive particles 314 can comprise a mixture of two or more particle compositions. In such examples, thermally conductive particles 314 can comprise a mixture of electrically insulating particles and electrically conductive particles (e.g., carbon fiber and aluminum oxide) to generate a desired property of the thermal interface component (e.g., a thermal interface component with a relatively low capacitance/relatively high impedance).

[0076] In some examples, thermally conductive particles 314 may be coated particles comprising a core material and a different coating material (e.g., coating 316). For example, an aluminum nitride particle coated with aluminum oxide can be used. Aluminum nitride can have desirable electrical and thermal conductivity properties, but is challenging to disperse within a non-silicone polymeric elastomer. Further, aluminum nitride can be susceptible to degradation when exposed to moisture or other compounds in a semiconductor processing environment. In contrast, aluminum oxide is more robust in such conditions. Thus, by coating the particle, a particle comprising a material with desirable electrical and/or thermal properties can be used, even if the material is not chemically compatible with a processing environment.

[0077] In some examples, particles in the dispersed phase can be functionalized with a ligand. The ligand comprises a chemical moiety that is bonded to a coated particle to functionalize a surface of the coated particle. The ligand can be cross-linked with the non-silicone polymer to fix the particles in the matrix of the continuous phase.

[0078] In some examples, a core of thermally conductive particles 314 comprises a diameter in a range of 1-100 μm. In some more specific examples, the core comprises a diameter in a range of 1-50 μm. In further, more specific examples, the core comprises a diameter in a range of 1-10 μm. Larger particles can have greater dispersibility in the continuous phase than smaller particles. Larger particles also may have less risk of agglomeration. However, smaller particles can flow more easily than larger particles. It will also be appreciated that the diameter of the core can be selected based upon the thickness of the thermal interface part. For example, the size of the core

can be selected to be smaller than the thickness of the thermal interface part to ensure that the dispersed phase can be dispersed within the thermal interface part.

[0079] The thermal interface components disclosed herein can help to avoid unsuitable levels of thermal variability, or drift, during substrate processing. In some examples, thermal variability can be quantified by a change in temperature (ΔT) across the thermal interface component. For example, a gas distribution plate can be in thermal communication with a heat sink that is set to a fixed temperature (e.g. 110 °C). Thermocouples can be used to measure a temperature of the inner electrode and/or outer electrode. Thus, temperatures differences across the thermal interface component, and between the inner and outer electrodes, can be measured in various examples. Temperature nonuniformities can be manifested as a higher than desired temperature difference across the thermal interface component, higher than desired temperature differences between the inner electrode and the outer electrode, and/or higher than desired changes in one or both of these temperature differences over time.

[0080] The thermal interface components disclosed herein can have suitable thermal conductivity to conduct heat between two or more other components of a processing tool. The thermal conductivity can be quantified by following American Society for Testing and Materials (ASTM) D 5470 as set forth by ASTM International. In some examples, the thermal conductivity is in a range of 1-50 W/mK. In some, more specific examples, the thermal conductivity is in a range of 2-40 W/mK. In further, more specific examples, the thermal conductivity is in a range of 2-5 W/mK. It will also be appreciated that the thermal conductivity can have any other suitable value. Other examples of suitable thermal conductivity values include values less than 1 W/mK and values greater than 10 W/mK. Similarly, the thermal interface components disclosed herein can have suitable thermal resistance to conduct heat between two or more other components of a processing tool. In some examples, the thermal resistance is in the range of 0.01-0.2 K/W.

[0081] The thermal interface components disclosed herein can have suitable flexibility to form a seal between two or more other components of a processing tool. In some such examples, the thermal interface components disclosed herein have a Shore A hardness value in a range of 0-100, In some, more specific examples, the Shore A hardness value is in a range of 60-100. In further, more specific examples, the Shore A hardness value is in a range of 70-85. It will also be appreciated that harder or softer thermal interface components can be used. Other examples of suitable thermal interface

component s include materials softer than a Shore A hardness value of zero, and materials harder than a Shore A hardness value of 100.

[0082] The thermal interface components disclosed herein can have suitable dielectric strength to serve as an electrical insulator. The dielectric strength can be quantified by following ASTM D 149 as set forth by ASTM International. In some examples, the dielectric strength is in a range of 1-100 kV/mm. In some, more specific examples, the dielectric strength is in a range of 10-20 kV/mm. In further, more specific examples, the dielectric strength is in a range of 14-16 kV/mm. It will also be appreciated that the dielectric strength can have any other suitable value. Other examples of suitable dielectric strength values include values less than 1 kV/mm and values greater than 100 kV/mm. Similarly, the thermal interface components disclosed herein can have suitable AC breakdown voltages. In some examples, the AC breakdown voltage is > 2.0 kV. In some, more specific examples, the AC breakdown voltage is > 4.0 kV. Similarly, the thermal interface components disclosed herein can have suitable relative permittivity. In some examples, the relative permittivity is in the range of 1-5. In some, more specific examples, the relative permittivity is in the range of 1.5-4.5. In further, more specific examples, the relative permittivity is in the range of 2-4.

[0083] The thermal interface components disclosed herein can have any suitable density. The density can be quantified by following ASTM D 611 as set forth by ASTM International. In some examples, the density is in a range of 1-10 g/cm^3. In some, more specific examples, the density is in a range of 1-5 g/cm^3. In further, more specific examples, the density is in a range of 1-3 g/cm^3. Other examples of suitable thermal interface components can have a density of less than 1 g/cm^3 or greater than 10 g/cm^3.

[0084] It will also be appreciated that the thermal interface components disclosed herein can be suitably inflammable to enable safe use in processing equipment. Flammability can be quantified following UL 94 as set forth by Underwriters Laboratories of Northbrook, IL, USA. For example, the thermal interface components disclosed herein can have a flammability rating of V-0 or VTM-0. The non-silicone polymeric elastomer can, in some examples, include one or more additives. For example, one or more additives can be used to change the viscosity, compliance, thermal conductivity, and electrical conductivity of the thermal interface component. In some such examples, the non-silicone polymeric elastomer includes a

silicon-based additive. For example, a silicone material can be used to impart pliability or electrical resistance to the thermal interface component.

[0085] The amount of silicon present in the non-silicone polymeric elastomer 312 can be quantified by any suitable method. One example of a suitable method for determining the amount of silicon is energy-dispersive X-ray spectrometry (EDX), as described in ASTM standard no. F1375. In some examples, the non-silicone polymeric elastomer 312 comprises less than five percent silicon by mass. In some, more specific examples, the non-silicone polymeric elastomer 312 comprises less than two percent silicon by mass. In further, more specific examples, the non-silicone polymeric elastomer 312 comprises less than one percent silicon by mass. In this manner, silicon can be used as an additive without substantially affecting the integrity of the thermal interface component.

[0086] The subject matter of the present disclosure includes all novel and non-obvious combinations and sub-combinations of the various processes, systems and configurations, and other features, functions, acts, and/or properties disclosed herein, as well as any and all equivalents thereof.

CLAIMS:

1. A plasma processing tool, comprising:

an outer electrode surrounding an inner electrode;

a gas distribution plate;

a thermal interface component positioned between the gas distribution plate and one or more of the inner electrode and the outer electrode, wherein the thermal interface component comprises a non-silicone polymeric elastomer as a continuous phase and thermally conductive particles as a dispersed phase.

2. The plasma processing tool of claim 1, wherein the gas distribution plate comprises a plurality of gas distribution openings, and wherein the thermal interface component comprises a plurality of holes positioned complementary to the gas distribution openings.

3. The plasma processing tool of claim 1, wherein the plasma processing tool comprises an edge ring, and further comprising a second thermal interface component situated between the edge ring and a substrate holder.

4. The plasma processing tool of claim 1, wherein the non-silicone polymeric elastomer comprises one or more of an epoxy-based matrix or a fluorocarbon-based matrix.

5. The plasma processing tool of claim 4, wherein the thermal interface component has a thickness of > 0.4 mm.

6. The plasma processing tool of claim 4, wherein the thermal interface component has an alternating current (AC) breakdown voltage of >4.0 kV.

7. The plasma processing tool of claim 4, wherein the thermal interface component has a thermal conductivity in a range of 2.0-40 W/mK.

8. The plasma processing tool of claim 4, wherein the thermal interface component has a relative permittivity in a range of 2-4.

9. The plasma processing tool of claim 1, wherein the thermal interface component comprises a core layer sandwiched between a first thermal interface component layer and a second thermal interface component layer.

10. The plasma processing tool of claim 1, wherein the thermally conductive particles are electrically insulating.

11. The plasma processing tool of claim 10, wherein the thermally conductive particles comprise boron nitride.

12. The plasma processing tool of claim 1, wherein the thermally conductive particles are electrically conductive.

13. The plasma processing tool of claim 12, wherein the thermally conductive particles comprise carbon fiber.

14. A thermal interface component for an electrode assembly of a plasma processing tool, the thermal interface component comprising:

a non-silicone polymeric elastomer as a continuous phase; and

thermally conductive particles as a dispersed phase.

15. The thermal interface component of claim 14, wherein the non-silicone polymeric elastomer comprises one or more of an epoxy-based matrix or a fluorocarbon-based matrix.

16. The thermal interface component of claim 15, wherein the thermally conductive particles comprise one or more of boron nitride, carbon fiber, graphite, aluminum oxide, or aluminum nitride.

17. The thermal interface component of claim 14, wherein the thermally conductive particles are electrically insulating.

18. The thermal interface component of claim 14, wherein the thermally conductive particles are electrically conductive.

19. The thermal interface component of claim 14, the thermal interface component is configured to be situated between a gas distribution plate and one or more of an inner electrode and an outer electrode of the electrode assembly, wherein the gas distribution plate comprises a plurality of gas distribution openings, and wherein the one or more thermal interface components comprises a plurality of holes positioned complementary to the gas distribution openings.

20. The thermal interface component of claim 14, wherein the thermal interface component comprises a core layer sandwiched between a first thermal interface component layer and a second thermal interface component layer.