SILICON CARBIDE FOCUS RING FOR PLASMA ETCHING SYSTEM

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ABSTRACT

A high resistivity silicon carbide focus ring for use in a plasma etching system is described. The focus ring comprises an upper surface, a lower surface, an inner radial edge, and an outer radial edge, and is configured to surround a substrate on a substrate holder in a plasma processing system. The focus ring comprises high resistivity silicon carbide having a resistivity greater than or equal to about 100 ohm-cm.
500

FORMING A FILM STACK ON A SUBSTRATE, THE FILM STACK COMPRISING A RADIATION SENSITIVE LAYER, AN ARC LAYER, A HARD MASK LAYER, AND A POLYSILICON LAYER

510

FORMING A PATTERN IN THE RADIATION SENSITIVE LAYER

520

TRIMMING A LATERAL DIMENSION IN THE PATTERN

530

TRANSFERRING THE TRIMMED PATTERN TO THE ARC LAYER

540

TRANSFERRING THE TRIMMED PATTERN TO THE HARD MASK LAYER

550

TRANSFERRING THE TRIMMED PATTERN TO THE POLYSILICON LAYER

560

FIG. 4
SILICON CARBIDE FOCUS RING FOR PLASMA ETCHING SYSTEM

BACKGROUND OF THE INVENTION

[0001] Field of Invention

The invention relates to a focus ring for use in a plasma processing system and, more particularly, to a high resistivity silicon carbide focus ring for use in a plasma etching system.

[0002] Description of Related Art

The fabrication of integrated circuits (IC) in the semiconductor industry typically employs plasma to create and assist surface chemistry within a vacuum processing system necessary to remove material from and deposit material to a substrate. In general, plasma is formed within the processing system under vacuum conditions by heating electrons to energies sufficient to sustain or replaceable components are considered part of the process kit, which is frequently maintained during system cleaning.

SUMMARY OF THE INVENTION

The invention relates to a focus ring for use in a plasma processing system and, more particularly, to a high resistivity silicon carbide focus ring for use in a plasma etching system.

According to one embodiment, a high resistivity silicon carbide focus ring for use in a plasma etching system is described. The focus ring comprises an upper surface, a lower surface, an inner radial edge, and an outer radial edge, and is configured to surround a substrate on a substrate holder in a plasma processing system. The focus ring comprises high resistivity silicon carbide having a resistivity greater than or equal to about 100 ohm-cm.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. 1 provides a schematic illustration of a plasma processing system according to an embodiment;

FIG. 2A shows a top view of a focus ring according to an embodiment;

FIG. 2B shows a cross-sectional view of the focus ring depicted in FIG. 2A;

FIG. 3A presents exemplary data for processing a substrate;

FIG. 3B presents additional exemplary data for processing a substrate; and

FIG. 4 illustrates a method of processing a substrate according to an embodiment.

DETAILED DESCRIPTION OF SEVERAL EMBODIMENTS

A focus ring for use in a plasma processing system is disclosed in various embodiments. However, one skilled in the relevant art will recognize that the various embodiments may be practiced without one or more of the specific details, or with other replacement and/or additional methods, materials, or components. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obscuring aspects of various embodiments of the invention. Similarly, for purposes of explanation, specific numbers, materials, and configurations are set forth in order to provide a thorough understanding of the invention. Nevertheless, the invention may be practiced without specific details. Furthermore, it is understood that the various embodiments shown in the figures are illustrative representations and are not necessarily drawn to scale.

Reference throughout this specification to “one embodiment” or “an embodiment” means that a particular feature, structure, material, or characteristic described in connection with the embodiment is included in at least one embodiment of the invention, but do not denote that they are present in every embodiment. Thus, the appearances of the phrases “in one embodiment” or “in an embodiment” in various places throughout this specification are not necessarily referring to the same embodiment of the invention. Furthermore, the particular features, structures, materials, or characteristics may be combined in any suitable manner in one or more embodiments. Various additional layers and/or structures may be included and/or described features may be omitted in other embodiments.

In material processing methodologies, pattern etching comprises the application of a thin layer of radiation sensitive material, such as photoresist, to an upper surface of a substrate, that is subsequently patterned in order to provide a mask for transferring this feature pattern to the underlying thin film during etching. The patterning of the radiation-sensitive material generally involves exposure of the lithographic layer to a geometric pattern of electromagnetic (EM) radiation using, for example, a micro-lithography system, followed by the removal of the irradiated regions of the radiation-sensitive material (as in the case of positive photoresist), or non-irradiated regions (as in the case of negative photoresist) using a developing solvent.
In plasma processing, a focus ring can, for example, be configured to surround a substrate on a substrate holder, and be employed to adjust and/or control the properties of the process chemistry local to the peripheral edge of the substrate. For conventional plasma processing systems, the focus ring comprises a ring of silicon, for instance for oxide etching, that rests atop the substrate holder and surrounds the substrate periphery. For other conventional plasma processing systems, the focus ring comprises a ring of quartz, for instance for silicon etching, that rests atop the substrate holder and surrounds the substrate periphery. However, the inventors have observed that focus rings prepared from conventional materials have caused non-uniform plasma processing of the substrate. For example, the critical dimension (CD) bias has been observed to vary across the substrate, which may be unacceptable due to loss in device yield.

Therefore, according to an embodiment, a high resistivity silicon carbide focus ring for use in a plasma etching system is described. The focus ring comprises an upper surface, a lower surface, an inner radial edge, and an outer radial edge, and is configured to surround a substrate on a substrate holder in a plasma processing system. The focus ring comprises high resistivity silicon carbide having a resistivity greater than or equal to about 100 ohm-cm.

According to an embodiment, a plasma processing system 1 is depicted in FIG. 1 comprising a plasma processing chamber 10, an upper assembly 20, an electrode plate assembly 24, a substrate holder 30, and a substrate transfer system 40 coupled to a vacuum pump (not shown) for providing a reduced pressure atmosphere 11 in plasma processing chamber 10. Plasma processing chamber 10 can facilitate the formation of a processing plasma in process space 12 adjacent substrate 35. The plasma processing system 1 can be configured to process substrates of any size, such as 200 mm substrates, 300 mm substrates, or larger. For example, the plasma processing system 1 may comprise a plasma etching system.

In the illustrated embodiment, electrode plate assembly 24 comprises an electrode plate 26 (FIG. 1) and an electrode 28 (FIG. 1). In an alternate embodiment, upper assembly 20 can comprise at least one of a cover, a gas injection assembly, and an upper electrode impedance match network. The electrode plate assembly 24 can be coupled to a source of radio frequency (RF) energy, such as an RF generator. In another alternate embodiment, the upper assembly 20 comprises a cover coupled to the electrode plate assembly 24, wherein the electrode plate assembly 24 is maintained at an electrical potential equivalent to that of the plasma processing chamber 10. For example, the plasma processing chamber 10, the upper assembly 20, and the electrode plate assembly 24 can be electrically connected to ground potential.

Plasma processing chamber 10 may further comprise an optical viewport 16 coupled to a deposition shield 14. Optical viewport 16 may comprise an optical window 17 coupled to the backside of an optical window deposition shield 18, and an optical window flange 19 may be configured to couple optical window 17 to the optical window deposition shield 18. Sealing members, such as O-rings, can be provided between the optical window flange 19 and the optical window 17, between the optical window 17 and the optical window deposition shield 18, and between the optical window deposition shield 18 and the plasma processing chamber 10. Optical viewport 16 can permit monitoring of optical emission from the processing plasma in process space 12.

Substrate holder 30 may further comprise a vertical translational device 50 surrounded by a bellows 52 coupled to the substrate holder 30 and the plasma processing chamber 10, and configured to seal the vertical translational device 50 from the reduced pressure atmosphere 11 in plasma processing chamber 10. Additionally, a bellows shield 54 may be coupled to the substrate holder 30 and configured to protect the bellows 52 from the processing plasma. Substrate holder 30 further comprises a focus ring 60, and may optionally comprise a shield ring 62. Furthermore, a baffle plate 64 can extend about a periphery of the substrate holder 30. The focus ring 60 comprises high resistivity silicon carbide having a resistivity greater than or equal to about 100 ohm-cm.

Substrate 35 can be transferred into and out of plasma processing chamber 10 through a slot valve (not shown) and chamber feed-through (not shown) via robotic substrate transfer system where it is received by substrate lift pins (not shown) housed within substrate holder 30 and mechanically translated by devices housed therein. Once substrate 35 is received from substrate transfer system, it is lowered to an upper surface of substrate holder 30.

Substrate 35 may be affixed to the substrate holder 30 via a mechanical clamping system or an electrical clamping system, such as an electrostatic clamping system. Furthermore, substrate holder 30 may further include a cooling system including a re-circulating coolant flow that receives heat from substrate holder 30 and transfers heat to a heat exchanger system (not shown), or when heating, transfers heat from the heat exchanger system. Moreover, gas may be delivered to the back-side of substrate 35 via a backside gas system (not shown) to improve the gas-gap thermal conductance between substrate 35 and substrate holder 30. Such a system may be utilized when temperature control of the substrate is required at elevated or reduced temperatures. In other embodiments, heating elements, such as resistive heating elements, or thermoelectric heaters/coolers may be included.

In the illustrated embodiment shown in FIG. 1, substrate holder 30 may comprise an electrode through which RF power is coupled to the processing plasma in process space 12. For example, substrate holder 30 can be electrically biased at an RF voltage via the transmission of RF power from a RF generator (not shown) through an impedance match network (not shown) to substrate holder 30. The RF bias may serve to heat electrons to form and maintain plasma. In this configuration, the system can operate as a reactive ion etch (RIE) reactor, wherein the chamber and upper gas injection electrode serve as ground surfaces. A typical frequency for the RF bias can range from about 1 MHz to about 100 MHz, for example, about 13.56 MHz. RF systems for plasma processing are well known to those skilled in the art.

Alternately, the processing plasma in process space 12 can be formed using a parallel-plate, capacitively coupled plasma (CCP) source, an inductively coupled plasma (ICP) source, any combination thereof, and with and without magnet systems. Alternately, the processing plasma in process space 12 can be formed using electron cyclotron resonance (ECR). In yet another embodiment, the processing plasma in process space 12 is formed from the launching of a Helicon wave. In yet another embodiment, the processing plasma in process space 12 is formed from a propagating surface wave.

Referring now to an illustrated embodiment depicted in FIG. 2A (top plan view) and FIG. 2B (cross sectional view), a focus ring 600 is described. The focus ring...
600 can form a ring comprising an upper surface 603, a lower surface 604, an inner radial edge 601, and an outer radial edge 602.

The focus ring 600 comprises high resistivity silicon carbide having a resistivity greater than or equal to about 100 ohm-cm. Additionally, the resistivity of the silicon carbide may be greater than or equal to 1000 ohm-cm. Additionally yet, the resistivity of the silicon carbide may range from about 100 ohm-cm to about 10^5 ohm-cm.

The focus ring 600 comprises high resistivity silicon carbide having a resistivity greater than or equal to about 100 ohm-cm at a temperature ranging from about 50 degrees C. to about 200 degrees C. For example, the temperature may be about 150 degrees C. Additionally, the resistivity of the silicon carbide may be greater than or equal to 1000 ohm-cm at a temperature ranging from about 50 degrees C. to about 200 degrees C. (for example, the temperature may be about 150 degrees C.). Additionally, yet, the resistivity of the silicon carbide may range from about 100 ohm-cm to about 10^5 ohm-cm at a temperature ranging from about 50 degrees C. to about 200 degrees C. (for example, the temperature may be about 150 degrees C.). Low resistivity silicon carbide may be considered to comprise a resistivity of less than about 10 ohm-cm at a temperature of about 150 degrees C.

Focus ring 600 may comprise high resistivity silicon carbide. Alternatively, focus ring 600 may consist essentially of high resistivity silicon carbide. Alternatively yet, focus ring 600 may consist of high resistivity silicon carbide.

Focus ring 600 may comprise vapor deposited high resistivity silicon carbide. For example, focus ring 600 may comprise chemical vapor deposited high resistivity silicon carbide. Alternatively, focus ring 600 may comprise sintered high resistivity silicon carbide. The manufacture of focus ring 600 may further comprise machining, milling, planarizing, grinding, polishing, coating, laser cutting, water-jet cutting, etc.

Focus ring 600 may comprise a plurality of layers, wherein at least one of the plurality of layers comprises high resistivity silicon carbide. Additionally, focus ring 600 may comprise a coating applied to at least one of the upper surface 603, the lower surface 604, the inner radial edge 601, and the outer radial edge 602. The coating may comprise a silicon-containing coating or a ceramic coating. For example, the coating may comprise a vapor deposited coating or a spray coating. Additionally, the coating may include at least one of a III-V element and a Lanthanum element, for example. The coating may comprise at least one of Al_2O_3, Y_2O_3, Sc_2O_3, Sc_3F_5, YF_3, La_2O_3, CeO_2, Eu_2O_3, and DyO_2. Methods of applying spray coatings are well known to those skilled in the art of surface material treatment.

Focus ring 600 can have a thickness ranging from about 0.5 to about 10 mm. Alternatively, the thickness can range from about 1 to about 5 mm, or the thickness can be approximately 1 mm.

Focus ring 600 may comprise a centering feature configured to center the focus ring 600 on the substrate holder. For example, the centering feature may comprise a flat or a notch formed in the outer radial edge 602 that is configured to mate with a similar feature formed in the substrate holder. Furthermore, as illustrated in FIG. 2B, focus ring 600 may comprise a step 610 formed in the inner radial edge 601, and configured to mate in close proximity with substrate 625.

Focus ring 600 may further comprise one or more wear indicators coupled to at least one of the upper surface 603 or the lower surface 604. For example, the one or more wear indicators may comprise a blind hole formed in the upper surface 603 and extending to a depth from the upper surface 603. The depth may comprise a fraction of the distance between the upper surface 603 and the lower surface 604. Additionally, for example, one or more wear indicators may comprise a blind hole formed in the lower surface 604 and extending to a depth from the lower surface 604. The depth may comprise a fraction of the distance between the upper surface 603 and the lower surface 604. Each wear indicator may have a constant length and width. Alternatively, each wear indicator may have a different length, and/or different width. Alternatively yet, each wear indicator may comprise a variable width along its length. As the focus ring 600 erodes, the size of the blind hole varies.

Visual inspection may be utilized to determine the extent of erosion for focus ring 600. For example, this observation can be made from run-to-run, while monitoring the focus ring 600 through an optical window, such as the optical window 17 in FIG. 1.

Additionally, each wear indicator may be placed at different radial locations on the focus ring 600 in order to observe radial variations in the consumption of the focus ring 600. Alternatively, each wear indicator may be placed at different azimuthal locations on the focus ring 600 in order to observe azimuthal variations in the consumption of the focus ring 600. A wear indicator may have a length ranging from about 1 mm to about 5 mm. Alternatively, the length may range from about 0.25 mm to about 1 mm, or the length may be approximately 0.5 mm. Alternatively, a wear indicator may be a fraction of the thickness of focus ring 600 within a fractional range from about 10% to about 90%. Alternatively, the fraction of the focus ring thickness can have a fractional range from about 25 to about 75%, or the fraction of the focus ring thickness can be approximately 50%. The one or more wear indicators may, for example, be fabricated using at least one of machining, etching, laser-milling, and sonic-milling.

Referring now to FIG. 4, an exemplary method for performing a pattern transfer process is presented. The method includes a flow chart 500 beginning in 510 with forming a film stack on a substrate. The film stack may comprise a polysilicon layer, a hard mask layer formed on the polysilicon (polycrystalline silicon) layer, an anti-reflective coating (ARC) layer formed on the hard mask layer, and a radiation sensitive layer formed on the ARC layer. For example, the film stack may facilitate the formation of a gate stack.

In 520, a pattern is formed in the radiation sensitive mask layer using a lithographic process. The radiation sensitive mask layer may include a resist. For example, the resist may comprise 248 nm (nanometer) resists, 193 nm resists, 157 nm resists, EUV (extreme ultraviolet) resists, or electron sensitive resists. The radiation sensitive layer may be formed using a track system. For example, the track system can comprise a Clean Track ACT 8, ACT 12, or Lithium resist coating and developing system commercially available from Tokyo Electron Limited (TEL). Other systems and methods for forming a photo-resist film on a substrate are well known to those skilled in the art of spin-on resist technology. The exposure to electromagnetic (EM) radiation may be performed in a dry or wet photo-lithography system, or an electron beam lithography system.

In 530, a lateral dimension of the radiation sensitive mask layer is optionally trimmed. The trimming process may comprise an etching process, such as a dry etching process or a wet etching process. The dry etching process may include a dry plasma etching process or a dry non-plasma etching process. For example, the trimming process may include trimming the pattern by introducing a process gas including as incipient ingredients a fluorocarbon gas and an oxygen-con-
taining gas, forming plasma from the process gas, and exposing the substrate to the plasma.

**[0042]** In 540, the trimmed pattern is transferred to the ARC layer. The pattern transfer process may comprise a first etching process, such as a dry etching process or a wet etching process. The dry etching process may include a dry plasma etching process or a dry non-plasma etching process. For example, the first etching process may include introducing a process gas including as incipient ingredients a fluorocarbon gas and an oxygen-containing gas, forming plasma from the process gas, and exposing the substrate to the plasma. The first etching process for transferring the trimmed pattern to the ARC layer may be performed simultaneously with trimming the pattern. Furthermore, following the transferring of the trimmed pattern to the ARC layer, an over-etch process on the ARC layer may optionally be performed.

**[0043]** In 550, the trimmed pattern is transferred to the hard mask layer using a second etching process, such as a dry etching process or a wet etching process. The dry etching process may include a dry plasma etching process or a dry non-plasma etching process. For example, the second etching process may include introducing a process gas including as incipient ingredients one or more fluorocarbon gases, forming plasma from the process gas, and exposing the substrate to the plasma.

**[0044]** In 560, the trimmed pattern is transferred to the polysilicon layer using a third etching process, such as a dry etching process or a wet etching process. The dry etching process may include a dry plasma etching process or a dry non-plasma etching process. For example, the third etching process may comprise one or more etching steps using a halogen-containing plasma chemistry, such as a HBr-containing plasma chemistry. The one or more etch steps may include a first main etch step, a second main etch step, and an overetch step.

**[0045]** The trimming process, the first etching process, the second etching process, the third etching process, and the over-etch process(es) may be performed in a plasma processing system. The plasma processing system may comprise various elements, such as described in FIG. 1.

**[0046]** In one embodiment, a method of performing a pattern transfer process on a substrate with reduced variability in process performance across the substrate is provided. For example, a process parameter space for a series of process steps can comprise a chamber pressure of about 1 to about 1000 mtorr (1 torr) (e.g., about 10 mtorr to about 150 mtorr), a process gas flow rate ranging from about 1 to about 1000 sccm, an upper electrode RF bias ranging from about 0 to about 2000 W, and a lower electrode RF bias ranging from about 10 to about 2000 W. Also, the upper electrode bias frequency can range from about 0.1 MHz to about 200 MHz, e.g., 60 MHz. In addition, the lower electrode bias frequency can range from about 0.1 MHz to about 100 MHz, e.g., 2 MHz.

**[0047]** According to an example, a method of reducing critical dimension (CD) bias variability in a pattern transfer process is presented. The process steps and parameters are provided in Table 1 for a quartz (QTZ) focus ring (F/R) having a low resistivity silicon carbide base layer. Furthermore, the process steps and parameters are provided in Table 2 for a high resistivity (H.R.) silicon carbide (SiC) F/R.

**[0048]** Table 1 and Table 2 provide process conditions for the pattern transfer process, including a trim/ARC pattern transfer step (e.g., 530 and 540 in FIG. 8), an ARC over-etch step, a hard mask pattern transfer step (e.g., 550 in FIG. 8), and a polysilicon pattern transfer step (e.g., 560 in FIG. 8). The polysilicon pattern transfer step includes a first polysilicon etch step, a second polysilicon etch step, and an overetch step. For each step, the pressure (P, mtorr), the RF power (coupled to the upper electrode, UEL, and the lower electrode, LEI, in watts, W), the flow rate (standard cubic centimeters per minute, sccm) for each process ingredient, the center (C) and edge (E) substrate backside pressures (B.P.) (torr), and the temperature setting for the UEL (T), chamber wall (W), substrate holder center (B) and edge (Edge) are provided.

### Table 1

<table>
<thead>
<tr>
<th>PROCESS STEP</th>
<th>P</th>
<th>UEL/LEI</th>
<th>SCCM</th>
<th>B.P. (C/E)</th>
<th>TEMP T/W/B (deg. C.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIM/ARC PATTERN TRANSFER</td>
<td>12</td>
<td>300/0</td>
<td>12</td>
<td>48</td>
<td>10/50</td>
</tr>
<tr>
<td>ARC OVER-ETCH</td>
<td>20</td>
<td>300/65</td>
<td>2.5</td>
<td>70</td>
<td>50/100/60/53</td>
</tr>
<tr>
<td>HARD MASK PATTERN TRANSFER</td>
<td>15</td>
<td>500/160</td>
<td>75</td>
<td>20</td>
<td>10/50</td>
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<tr>
<td>POLYSILICON ETCH STEP 1</td>
<td>20</td>
<td>600/100</td>
<td>550</td>
<td>4</td>
<td>10/10/60/53</td>
</tr>
<tr>
<td>POLYSILICON ETCH STEP 2</td>
<td>10</td>
<td>300/30</td>
<td>250</td>
<td>4</td>
<td>10/10/60/53</td>
</tr>
<tr>
<td>POLYSILICON OVER-ETCH</td>
<td>40</td>
<td>135/45</td>
<td>500</td>
<td>9</td>
<td>10/10/60/53</td>
</tr>
<tr>
<td>O2 FLASH</td>
<td>15</td>
<td>375/0</td>
<td>200</td>
<td></td>
<td>3/3</td>
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### Table 2

<table>
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<tr>
<th>PROCESS STEP</th>
<th>P</th>
<th>UEL/LEI</th>
<th>SCCM</th>
<th>B.P. (C/E)</th>
<th>TEMP T/W/B (deg. C.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TRIM/ARC PATTERN TRANSFER</td>
<td>12</td>
<td>300/0</td>
<td>12</td>
<td>48</td>
<td>10/50</td>
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<tr>
<td>ARC OVER-ETCH</td>
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<td>300/65</td>
<td>2.5</td>
<td>70</td>
<td>50/100/60/65</td>
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<tr>
<td>HARD MASK PATTERN TRANSFER</td>
<td>15</td>
<td>500/160</td>
<td>75</td>
<td>20</td>
<td>10/50</td>
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TABLE 2-continued

<table>
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<tr>
<th>PROCESS STEP</th>
<th>POWER (W)</th>
<th>HBr</th>
<th>O₂</th>
<th>CF₄</th>
<th>C₂F₆</th>
<th>CH₂F₂</th>
<th>He</th>
<th>N₂</th>
<th>TEMP T/WB (deg. C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>POLYSILICON ETCH STEP 1</td>
<td>20</td>
<td>600</td>
<td>100</td>
<td>550</td>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td>10/10</td>
</tr>
<tr>
<td>POLYSILICON ETCH STEP 2</td>
<td>10</td>
<td>300</td>
<td>30</td>
<td>250</td>
<td>4</td>
<td></td>
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<td>10/10</td>
</tr>
<tr>
<td>POLYSILICON OVER-ETCH</td>
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<td>45</td>
<td>500</td>
<td>9</td>
<td></td>
<td></td>
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<td></td>
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<td></td>
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<td>3/3</td>
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</tbody>
</table>

[0049] The pattern transfer process, illustrated in Table 1 and Table 2, is conducted with a quartz F/R and a H.R. SiC F/R, respectively. The CD bias (i.e., difference between the initial CD and the final CD) is approximately the same for both F/Rs. For example, with a quartz F/R, the CD bias is 25.6 nm (3σ=3.5 nm) for dense structures (e.g., closely spaced structures) and the CD bias is 25.5 nm (3σ=3.2 nm) for isolated structures (e.g., widely spaced structures). Additionally, for example, with a H.R. SiC F/R, the CD bias is 26.9 nm (3σ=2.6 nm) for dense structures (e.g., closely spaced structures) and the CD bias is 26.4 nm (3σ=3.0 nm) for isolated structures (e.g., widely spaced structures).

[0050] However, the variation in the CD bias across the substrate is markedly different for the different F/R compositions. Referring now to FIGS. 3A and 3B, the CD bias (A, angstroms) as a function of the distance from the substrate center (m, millimeters) is provided for dense structures and isolated structures, respectively. As evident in both FIGS. 3A and 3B, the inventors have observed a reduction in the CD bias variation particularly near the substrate edge. For instance, with the quartz F/R, the variation may be as great as 150 Å. This variation is substantially reduced when utilizing a high resistivity silicon carbide F/R. Furthermore, the inventors have observed a reduction in particle generation with the use of the H.R. SiC F/R versus the QTZ F/R.

[0051] Although only certain embodiments of this invention have been described in detail above, those skilled in the art will readily appreciate that many modifications are possible in the embodiments without materially departing from the novel teachings and advantages of this invention. Accordingly, all such modifications are intended to be included within the scope of this invention.

What is claimed is:

1. A focus ring for surrounding a substrate on a substrate holder in a plasma processing system, comprising:
   - a focus ring having an upper surface, a lower surface, an inner radial edge, and an outer radial edge, wherein said focus ring comprises high resistivity silicon carbide having a resistivity greater than or equal to about 100 ohm-cm.
2. The focus ring of claim 1, wherein said resistivity is greater than or equal to about 1000 ohm-cm.
3. The focus ring of claim 1, wherein said resistivity ranges from about 100 ohm-cm to about 10⁶ ohm-cm.
4. The focus ring of claim 1, wherein said focus ring consists essentially of high resistivity silicon carbide.
5. The focus ring of claim 1, wherein said focus ring consists of high resistivity silicon carbide.
6. The focus ring of claim 1, wherein said focus ring comprises vapor deposited high resistivity silicon carbide.
7. The focus ring of claim 1, wherein said focus ring comprises chemical vapor deposited high resistivity silicon carbide.
8. The focus ring of claim 1, wherein said focus ring comprises sintered high resistivity silicon carbide.
9. The focus ring of claim 1, wherein said focus ring comprises a centering feature configured to center said focus ring on said substrate holder.
10. The focus ring of claim 1, wherein said focus ring comprises one or more wear indicators coupled to at least one of said upper surface or said lower surface.
11. The focus ring of claim 10, wherein said one or more wear indicators comprises a hole in said upper surface and extending to a depth from said upper surface, said depth comprising a fraction of the distance between said upper surface and said lower surface.
12. The focus ring of claim 10, wherein said one or more wear indicators comprise a hole in said lower surface and extending to a depth from said lower surface, said depth comprising a fraction of the distance between said upper surface and said lower surface.
13. The focus ring of claim 1, wherein said focus ring comprises a plurality of layers, wherein at least one of said plurality of layers comprises high resistivity silicon carbide.
14. The focus ring of claim 1, wherein said focus ring comprises a coating applied to at least one of said upper surface, said lower surface, said inner radial edge, and said outer radial edge.
15. The focus ring of claim 1, wherein said focus ring comprises a step formed in said inner radial edge.

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