METHOD AND APPARATUS FOR PROVIDING AN ELECTROSTATIC CHUCK WITH REDUCED PLASMA PENETRATION AND ARCING

BACKGROUND OF THE INVENTION

Field of the Invention

[0001] Embodiments of the present invention generally relate to equipment for performing semiconductor device fabrication, and more particularly, to an electrostatic chuck for supporting a semiconductor wafer during processing.

Description of the Related Art

[0002] Electrostatic chucks are widely used for providing support to substrates (also referred to herein as semiconductor wafers or wafers) within semiconductor processing equipment such as a plasma processing chamber. An electrostatic chuck generally holds a substrate in a stationary position during processing of the substrate, i.e., during material deposition or etching. Electrostatic chucks utilize capacitive and Johnsen-Rahbeck attractive forces for holding the substrate in position.

[0003] One type of electrostatic chuck includes a body and a fluid distribution element covered with a layer of a dielectric material thereby forming a support surface. The body is generally conductive such that the body forms an electrode of the electrostatic chuck. A substrate is placed onto the support surface. The fluid distribution element includes a plenum that carries the fluid multiple passages formed in the support surface of the electrostatic chuck for distributing a heat transfer fluid such as a gas between the support surface of the chuck and the backside of the substrate. Generally, the gas fills the interstitial area between the electrostatic chuck and the substrate, thus enhancing the rate and uniformity of heat transfer between electrostatic chuck and the substrate.

[0004] In plasma processing chambers, the electrostatic chuck is subjected to high power radio frequency (RF) fields and high density plasmas in the vicinity of the substrate. In such plasma processing chambers, it is possible to have the gas breakdown due to high electric field generation in the gas passages. The operation

and service life of the electrostatic chuck is adversely affected by plasma formation in the gas passages. Such plasma may damage the substrate, the electrostatic chuck or both. Furthermore, plasma formation in a gas passage can lead to arcing that forms particulate contaminants in the chamber.

[0005] There exist various techniques for reducing the plasma formation in gas passages. One technique includes inserting a porous dielectric plug into the passage at the surface of the chuck. The porosity of the plug is selected to ensure a dimension of the pores inhibits plasma formation, yet allows the heat transfer fluid to reach the substrate support surface. While the porous material provides protection against plasma formation, fabrication of such electrostatic chucks is difficult, time consuming and costly.

[0006] Accordingly, there is a need for an improved electrostatic chuck that reduces plasma formation and arcing.

SUMMARY

[0007] The present invention generally provides a method and apparatus for providing a fluid distribution element for an electrostatic chuck that reduces plasma formation and arcing within heat transfer fluid passages. One embodiment comprises a plate and a dielectric component, where the dielectric component is inserted into the plate. The plate is adapted to be positioned within a channel to define a plenum, wherein the dielectric component provides at least a portion of a fluid passage coupled to the plenum. A porous dielectric layer, formed upon the dielectric component, provides at least another portion of a fluid passage coupled to the plenum. In other embodiments, the fluid distribution element comprises various arrangements of components to define a fluid passage that does not provide a line-of-sight path from the support surface for a substrate to a plenum.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] So that the manner in which the above recited features of the present invention can be understood in detail, a more particular description of the invention, briefly summarized above, may be had by reference to embodiments, some of which are illustrated in the appended drawings. It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are

therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

[0009] Figure 1 illustrates a plasma-based substrate processing system comprising an electrostatic chuck having a fluid distribution element according to various embodiments of the present invention;

[0010] Figure 2 illustrates a top view of the electrostatic chuck of Figure 1;

[0011] Figure 2A illustrates a partial sectional perspective view of a portion of the electrostatic chuck of Fig.2;

[0012] Figure 3 illustrates a cross-sectional view of the electrostatic chuck of Figure 2 along the line 3-3;

[0013] Figure 4 depicts a cross-sectional view of a fluid distribution element of an electrostatic chuck according to one embodiment of the present invention;

[0014] Figure 5 depicts a cross-sectional view of a fluid distribution element of an electrostatic chuck according to another embodiment;

[0015] Figure 6 depicts a cross-sectional view of a fluid distribution element for an electrostatic chuck according to another embodiment;

[0016] Figure 7 depicts a cross-sectional view of a fluid distribution element of an electrostatic chuck according to yet another embodiment of the present invention;

[0017] Figure 8 depicts a cross-sectional view of a fluid distribution element of an electrostatic chuck according to various embodiments of the present invention;

[0018] Figure 9 depicts a cross-sectional view of a fluid distribution element of an electrostatic chuck according to various embodiments of the present invention; and

[0019] Figure 10 depicts a cross-sectional view of a fluid distribution element of an electrostatic chuck according to various embodiments of the present inventions.

[0020] While the invention is described herein by way of example using several embodiments and illustrative drawings, those skilled in the art will recognize that the invention is not limited to the embodiments of drawing or drawings described. It should be understood that the drawings and detailed description thereto are not

intended to limit the invention to the particular form disclosed, but on the contrary, the invention is to cover all modification, equivalents and alternatives falling within the spirit and scope of the present invention as defined by the appended claims. The headings used herein are for organizational purposes only and are not meant to be used to limit the scope of the description or the claims. As used throughout this application, the word "may" is used in a permissive sense (i.e., meaning having the potential to), rather than the mandatory sense (i.e., meaning must). Similarly, the words "include," "including," and "includes" mean including, but not limited to. Further, the words "a" or "an" means "at least one" unless otherwise mentioned.

DETAILED DESCRIPTION

[0021] Figure 1 illustrates a plasma-based substrate processing system 36 comprising an electrostatic chuck 68 according to various embodiments of the present invention. The plasma processing system 36 is used for temperature controlled processing of substrates, such as Silicon wafers, GaAs wafers and the like, while creating and maintaining a plasma environment in which to process the substrates. The plasma is created in the vicinity of the substrate for processing the substrate, and the temperature of the substrate is controlled using various techniques, such as, by supplying a heat transfer fluid to the back surface of the substrate. Although one embodiment of a plasma processing chamber is described illustratively in a high density plasma–chemical vapor deposition (HDP-CVD) system such as the 300mm HDP-CVD Ultima X system available from Applied Materials, Inc. of Santa Clara, Calif., the invention has utility in other process chambers where plasma is used including physical vapor deposition chambers, chemical vapor deposition chambers, etch chambers and other applications where a temperature control of a substrate is desired.

[0022] FIG. 1 illustrates one embodiment of a HDP-CVD system 36, in which an electrostatic chuck 68 is used to secure a substrate during processing. In accordance with embodiments of the present invention, the electrostatic chuck 68 is designed to reduce plasma penetration and arcing proximate the chuck 68.

[0023] The system 36 includes a process chamber 38, a vacuum system 40, a source plasma system 42, a bias plasma system 44, a gas delivery system 46, and a remote plasma cleaning system 48.

[0024] An upper portion of process chamber 38 includes a dome 50, which is made of a dielectric material, such as alumina or aluminum nitride. The dome 50 defines an upper boundary of a plasma processing region 52. The plasma processing region 52 is bounded on the bottom by the upper surface of substrate 54 and the substrate support member 56.

[0025] A heater plate 58 and a cold plate 60 surmount, and are thermally coupled to, the dome 50. The heater plate 58 and the cold plate 60 allow control of the dome temperature to within about +/-10 degree Centigrade over a range of about 100 to 200 degree Centigrade. This allows optimizing the dome temperature for the various processes. For example, it may be desirable to maintain the dome at a higher temperature for cleaning or etching processes than for deposition processes. Accurate control of the dome temperature also reduces the flake or particle counts in the process chamber and improves adhesion between the deposited layer and the substrate.

[0026] The lower portion of process chamber 38 includes a body member 62, which joins the process chamber to the vacuum system. A base portion 64 of the substrate support member 56 is mounted on, and forms a continuous inner surface with, body member 62. Substrates are transferred into and out of process chamber 38 by a robot blade (not shown) through an insertion/removal opening 95 in the side of process chamber 38. A pneumatic actuator (not shown) raises and lowers a lift-pin plate (not shown) that raises and lowers lift pins (not shown) that raise and lower the wafer. Upon transfer into process chamber 38, substrates are loaded onto the raised lift pins, and then lowered to a substrate receiving portion 66 of substrate support member 56. Substrate receiving portion 66 includes an electrostatic chuck 68 that secures the substrate to substrate support member 56 during substrate processing.

[0027] The vacuum system 40 includes a throttle body 70, which houses multi-blade throttle valve 72 and is attached to gate valve 74 and turbomolecular pump 76. It should be noted that throttle body 70 offers minimum obstruction to gas flow, and allows symmetric pumping, as described in co-pending, commonly assigned United States patent application, originally filed on filed Dec. 12, 1995, and assigned Ser. No. 08/574,839, refiled on Sep. 11, 1996 and assigned Ser. No. 08/712,724 entitled "SYMMETRIC CHAMBER". The gate valve 74 can isolate the pump 76 from the throttle body 70, and can also control process chamber pressure by restricting the

exhaust flow capacity when throttle valve 72 is fully open. The arrangement of the throttle valve 72, gate valve 74, and turbo molecular pump 76 allow accurate and stable control of process chamber pressures from about 1 to 100 millitorr.

[0028] The source plasma system 42 includes a top coil 78 and side coil 80, mounted on dome 50. A symmetrical ground shield (not shown) reduces electrical coupling between the coils. Top coil 78 is powered by top RF source generator 82, while the side coil 80 is powered by side RF source generator 84, allowing independent power levels and frequencies of operation for each coil. This dual coil system allows control of the radial ion density in process chamber 38, thereby improving plasma uniformity. Side coil 80 and top coil 78 couple energy into the chamber 38 inductively. In a specific embodiment, the top RF source generator 82 provides up to 8000 W of RF power at nominally 2 MHz and the side RF source generator 84 provides up to 8000 W of RF power at nominally 2 MHz. The operating frequencies of the top and side RF generators may be offset from the nominal operating frequency (e.g., to 1.7 - 1.9 MHz and 1.9 - 2.1 MHz, respectively) to improve plasma-generation efficiency.

[0029] The RF generators 82 and 84 include digitally controlled synthesizers and operate over a frequency range from about 1.7 to about 2.1 MHz. Each generator includes an RF control circuit (not shown) that measures reflected power from the process chamber and coil back to the generator, and adjusts the frequency of operation to obtain the lowest reflected power, as understood by a person of ordinary skill in the art. RF generators are typically designed to operate into a load with a characteristic impedance of 50 ohms. RF power may be reflected from loads that have a different characteristic impedance than the generator. This can reduce power transferred to the load. Additionally, power reflected from the load back to the generator may overload and damage the generator. Because the impedance of a plasma may range from less than 5 ohms to over 900 ohms, depending on the plasma ion density among other factors, and because reflected power may be a function of frequency, adjusting the generator frequency according to the reflected power increases the power transferred from the RF generator to the plasma and protects the generator. Another way to reduce reflected power and improve efficiency is with a matching network.

[0030] Matching networks 89 and 90 match the output impedance of generators 82 and 84 with coils 78 and 80, respectively. The RF control circuit may tune both matching networks by changing the value of capacitors within the matching networks to match the generator to the load as the load changes. The RF control circuit may tune a matching network when the power reflected from the load back to the generator exceeds a certain limit. One way to provide a constant match, and effectively disable the RF control circuit from tuning the matching network, is to set the reflected power limit above any expected value of reflected power. This may help stabilize a plasma under some conditions by holding the matching network constant at its most recent condition.

[0031] The bias plasma system 44 includes a RF bias generator 86 and a bias matching network 88. The bias plasma system 44 capacitively couples substrate receiving portion 66 to the body member 62, which act as complementary electrodes. The bias plasma system 44 serves to enhance the transport of plasma species created by the source plasma system 42 to the surface of the substrate. In a specific embodiment, the RF bias generator 86 provides up to 10000 W of RF power at 13.56 MHz.

[0032] Other measures may also help stabilize a plasma. For example, the RF control circuit can be used to determine the power delivered to the load (plasma) and may increase or decrease the generator output power to keep the delivered power substantially constant during deposition of a layer.

[0033] The gas delivery system 46 includes a plurality of gas sources 100a, 100b, 100c, 100d and 100e. In one embodiment, the aforementioned gas sources comprise of silane, molecular oxygen, helium and argon, respectively. The gas delivery system 46 provides gases from several sources to the process chamber for processing the substrate via gas delivery lines 92 (only some of which are shown). Gases are introduced into the process chamber 38 through a gas ring 94, a top nozzle 96, and a top vent 98. Specifically, gas sources, 100a and 100d, provide gas to top nozzle 96 via flow controllers 120a and 120c, respectively, and gas delivery lines 92. Gas from gas source 100b is provided to gas vent 98 via flow controller 120b. The top nozzle 96 and top vent 98 allow independent control of top and side flows of the gases, which improves film uniformity and allows fine adjustment of the film's deposition and doping parameters. The top vent 98 is an annular opening

around the top nozzle 96 through which gas may flow into the process chamber from the gas delivery system.

[0034] Gas is provided from each of the aforementioned gas sources to gas ring 94 via flow controller 102a, 102b, 102c, 102d and 102e and gas delivery lines 92. Gas ring 94 has a plurality of gas nozzles 106 and 108 (only two of which is shown) that provide a uniform flow of gas over the substrate. Nozzle length and nozzle angle may be changed by changing gas ring 94. This allows tailoring the uniformity profile and gas utilization efficiency for a particular process within an individual process chamber. In a specific embodiment, the gas ring 94 has a total of thirty-six gas nozzles, twenty-four first gas nozzles 108 and twelve second gas nozzles 106. Typically, gas nozzles 108 (only one of which is shown), are coplanar with, and shorter than, the second gas nozzles 106.

[0035] In some embodiments, flammable, toxic, or corrosive gases may be used. In these instances, it may be desirable to eliminate gas remaining in the gas delivery lines after a deposition. This may be accomplished using a three-way valve, such as valve 112, to isolate process chamber 38 from delivery line 92a, and to vent delivery line 92a to vacuum foreline 114, for example. As shown in FIG. 1, other similar valves, such as 112a and 112b, may be incorporated on other gas delivery lines. Such three-way valves may be placed as close to process chamber 38 as practical, to minimize the volume of the unvented gas delivery line (between the three-way valve and the process chamber). Additionally, two-way (on-off) valves (not shown) may be placed between a mass flow controller (MFC) and the process chamber or between a gas source and an MFC.

[0036] The system 36 may further include a remote cleaning RF plasma source (not shown) for providing a cleaning gas to the top nozzle 96 of the chamber 38. In other embodiments, cleaning gas (if used) may enter the chamber 38 at other locations.

[0037] A system controller 132 regulates the operation of system 36 and includes a processor 134 in electrical communication therewith to regulate the operations thereof. Typically, the processor 134 is part of a single-board computer (SBC), that includes analog and digital input/output boards, interface boards and stepper motor controller boards. Various components of the CVD system 36 conform to the Versa Modular European (VME) standard, which defines board, card cage, as well as

connector type and dimensions. The VME standard also defines the bus structure as having a 16-bit data bus and a 24-bit address bus. The processor 134 executes system control software, which is a computer program stored in a memory 136, electronically coupled to the processor 134. Any type of memory device may be employed, such as a hard disk drive, a floppy disk drive, a card rack or a combination thereof. The system control software includes sets of instructions that dictate the timing, mixture of gases, process chamber pressure, process chamber temperature, microwave power levels, pedestal position, and other parameters of a particular process

[0038] Temperature of the substrate 104 and uniformity of the substrate temperature are important processing parameters for processing the substrate 104. To generate a uniform temperature profile, a heat transfer fluid is applied between the chuck 68 and the back surface of the substrate 104. One embodiment of the invention uses, for example, helium as the heat transfer fluid. Generally, the electrostatic chuck 68 is circular in shape, but alternatively, the electrostatic chuck 68 may comprise various regular and irregular geometries to accommodate non-circular substrates, for example, square or rectangular substrate such as flat panels.

[0039] In operation, the substrate 104 is placed on the electrostatic chuck 68 and multiple gaseous components are supplied from gas panel 46 into the processing region 52 of the plasma processing chamber 38 to form a gaseous mixture. To ignite a plasma, RF power is applied to one or more of an electrode in the substrate support member 56, the top coil 78, or side coil 80. To maintain temperature uniformity of the substrate during processing, a heat transfer fluid, such as helium gas, is supplied via at least one fluid distribution element (shown and discussed below) in accordance with the embodiments of the present invention.

[0040] Figure 2 illustrates a top plan view of the electrostatic chuck 68 having the fluid distribution element 222 according to one embodiment of the present invention. Fig. 2A depicts a partial sectional perspective view of the electrostatic chuck 68 of Fig. 2. Figure 3 depicts a cross-sectional view of the chuck 68 of Figure 2 taken along line 3-3. The following disclosure is best understood by simultaneously viewing Figures 2 and 3. The electrostatic chuck 68 comprises a body 220, a fluid distribution element 222, and a dielectric layer 224. In one embodiment of the electrostatic chuck 68, the body 220 is fabricated of a conductive material such as

aluminum and the dielectric layer 224 is a ceramic material such as aluminum-nitride, alumina, and the like. The fluid distribution element 222 is disposed circumferentially near the periphery of the electrostatic chuck 68. The fluid distribution element 222 comprises multiple holes 230 (or other forms of passages) penetrating the dielectric layer 224 for distributing a fluid such as helium gas from the electrostatic chuck to the back surface of the substrate. For the electrostatic chuck 102 used in combination with an 12 inch (300 mm) diameter semiconductor wafer, there are between 60 to 360 holes around the periphery of the electrostatic chuck 102. Each of the multiple holes 230 typically ranges from about 0.15 mm diameter. These dimensions are adjusted depending on the kind of fluid distribution element used, the pressures used within the processing chamber, and the amount of gas flow through the fluid distribution element 222.

[0041] The fluid distribution element 222 has a ring-shaped structure. However, in alternate embodiments, the fluid distribution element 222 may have various geometrical designs as per the need of the processing methods and a user including multiple rings, radial arms, combinations of radials and rings, and so on. The embodiments of the invention do not limit the geometry of the fluid distribution element or elements.

[0042] The dielectric layer 224 covers at least a portion of the top surface of the body 220 and at least a portion of the fluid distribution element 222 thereby forming a support surface 228. The support surface 228 supports the substrate 104 placed thereon. The dielectric layer 224 may be sprayed onto the top surface of the body and polished to a desired thickness.

[0043] The body 220 comprises the top surface 332 and a channel 334 that is formed into top surface 332 of the body 220. Generally, the channel 334 has a rectangular cross-sectional shape. However, in alternate embodiments the channel 334 may have various geometrical cross-sectional shapes. The fluid distribution element 222 is coupled to the body 220 such that the channel 334 and the fluid distribution element 222 form a plenum 336 i.e., the element 222 is positioned into the channel 334 and fixed thereto. Further, the body 220 comprises a conduit 338 connected to the channel 334 for providing fluids to the plenum 336. According to one embodiment of the present invention, the cooling gas may be supplied through the conduit 338 and distributed by the plenum to the fluid distribution element 222.

The gas exits through one or more of the multiple holes 230 (or other forms of passages) thereby supplying a heat transfer medium to the back surface of a substrate.

[0044] Figures 4 to 10 illustrate cross-section views of the dotted line portion 230 of an electrostatic chuck, for example, the electrostatic chuck 102, the portion having a fluid distribution element 222, dielectric layer 228 and the body 220. In the illustrations, the dimensions of the electrostatic chuck have been exaggerated to illustrate the cross-section of the fluid distribution element and the body.

[0045] In particular, Figure 4 illustrates a portion of an electrostatic chuck 402 according to one embodiment of the present invention. The body 220 comprises a dual damascene channel 404 having a lower channel 404A and an upper channel 404B, where the lower channel 404A is narrower than the upper channel 404B. The electrostatic chuck 402 includes a fluid distribution element 422 comprising a plate 440 and a dielectric tube 442. The plate 440 fits into the upper channel 404B (e.g., the plate has a circular plan form to match the channel 404) such that the base 406 of the upper channel 404B forms a stop. The height of the plate 440 is substantially the same as the height of the upper channel 404B such that the top 408 of the plate 440 is substantially coplanar with the top 332 of the body 220. The plate 440 may be fabricated of a conductive material such as aluminum and welded into place in the upper channel 404B. The plate 440 further comprises a channel 410 formed in the bottom surface of the plate 440. In one embodiment of the invention, the width of channel 410 is substantially similar to the width of lower channel 404A; however, in other embodiments, the channel 410 may have a narrower width than lower channel 404A. The combination of the lower channel 404A and the channel 410 defines a plenum 336.

[0046] A dielectric tube 442 (an electrical isolator) comprises a first end 446, a second end 448, and an axial through hole 450. The dielectric tube 442, for example, made of alumina, has a diameter substantially matching the diameter of an opening 444 in the plate 440. The diameter of the opening 444 is generally, but not by way of limitation, about 0.008 inches (about 0.2 mm) or larger. In alternate embodiments, the opening 444 may have various geometrical shapes such as circular, rectangular, square, and the like. Moreover, the shape and size of the opening substantially matches to the shape and size of an outer diameter of the

dielectric tube 442. The dielectric tube 442 is positioned (e.g., press fit) into the opening 444. The opening 444 comprises a flange 412 upon which the tube 442 rests (i.e., the flange forms a stop). In the depicted embodiment, the first end 446 of the tube 442 extends above the surface 332 of the body 220. In other embodiments, the first end 446 of the tube 442 may be coplanar with the surface 332.

[0047] At least a portion of the body 220 and at least a portion of the fluid distribution element 422 are covered by the dielectric layer 224 thereby forming the support surface 428. The dielectric layer 224 may be sprayed onto the top surface of the body and polished to a desired thickness. In one embodiment, the dielectric layer 224 comprises thermally sprayed Alumina or sprayed Alumina/Titania. Processes for application of this thermally sprayed dielectric layer are known in the art. The thermal spraying process can be selected from several different methods such as plasma spraying, detonation gun spraying, high velocity oxygen fuel (HVOF) spraying and flame spraying.

[0048] In one embodiment, the dielectric layer 224 is polished to a thickness represented by line 414 such that the surface 428 of the layer 224 is coplanar with the end 446 of the tube 442. Alternatively, the dielectric layer 224 may be a porous ceramic such that the layer 224 is polished to a specific flatness, but the layer 224 covers at least the first end 446 of the tube 442. Due to the porosity of the ceramic, gas from the plenum flows through the tube 442 and the dielectric layer 224. For example, the dielectric layer 224 proximate the first end 446 of the tube 442 may be wholly or partially formed of alumina with a porosity of between 10 and 60 percent by volume that results in pore diameters of about 1 to 100 um. In some embodiments, as discussed below with respect to Figure 8, the dielectric layer may be porous proximate the end 446 of the tube 442, and less porous elsewhere. As illustrated, the passage 445 advantageously lacks a direct line-of-sight path from the support surface 428 to the plenum 436 thereby limiting the potential for formation of a plasma in the passage 445. In another embodiment, the dielectric layer 224 is polished to a specific flatness with the layer 224 covering the first end 446 of the tube 442. A hole 416 can be bored or otherwise formed (e.g., laser drilling) through the dielectric layer 416 into the passage 445. The boring process only bores

through the dielectric material, i.e., the conductive material of the body is not sputtered by the boring process.

[0049] As known in the art, the support surface 428 may further be processed to provide a pattern of grooves (not shown in the figure) made onto the dielectric layer 224. The grooves are machined or otherwise formed into the support surface 428 so that they intersect with the passage 445. The cooling gas can proceed from passage 445 and into the grooves for distributing the cooling gas uniformly over the entire support surface 428 of electrostatic chuck 402.

[0050] By using an electrical isolator (the dielectric tube and/or the dielectric layer) to define the passage between the plenum and the substrate surface, the possibility for plasma formation from the heat transfer gas or arcing caused by plasma formation is reduced. By reducing or eliminating plasma formation and arcing, the life of an electrostatic chuck is significantly increased. The use of an isolator, reduces the electric fields in the passage; thus, reducing the chance for plasma formation. In addition, certain embodiments of the invention utilize a fluid distribution element structure that further reduces the electric fields in the passage by eliminating a line of sight path between the substrate support surface (where high electric fields exist) and the conductive surface of a plenum. When such a line-of-sight path exists, the volume of fluid in the passage is sufficient to be ignited into a plasma. Using a non-line-of-sight path reduces the electric fields that are established across sufficiently large volumes of fluid that might result in plasma formation. As such, plasma formation and associated arcing are reduced or eliminated.

[0051] Figure 5 illustrates a cross-section of a portion an electrostatic chuck 502 according to another embodiment of the present invention. Similar to the embodiment of Figure 4, a dielectric tube 542 is positioned through the plate 440. In this alternative embodiment, the tube 542 extends to the bottom of the channel 534 where a second end 548 of the tube 542 rests upon a supporting element (e.g., a step 556) formed in the bottom of the channel 534. As in the previous embodiment, the dielectric tube 542 and/or the portion of dielectric layer 224 forms an electrical isolator that defines a passage 545 for the fluid from a plenum 536 to the surface 528.

[0052] Figure 6 illustrates a cross-section of a portion the electrostatic chuck 602 according to another embodiment of the present invention. Similar to the embodiments of Figures 4 and 5, a dielectric tube 642 is positioned through the plate 440. In this alternative embodiment, the dielectric tube 642 comprises at least one notch 656 formed in the second end 604. In an alternative embodiment, the tube 642 may comprise holes to facilitate fluid flow from the plenum 636 to a passage 645 in the tube 642. As with prior embodiments, the dielectric layer 224 may be porous and cover a first end 606 of the tube 642, the layer 224 may be polished to expose the first end end 606 of tube 642, or a hole formed in the layer to access the passage 645. The dielectric tube 642 and the portion of dielectric layer 224 forms a passage 645 for the fluid from a plenum 636. As illustrated, when the dielectric layer 224 is porous and covers the tube 642, the passage 645 advantageously lacks a direct line-of-sight path from the support surface 628 to the plenum 636 thereby limiting formation of a plasma in the passage 645.

[0053] Figure 7 illustrates a cross-section of a portion of an electrostatic chuck 702 according to yet another embodiment of the present invention. The electrostatic chuck 702 comprises a body 720 and fluid distribution element 722. The fluid distribution element 722 comprises a plate 740 and a dielectric tube 742 that are assembled in the same manner as the previous embodiments. In this embodiment, the body 720 comprises a channel 734 comprising a dielectric end cap 760. The dielectric end cap 760 is positioned at the bottom of the channel 734. The dielectric end cap 760 comprises an opening 762 such that the cap 760 is cup shaped. The dielectric tube 742 comprises a first end 746, a second end 748, and an axial through hole 750 connecting the first end 746 and the second end 748. In one embodiment of the invention, the dielectric layer 724 covers the first end 746 of the tube 742 and, in a second embodiment, the dielectric layer 724 is polished to line 414 to expose the first end 746 of the tube 742. The dielectric cap 760 is positioned into the channel 734 such that the second end 748 of the tube 742 extends into the opening 762, but is spaced apart therefrom to form a gap. The tube 742 and the end cap 760 form a labyrinth channel through which the fluid flows. Using such a channel ensures that a line-of-sight path from the conductive plenum walls to the chuck surface does not exist.

[0054] Figure 8 illustrates a cross-section of a portion an electrostatic chuck 802 according to another embodiment of the present invention. The electrostatic chuck 802 comprises a fluid distribution element 822. The fluid distribution element 822 comprises a plate 840 comprising an opening 844. The plate 840 is coupled to a body 820 such that a channel 834 and the plate 840 form a plenum 836. A dielectric layer 824 covers at least a portion of the body 820 and at least a portion of the fluid distribution element 822. The dielectric layer 824 comprises a porous dielectric segment 870 such that at least a portion of the porous dielectric segment 870 overlaps the opening 844. The porous dielectric segment 870 is a porous ceramic, such as alumina having a porosity ranging from about 10% in volume to about 60% in volume, with interconnected openings that form continuous passageways through the porous dielectric segment 870. The opening 844 and at least a portion of the porous dielectric segment 870 form a passage 845 for the fluid to flow from the plenum 836 to the support surface 828 of the electrostatic chuck 802. As illustrated, the passage 845 advantageously lacks direct line-of-sight path from the support surface 828 to the conductive plenum 836 thereby inhibiting formation of a plasma into the passage 845.

[0055] Figure 9 illustrates a cross-section of a portion an electrostatic chuck 902 according to another embodiment of the present invention. The electrostatic chuck 902 comprises a fluid distribution element 922. The fluid distribution element 922 comprises a plate 940 having an opening 944 and a dielectric plug 980. The plate 940 is coupled to a body 920 such that a channel 934 and the plate 940 form a plenum 936. The plate 940 and body 920 are assembled as discussed above with respect to the other embodiments of the invention. Diameter of the dielectric plug 980 substantially matches with the diameter of the opening 944. The dielectric plug 980 is positioned in the opening 1044 and generally press fit therein. The dielectric layer 224 covers at least a portion of the body 920 and at least a portion of the fluid distribution element 922 thereby forming a support surface 928. The dielectric layer 224 may be sprayed onto the top surface of the body 920 and the fluid distribution element 922, and polished to a desired thickness. A hole 982 is formed through the dielectric layer 224 and through the dielectric plug 980. The hole 982 enables flow of the fluid from the plenum 936 to the support surface 928 of the electrostatic chuck 902. The hole 982 may be formed using various techniques such as mechanical drilling, laser drilling and the like. The hole 982 is formed through only dielectric

material. As such, no metallic residue from the drilling process can form on the axial through hole 982. Without such metallic residue, the possibility of plasma formation or arcing in the hold 982 is limited.

[0056] Figure 10 illustrates a cross-section of a portion an electrostatic chuck 1002 according to another embodiment of the present invention. The electrostatic chuck 1002 comprises a fluid distribution element 1022. The fluid distribution element 1022 comprises a plate 1040 and a dielectric cap 1042. The plate 1040 comprises two circular rings 1040A and 1040B. The ring 1040A has a smaller diameter than ring 1040B. Each ring 1040A and 1040B rests upon the ledge 406 formed at the bottom of the upper channel 404B. The plate 1040 is welded to the body 1020 to retain the plate in the upper channel 404B. The dielectric cap 1042 (ring shaped to form the plenum 1036) is inserted into the upper channel 404B and rests upon the plate 1040.

[0057] In another embodiment, the plate 1040 may comprise an inverted U-shaped cross-section (e.g., the plate 440 of Fig. 4) having a plurality of counter-sunk holes. A circular (donut-shaped) dielectric element having a cross-section similar to the element 1042 may be inserted into such a counter-sunk hole. The fluid distribution element 1022 is coupled to a body 1020 such that the fluid distribution element 1022 and a channel 1034 form a plenum 1036. The dielectric layer 224 covers at least a portion of the body 1020 and at least a portion of the fluid distribution element 1022, thereby forming a support surface 1028. The dielectric layer 224 may be sprayed onto the top surface of the body 1020 and the fluid distribution element 1022 and polished to a desired thickness. A hole 1082 is formed through the dielectric layer 224 and the dielectric cap 1090. The hole 1082 may be drilled using various techniques such as mechanical drilling, laser drilling and the like. As with the embodiment of Figure 9, the hole 1082 is formed through dielectric material only. As such, no conductive residue remains in the hole 1082.

[0058] In each of the foregoing embodiments, in the unlikely occurrence that an electrostatic chuck utilizing the inventive fluid distribution element(s) is damaged by plasma formation or arcing, the chuck can be easily repaired (or refurbished) using a number of methods. Generally, a damaging plasma formation or arcing will occur proximate or within a dielectric component (tube, porous insert, and the like). As such, the dielectric layer can be removed locally (over the dielectric component) or

globally (across the entire chuck) to expose the dielectric component. The component can then be removed using an extraction tool to drill out or pull out the component. Once removed, a new dielectric component can be inserted and the dielectric layer replaced either locally or globally as needed. In some embodiments, the dielectric component may extend to the support surface of the chuck (as discussed above) and not require removal of the dielectric layer before extraction. In those situation, the damaged dielectric component is removed and a new dielectric component is inserted (generally press fit) into the opening in the plate. In this manner, an electrostatic chuck can be repaired at substantial savings when compared to replacing an entire electrostatic chuck upon arcing or plasma formation in or near the heat transfer fluid passages.

[0059] While the foregoing is directed to embodiments of the present invention, other and further embodiments of the invention may be devised without departing from the basic scope thereof, and the scope thereof is determined by the claims that follow.

What is claimed is:

1. A method for refurbishing at least a portion of an electrostatic chuck comprising:

removing a first dielectric component from a fluid distribution element of the electrostatic chuck; and

replacing the first dielectric component with a second dielectric component.

2. The method of claim 1, further comprising:

removing at least a portion of a dielectric layer to expose the first dielectric component; and

replacing the removed at least a portion of the dielectric layer with a new at least a portion of the dielectric layer after replacing the first dielectric component with the second dielectric component.

3. The method of any of claims 1-2, wherein the second dielectric component is press fit into an opening in the fluid distribution element.

4. The method of any of claims 1-2, wherein at least one of the first or second dielectric components comprise a tube.

5. The method of any of claims 1-2, wherein at least one of the first or second dielectric components comprise a porous plug.

6. The method of any of claims 1-2, wherein at least one of the first or second dielectric components comprise a ceramic.

7. The method of claim 6, wherein the ceramic comprises alumina.

8. The method of any of claims 1-2, wherein the removing step comprises drilling the first dielectric component.

9. The method of claim 2, further comprising polishing the replaced dielectric layer.

10. An electrostatic chuck comprising:

a body comprising a channel;

a plate comprising an opening, the plate adapted to be coupled to the channel to form a plenum;

a dielectric component positioned in the opening to define at least a portion of a fluid passage from the plenum;

a dielectric layer covering at least a portion of the body and at least a portion of the plate to form a substrate support surface; and

a porous dielectric layer covering the dielectric component to form a portion of the fluid passage.

11. The electrostatic chuck of claim 10, wherein the fluid passage does not form a line-of-sight path from the plenum to the substrate support surface.

12. The electrostatic chuck of claim 10, wherein the dielectric component is a dielectric tube comprising a first end, a second end, and an axial through hole, wherein the dielectric tube is positioned into the opening in the plate, and wherein the dielectric layer covers at least a portion of the first end of the dielectric tube and the axial through hole and the at least a portion of the dielectric layer form the fluid passage.

13. An apparatus for processing semiconductor substrates, comprising:

a chamber defining a process region; and

an electrostatic chuck as described in any of claims 10-12 for retaining a semiconductor substrate in the process region.

14. A method of making an electrostatic chuck, comprising:

positioning a plate into a channel in a body to form a plenum;

inserting a dielectric component into an opening in the plate, where the dielectric component defines a portion of a passage from the plenum;

depositing a dielectric layer covering at least a portion of the body and at least a portion of the plate to form a support surface;

polishing the dielectric layer to a specified thickness; and

forming an opening through the dielectric layer and the dielectric component to define a passage between the support surface and the plenum.

15. The method of claim 14, wherein the dielectric component comprises a dielectric tube comprising a first end, a second end and an axial through hole connecting the first end and the second end; and either

positioning an end cap within the channel, wherein the second end of the dielectric tube extends inside the dielectric end cap while being spaced apart therefrom to form a gap, wherein the gap and the through hole form the passage; or

positioning the dielectric tube into the opening and covering at least a portion of the first end with the dielectric layer, wherein the axial through hole and at least a portion of the dielectric layer form the passage.