PLASMA PROCESSING APPARATUS AND PLASMA PROCESSING METHOD

FIELD

[0001] Exemplary embodiments of the present disclosure relate to a plasma processing apparatus and a plasma processing method.

BACKGROUND

[0002] Patent Literature 1 describes a technique for precoating a plasma processing chamber.

CITATION LIST

PATENT LITERATURE

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication (Translation of PCT Application) No. 2008-505490

BRIEF SUMMARY

TECHNICAL PROBLEM

[0004] One or more aspects of the present disclosure are directed to a technique for increasing a deposition rate of a precoat.

SOLUTION TO PROBLEM

[0005] In one exemplary embodiment of the present disclosure, a plasma processing apparatus includes a chamber, a gas supply, a substrate support in the chamber, a plasma generator that generates a plasma in the chamber, and a controller. The controller performs control operations including (a) supplying a first processing gas from the gas supply to the chamber. The first processing gas includes an alkyne gas having three or more carbon atoms. The operations include (b) generating, with the plasma generator, a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber, (c) providing a substrate on the substrate support, (d) supplying a second processing gas from the gas supply to the chamber, and (e) generating, with the plasma generator, a plasma

from the second processing gas and performing plasma processing of the substrate.

ADVANTAGEOUS EFFECTS

[0006] The technique according to one exemplary embodiment of the present disclosure can increase a deposition rate of a precoat.

BRIEF DESCRIPTION OF DRAWINGS

[0007] FIG. 1 is a diagram of a plasma processing apparatus, illustrating an example structure.

FIG. 2 is a diagram of a capacitively coupled plasma processing apparatus, illustrating an example structure.

FIG. 3 is a flowchart of an example of a method MT.

FIG. 4 is a diagram of a component CP after step ST2, showing an example cross-sectional structure.

DETAILED DESCRIPTION

[0008] One or more embodiments of the present disclosure will be described below.

[0009] In one exemplary embodiment, a plasma processing apparatus includes a chamber, a gas supply, a substrate support in the chamber, a plasma generator that generates a plasma in the chamber, and a controller. The controller performs control operations including (a) supplying a first processing gas from the gas supply to the chamber. The first processing gas includes an alkyne gas having three or more carbon atoms. The operations include (b) generating, with the plasma generator, a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber, (c) providing a substrate on the substrate support, (d) supplying a second processing gas from the gas supply to the chamber, and (e) generating, with the plasma generator, a plasma from the second processing gas and performing plasma processing of the substrate.

[0010] In one exemplary embodiment, the alkyne gas includes at least one gas selected from the group consisting of a propyne gas, a butyne (1-butyne or 2-butyne) gas, and a pentyne

(1-pentyne or 2-pentyne) gas.

[0011] In one exemplary embodiment, the first processing gas includes more than or equal to 50 vol% of the alkyne gas.

[0012] In one exemplary embodiment, the first processing gas includes more than or equal to 95 vol% of the alkyne gas.

[0013] In one exemplary embodiment, the first processing gas further includes a halogen-containing gas.

[0014] In one exemplary embodiment, the halogen-containing gas is at least one of a chlorine-containing gas or a fluorine-containing gas.

[0015] In one exemplary embodiment, the halogen-containing gas is at least one gas selected from the group consisting of a Cl_2 gas, an HF gas, an NF_3 gas, a C_4F_6 gas, a CF_4 gas, and a PF_3 gas.

[0016] In one exemplary embodiment, (b) includes providing a bias signal to the substrate support.

[0017] In one exemplary embodiment, (b) is performed with a substrate different from the substrate to be provided in (c) being placed on the substrate support.

[0018] In one exemplary embodiment, (b) is performed with a surface of the substrate support exposed to a space in the chamber.

[0019] In one exemplary embodiment, the component in the chamber is exposed to the plasma in (e).

[0020] In one exemplary embodiment, the second processing gas includes a hydrogen fluoride gas.

[0021] In one exemplary embodiment, the second processing gas includes more than or equal to 50 vol% of the hydrogen fluoride gas.

[0022] In one exemplary embodiment, a plasma processing method includes (a) supplying a first processing gas to a chamber. The first processing gas includes an alkyne gas having three or more carbon atoms. The plasma processing method includes (b) generating a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber, (c) providing a substrate on a substrate support in the chamber, (d)

supplying a second processing gas to the chamber, and (e) generating a plasma from the second processing gas and performing plasma processing of the substrate.

[0023] One or more embodiments of the present disclosure will be described below with reference to the drawings. In the drawings, like reference numerals denote the same or like components. Such components will not be described repeatedly. Unless otherwise specified, the positional relationships shown in the drawings are used to describe the vertical, lateral, and other positions. The drawings are not drawn to scale relative to the actual ratio of each component, and the actual ratio is not limited to the ratio in the drawings.

Example Structure of Plasma Processing Apparatus

[0024] FIG. 1 is a diagram of a plasma processing apparatus, illustrating an example structure. In one embodiment, a plasma processing apparatus 1 is an example of a substrate processing apparatus. The plasma processing apparatus 1 includes a controller 2, a plasma processing chamber 10, a substrate support 11, and a plasma generator 12. The plasma processing chamber 10 has a plasma processing space. The plasma processing chamber 10 also has at least one gas inlet for supplying at least one processing gas into the plasma processing space and at least one gas outlet for exhausting the gas from the plasma processing space. The gas inlet is connected to a gas supply 20 (described later). The gas outlet is connected to an exhaust system 40 (described later). The substrate support 11 is located in the plasma processing space and has a substrate support surface for supporting a substrate.

[0025] The plasma generator 12 generates a plasma from at least one processing gas supplied into the plasma processing space. The plasma generated in the plasma processing space may be, for example, a capacitively coupled plasma (CCP), an inductively coupled plasma (ICP), an electron cyclotron resonance (ECR) plasma, a helicon wave plasma (HWP), or a surface wave plasma (SWP). The plasma generator 12 may be one of various plasma generators including an alternating current (AC) plasma generator and a direct current (DC) plasma generator. In one embodiment, an AC signal (AC power) used in the AC plasma generator has a frequency in a range of 100 kHz to 10 GHz. Thus, the AC signal may be a radio-frequency (RF) signal or a microwave signal. In one embodiment, the RF signal has a frequency in a range of 100 kHz to 150 MHz.

[0026] The controller 2 processes computer-executable instructions that cause the plasma processing apparatus 1 to perform various steps described in one or more embodiments of the present disclosure. The controller 2 may cause the components of the plasma processing apparatus 1 to perform the various steps described herein. In one embodiment, some or all of the components of the controller 2 may be included in a system external to the plasma processing apparatus 1. The controller 2 may include a processor 2a1, a storage 2a2, and a communication interface 2a3. The controller 2 is implemented by, for example, a computer 2a. The processor 2a1 may perform various control operations by loading programs from the storage 2a2 and executing the loaded programs. The programs may be prestored in the storage 2a2 or may be obtained through a medium as appropriate. The obtained programs are stored into the storage 2a2 to be loaded from the storage 2a2 and executed by the processor 2a1. The medium may be one of various storage media readable by the computer 2a or a communication line connected to the communication interface 2a3. The processor 2a1 may be a central processing unit (CPU). The storage 2a2 may include a random-access memory (RAM), a read-only memory (ROM), a hard disk drive (HDD), a solid-state drive (SSD), or a combination of these. The communication interface 2a3 may communicate with the components of the plasma processing apparatus 1 through a communication line such as a local area network (LAN).

[0027] An example structure of a capacitively coupled plasma processing apparatus as an example of the plasma processing apparatus 1 will now be described. FIG. 2 is a diagram of the capacitively coupled plasma processing apparatus, illustrating an example structure.

[0028] The capacitively coupled plasma processing apparatus 1 includes the controller 2, the plasma processing chamber 10, the gas supply 20, a power supply 30, and the exhaust system 40. The plasma processing apparatus 1 further includes the substrate support 11 and a gas guide unit. The gas guide unit allows at least one processing gas to be introduced into the plasma processing chamber 10. The gas guide unit includes a showerhead 13. The substrate support 11 is located in the plasma processing chamber 10. The showerhead 13 is located above the substrate support 11. In one embodiment, the showerhead 13 defines at least a part of the ceiling of the plasma processing chamber 10. The plasma processing chamber 10 has a

plasma processing space 10s defined by the showerhead 13, a sidewall 10a of the plasma processing chamber 10, and the substrate support 11. The plasma processing chamber 10 is grounded. The showerhead 13 and the substrate support 11 are electrically insulated from the housing of the plasma processing chamber 10.

[0029] The substrate support 11 includes a body 111 and a ring assembly 112. The body 111 includes a central portion 111a for supporting a substrate W and an annular portion 111b for supporting the ring assembly 112. A wafer is an example of the substrate W. The annular portion 111b of the body 111 surrounds the central portion 111a of the body 111 as viewed in plan. The substrate W is placeable on the central portion 111a of the body 111. The ring assembly 112 is located on the annular portion 111b of the body 111 to surround the substrate W on the central portion 111a of the body 111. Thus, the central portion 111a is also referred to as a substrate support surface for supporting the substrate W. The annular portion 111b is also referred to as a ring support surface for supporting the ring assembly 112.

[0030] In one embodiment, the body 111 includes a base 1110 and an electrostatic chuck (ESC) 1111. The base 1110 includes a conductive member. The conductive member in the base 1110 may function as a lower electrode. The ESC 1111 is located on the base 1110. The ESC 1111 includes a ceramic member 1111a and an electrostatic electrode 1111b located inside the ceramic member 1111a. The ceramic member 1111a includes the central portion 111a. In one embodiment, the ceramic member 1111a also includes the annular portion 111b. The annular portion 111b may be included in another member surrounding the ESC 1111, such as an annular ESC or an annular insulating member. In this case, the ring assembly 112 may be located on the annular ESC or the annular insulating member, or may be located on both the ESC 1111 and the annular insulating member. At least one RF/DC electrode coupled to an RF power supply 31 or a DC power supply 32, or both (described later) may be located inside the ceramic member 1111a. In this case, the RF/DC electrode functions as a lower electrode. When a bias RF signal or a DC signal, or both (described later) are provided to at least one RF/DC electrode, the RF/DC electrode is also referred to as a bias electrode. The conductive member in the base 1110 and at least one RF/DC electrode may function as multiple lower electrodes. The electrostatic electrode 1111b may also function as a lower electrode. The

substrate support 11 thus includes at least one lower electrode.

[0031] The ring assembly 112 includes one or more annular members. In one embodiment, the one or more annular members include one or more edge rings and at least one cover ring. The edge ring(s) is formed from a conductive material or an insulating material. The cover ring(s) is formed from an insulating material.

[0032] The substrate support 11 may include a temperature controller that adjusts the temperature of at least one of the ESC 1111, the ring assembly 112, or the substrate to a target temperature. The temperature controller may include a heater, a heat transfer medium, a channel 1110a, or a combination of these. The channel 1110a carries a heat transfer fluid such as brine or a gas. In one embodiment, the channel 1110a is defined inside the base 1110, and one or more heaters are located inside the ceramic member 1111a in the ESC 1111. The substrate support 11 may include a heat transfer gas supply to supply a heat transfer gas into a space between the back surface of the substrate W and the central portion 111a.

[0033] The showerhead 13 introduces at least one processing gas from the gas supply 20 into the plasma processing space 10s. The showerhead 13 includes at least one gas inlet 13a, at least one gas-diffusion compartment 13b, and multiple gas guides 13c. The processing gas supplied to the gas inlet 13a passes through the gas-diffusion compartment 13b and is introduced into the plasma processing space 10s through the multiple gas guides 13c. The showerhead 13 further includes at least one upper electrode. In addition to the showerhead 13, the gas guide unit may include one or more side gas injectors (SGIs) installed in one or more openings in the sidewall 10a.

[0034] The gas supply 20 may include at least one gas source 21 and at least one flow controller 22. In one embodiment, the gas supply 20 supplies at least one processing gas from the corresponding gas source 21 to the showerhead 13 through the corresponding flow controller 22. The flow controller 22 may be, for example, a mass flow controller or a pressure-based flow controller. The gas supply 20 may further include at least one flow rate modulator that causes at least one processing gas to be supplied at a modulated flow rate or in a pulsed manner.

[0035] The power supply 30 includes the RF power supply 31 coupled to the plasma

processing chamber 10 through at least one impedance matching circuit. The RF power supply 31 provides at least one RF signal (RF power) to at least one lower electrode or at least one upper electrode, or both. This generates a plasma from at least one processing gas supplied into the plasma processing space 10s. The RF power supply 31 may thus function as at least a part of the plasma generator 12. A bias RF signal is provided to at least one lower electrode to generate a bias potential in the substrate W, thus drawing ion components in the generated plasma toward the substrate W.

[0036] In one embodiment, the RF power supply 31 includes a first RF generator 31a and a second RF generator 31b. The first RF generator 31a is coupled to at least one lower electrode or at least one upper electrode, or both through at least one impedance matching circuit to generate a source RF signal (source RF power) for plasma generation. In one embodiment, the source RF signal has a frequency in a range of 10 to 150 MHz. In one embodiment, the first RF generator 31a may generate multiple source RF signals with different frequencies. The one or more generated source RF signals are provided to at least one lower electrode or at least one upper electrode, or both.

[0037] The second RF generator 31b is coupled to at least one lower electrode through at least one impedance matching circuit to generate a bias RF signal (bias RF power). The frequency of the bias RF signal may be the same as or different from the frequency of the source RF signal. In one embodiment, the bias RF signal has a lower frequency than the source RF signal. In one embodiment, the bias RF signal has a frequency in a range of 100 kHz to 60 MHz. In one embodiment, the second RF generator 31b may generate multiple bias RF signals with different frequencies. The one or more generated bias RF signals are provided to at least one lower electrode. In various embodiments, at least one of the source RF signal or the bias RF signal may be pulsed.

[0038] The power supply 30 may include the DC power supply 32 coupled to the plasma processing chamber 10. The DC power supply 32 includes a first DC generator 32a and a second DC generator 32b. In one embodiment, the first DC generator 32a is coupled to at least one lower electrode to generate a first DC signal. The generated first DC signal is applied to at least one lower electrode. In one embodiment, the second DC generator 32b is coupled

to at least one upper electrode to generate a second DC signal. The generated second DC signal is applied to at least one upper electrode.

[0039] In various embodiments, the first DC signal and the second DC signal may be pulsed. In this case, the sequence of voltage pulses is applied to at least one lower electrode or at least one upper electrode, or both. The voltage pulses may have rectangular, trapezoidal, or triangular pulse waveforms, or a combination of these. In one embodiment, a waveform generator for generating a sequence of voltage pulses based on DC signals is coupled between the first DC generator 32a and at least one lower electrode. Thus, the first DC generator 32a and the waveform generator form a voltage pulse generator. When the second DC generator 32b and the waveform generator form a voltage pulse generator, the voltage pulse generator is coupled to at least one upper electrode. The voltage pulses may have positive polarity or negative polarity. The sequence of voltage pulses may include one or more positive voltage pulses and one or more negative voltage pulses within one cycle. The power supply 30 may include the first DC generator 32a and the second DC generator 32b in addition to the RF power supply 31 or may include the first DC generator 32a in place of the second RF generator 31b.

[0040] The exhaust system 40 is connectable to, for example, a gas outlet 10e in the bottom of the plasma processing chamber 10. The exhaust system 40 may include a pressure control valve and a vacuum pump. The pressure control valve regulates the pressure in the plasma processing space 10s. The vacuum pump may be a turbomolecular pump, a dry pump, or a combination of these.

[0041] In one embodiment, the plasma processing chamber 10 (hereafter also referred to as the chamber 10) may include shield 50. The shield 50 may be located along the sidewall 10a of the chamber 10 in a detachable manner. The shield 50 defines a part of the plasma processing space 10s. The shield 50 may reduce adhesion of by-products resulting from etching to the sidewall 10a. Further, the shield 50 may be located along the outer periphery of the substrate support 11 in a detachable manner.

[0042] In one embodiment, the chamber 10 may include a baffle plate 60. The baffle plate 60 divides the chamber 10 into the plasma processing space 10s and an exhaust space including an area adjacent to the gas outlet 10e. The baffle plate 60 may reduce entry of a

plasma into an exhaust space downstream from the baffle plate 60. The baffle plate 60 may be located between the substrate support 11 and the sidewall 10a of the chamber 10 near the bottom of the chamber 10. The baffle plate 60 may be an annular plate. The baffle plate 60 may have an opening for exhausting air, such as a through-hole or a slit.

[0043] In one embodiment, the chamber 10 may include a ground (GND) block 70. The GND block 70 is exposed from the shield 50 to the plasma processing space 10s. For example, the GND block 70 may be a ring on the inner peripheries of the shield 50. The GND block 70 may be exposed to the plasma processing space 10s and may be, for example, a ring located outside or adjacent to the showerhead 13. The GND block 70 is a conductive member. For example, the GND block may be formed from a silicon-containing material. Examples of the silicon-containing material include silicon (Si) and silicon carbide (SiC). The GND block 70 is connected to a ground potential through the shield 50 and the sidewall 10a. The GND block 70 is electrically connected to the upper electrode or the lower electrode with the plasma generated in the plasma processing space 10s and may reduce abnormal discharge in the chamber 10.

Example of Plasma Processing Method

[0044] A plasma processing method (hereafter also referred to as a method MT) according to exemplary embodiments of the present disclosure will be described. The processing in each step may be performed in the plasma processing apparatus shown in FIGs. 1 and 2. In the example described below, the controller 2 causes the components of the capacitively coupled plasma processing apparatus 1 (refer to FIG. 2) to implement the processing method.

[0045] FIG. 3 is a flowchart of an example of the method MT. As shown in FIG. 3, the method MT includes step ST1 of supplying a first processing gas and step ST2 of forming a precoat. In one embodiment, the method MT may include, after step ST2, step ST3 of providing a substrate, step ST4 of supplying a second processing gas, and step ST5 of performing plasma processing of the substrate. In one embodiment, the method MT may further include step ST6 of cleaning the inside of the chamber after step ST5.

Step ST1

[0046] In step ST1, the first processing gas is supplied. In one embodiment, the gas

supply 20 supplies the first processing gas into the plasma processing space 10s in the chamber 10 through the showerhead 13. The first processing gas includes an alkyne gas having three or more carbon atoms (hereafter also referred to as an alkyne gas AG). The alkyne gas AG contains one or more carbon triple bonds in a molecule. In the alkyne gas AG, terminal carbon or carbon other than the terminal carbon may have the triple bonds. In one embodiment, the alkyne gas AG includes at least one gas selected from the group consisting of a propyne (methylacetylene) gas, a butyne (1-butyne or 2-butyne) gas, and a pentyne (1-pentyne or 2-pentyne) gas.

[0047] The alkyne gas AG is more stable and less flammable than an acetylene gas. Thus, the first processing gas may include the alkyne gas AG at a higher flow rate (partial pressure). In one embodiment, the alkyne gas AG may have the highest flow rate (partial pressure) among the components of the first processing gas. In one example, the flow rate of the alkyne gas AG may be 50 vol% or more, 60 vol% or more, 70 vol% or more, 80 vol% or more, 90 vol% or more, or 95 vol% or more of the total flow rate of all components of the first processing gas. In one embodiment, the first processing gas includes 100 vol% of the alkyne gas AG.

[0048] In one embodiment, the first processing gas may further include a halogen-containing gas as an additive gas. The halogen-containing gas may be, for example, at least one of a chlorine-containing gas or a fluorine-containing gas. In one example, the chlorine-containing gas is a Cl_2 gas. In one example, the fluorine-containing gas is at least one gas selected from the group consisting of a Cl_2 gas, an HF gas, an NF_3 gas, a C_4F_6 gas, a CF_4 gas, and a PF_3 gas. The flow rate of the halogen-containing gas may be lower than the flow rate of the alkyne gas.

[0049] As described above, the alkyne gas AG is more stable and less flammable than an acetylene gas. The first processing gas may thus be free of a diluent gas such as an Ar gas, a He gas, or a Kr gas. The first processing gas may include a diluent gas such as an Ar gas, a He gas, or a Kr gas.

[0050] In one embodiment, the first processing gas may further include a hydrocarbon gas different from the alkyne gas AG or a halogenated hydrocarbon gas, or both. The hydrocarbon gas may be, for example, a CH_4 gas, a C_2H_2 gas, or a C_2H_4 gas. The flow rate of the

hydrocarbon gas may be lower than the flow rate of the alkyne gas. The halogenated hydrocarbon gas is a gas generated by substituting hydrogen atoms in a hydrocarbon molecule with a halogen, and may be, for example, a CHF-based gas, a CHCl-based gas, or a CHBr-based gas. The flow rate of the halogenated hydrocarbon gas may be lower than the flow rate of the alkyne gas.

Step ST2

[0051] In step ST2, a plasma generated from the first processing gas forms a precoat including a carbon-containing film on a component in the chamber.

[0052] In one embodiment, a source RF signal is provided from the first RF generator 31a to the lower electrode of the substrate support 11 or the upper electrode of the showerhead 13, or both. This generates the plasma from the first processing gas. Carbon contained in, for example, the alkyne gas AG in the first processing gas is dissociated in the plasma and deposited on the surface of the component in the chamber 10. This forms the precoat. The precoat is a carbon-containing film. The precoat may function as a protective film in, for example, the plasma processing of the substrate W in step ST5 (described later).

[0053] In one embodiment, the precoat is formed partially or entirely on a plasma exposed surface (a surface exposed to the plasma processing space 10s) of the component in the chamber 10 (hereafter, the component on which the precoat is formed is also referred to as a component CP). The component CP may be, for example, at least one of the substrate support 11, the showerhead 13, the ring assembly 112, the sidewall 10a, the shield 50, the baffle plate 60, or the GND block 70. The component CP may be formed from, for example, a silicon-containing material such as silicon or silicon carbide. The component CP may be formed from, for example, a metal material such as aluminum.

[0054] In one embodiment, step ST2 may be performed with a dummy substrate placed on the substrate support 11. In this case, the precoat is not formed on the plasma exposed surface of the substrate support 11 in step ST2. The dummy substrate may have the same dimensions and shape as the substrate W provided in step ST3.

[0055] In one embodiment, step ST2 may be performed while a bias signal is being provided to the chamber 10. In one embodiment, the bias signal may be a bias RF signal

provided from the second RF generator 31b to the lower electrode of the substrate support 11. In one embodiment, the bias signal may be a bias DC signal provided from the DC generator 32a to the lower electrode of the substrate support 11. The bias DC signal may be negative. In one embodiment, the bias signal may be provided directly to the component CP (e.g., the ring assembly 112).

[0056] In one embodiment, the temperature of the substrate support 11 may be controlled in a range of −70 to 100 °C inclusive in step ST2.

[0057] FIG. 4 is a diagram of the component after step ST2 showing an example cross-sectional structure. As shown in FIG. 4, the precoat PC is formed on the surface of the component CP. The film thickness of the precoat PC may be adjusted based on, for example, the component on which the precoat PC is formed and processing conditions in step ST3. The precoat PC has a film thickness of, for example, greater than or equal to 100 nm. The precoat PC has a film thickness of, for example, less than or equal to 1500 nm. In one example, the precoat PC with such a thickness may be formed on the surface of the edge ring.

[0058] In step ST2, the plasma is generated from the first processing gas including the alkyne gas AG to form the precoat. The carbon ratio per flow rate can thus be higher than when a plasma is generated from a hydrocarbon gas with fewer carbon atoms, such as a methane gas, to form a precoat. This may increase the deposition rate of the precoat. The alkyne gas AG has the carbon triple bonds that are dissociated in the plasma to form precursors containing active species of an ethynyl group. The precursors may be bonded with one another inside the film to form the precoat. In this reaction, hydrogen is not to be extracted as in, for example, forming the precoat from a methane gas. The alkyne gas AG thus uses less energy for forming the precoat than, for example, a methane gas. This may increase the deposition rate of the precoat. The precoat formed from the precursors containing active species of an ethynyl group tends to contain SP^2-bonded carbon (graphite) at a high proportion and hydrogen at a low proportion. Thus, the precoat may have higher conductivity and higher film density (hardness).

[0059] When the first processing gas includes a halogen-containing gas as an additive gas, the hydrogen in the precoat may be scavenged with the halogen dissociated in the plasma in

step ST2. This may improve the film quality of the precoat. The improvement in the film quality may be the improvement in the conductivity resulting from an increase in the proportion of the SP^2-bonded carbon (graphite). The improvement in the film quality may be the improvement in the film density (hardness) resulting from a decrease in the proportion of the hydrogen in the film.

[0060] When the bias signal is provided in step ST2, ions in the plasma may be incorporated into the precoat formed on the surface of the component. The kinetic energy of the ions may be converted to thermal energy to change the bonding state of the carbon-containing film in the precoat. This may improve the film quality of the precoat. The improvement in the film quality may be the improvement in the conductivity resulting from an increase in the proportion of the SP^2-bonded carbon (graphite). The improvement in the film quality may be the improvement in the film density (hardness) resulting from a decrease in the proportion of the hydrogen in the film.

Step ST3

[0061] In step ST3, the substrate W is provided into the chamber 10. In one embodiment, the substrate W is loaded into the chamber 10 with a transfer arm, placed onto the substrate support 11 with a lifter, and clamped on the substrate support 11 as illustrated in FIG. 2. The substrate W may be used for manufacturing a semiconductor device. Examples of the semiconductor device include a memory device such as a dynamic RAM (DRAM) or a three-dimensional NOT-AND (3D-NAND) flash memory, and a logic device. In one embodiment, the substrate W may include a silicon-containing film.

Step ST4

[0062] In step ST4, the second processing gas is supplied. In one embodiment, the gas supply 20 supplies the second processing gas into the plasma processing space 10s in the chamber 10 through the showerhead 13. The second processing gas is selected as appropriate for the plasma processing performed on the substrate W in step ST5.

[0063] In one embodiment, the second processing gas includes a hydrogen fluoride (HF) gas. The HF gas may have the highest flow rate (partial pressure) among the components of the second processing gas excluding an inert component. In one embodiment, the second

processing gas may include, in place of part or all of the HF gas, a gas that can generate an active species of hydrogen fluoride (HF species) in the plasma. The HF species includes at least any of a gas, radicals, or ions of HF. In one embodiment, the second processing gas further includes at least one gas selected from the group consisting of a phosphorus-containing gas, a metal-containing gas, a gas containing a halogen other than fluorine, a carbon-containing gas, an oxygen-containing gas, and an inert gas, in addition to the HF gas.

Step ST5

[0064] In step ST5, plasma processing is performed on the substrate W. In one embodiment, a source RF signal is provided to the lower electrode of the substrate support 11 or the upper electrode of the showerhead 13, or both. In response to an RF electric field being generated between the showerhead 13 and the substrate support 11, a plasma is generated from the second processing gas in the chamber 10. Plasma processing is performed on the substrate W with the plasma. In one example, the plasma processing may be etching of the film on the substrate W. In one example, the plasma processing may be film deposition that forms a film on the substrate W.

[0065] In step ST5, the precoat formed on the plasma exposed surface of the component CP may function as a protective film against the plasma generated from the second processing gas, as described above. In one example described below, the plasma exposed surface of the component CP contains silicon and the second processing gas contains an HF gas. The precoat may reduce the likelihood that the silicon on the plasma exposed surface of the component CP reacts with the HF species in the plasma and volatilizes as a silicon fluoride compound. This may reduce the likelihood of the plasma exposed surface of the component CP being etched (damaged). This also reduces the likelihood of the HF species in the plasma being consumed in areas other than the substrate W. Thus, the plasma processing of the substrate W may be facilitated.

[0066] After the plasma processing in step ST5, the substrate W is unloaded from the chamber 10 by a transfer unit.

Step ST6

[0067] In step ST6, the chamber 10 is cleaned. In one embodiment, the gas supply 20

supplies a cleaning gas into the plasma processing space 10s through the showerhead 13. The cleaning gas may be, for example, an oxygen-containing gas. A plasma is then generated from the cleaning gas. This may remove some or all of the precoat or a reaction product formed on the plasma exposed surface of the component in the chamber 10. When multiple substrates W are processed as a single unit (lot), step ST6 may be performed after steps ST3 to ST5 for one or more substrates W included in the lot. In other words, step ST6 may be performed after steps ST3 to ST5 are performed repeatedly.

[0068] The technique according to one embodiment can increase the deposition rate of a precoat.

[0069] The embodiments of the present disclosure further include the aspects described below.

Aspect 1

[0070] A plasma processing apparatus, comprising:

a chamber;

a gas supply;

a substrate support in the chamber;

a plasma generator configured to generate a plasma in the chamber; and

a controller configured to perform control operations including

(a) supplying a first processing gas from the gas supply to the chamber, the first processing gas including an alkyne gas having three or more carbon atoms,

(b) generating, with the plasma generator, a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber,

(c) providing a substrate on the substrate support,

(d) supplying a second processing gas from the gas supply to the chamber, and

(e) generating, with the plasma generator, a plasma from the second processing gas and performing plasma processing of the substrate.

Aspect 2

[0071] The plasma processing apparatus according to aspect 1, wherein

the alkyne gas includes at least one gas selected from the group consisting of a propyne

gas, a butyne (1-butyne or 2-butyne) gas, and a pentyne (1-pentyne or 2-pentyne) gas.

Aspect 3

[0072] The plasma processing apparatus according to aspect 1 or aspect 2, wherein the first processing gas includes more than or equal to 50 vol% of the alkyne gas.

Aspect 4

[0073] The plasma processing apparatus according to any one of aspects 1 to 3, wherein the first processing gas includes more than or equal to 95 vol% of the alkyne gas.

Aspect 5

[0074] The plasma processing apparatus according to any one of aspects 1 to 4, wherein the first processing gas further includes a halogen-containing gas.

Aspect 6

[0075] The plasma processing apparatus according to aspect 5, wherein the halogen-containing gas is at least one of a chlorine-containing gas or a fluorine-containing gas.

Aspect 7

[0076] The plasma processing apparatus according to aspect 5, wherein the halogen-containing gas is at least one gas selected from the group consisting of a Cl_2 gas, an HF gas, an NF_3 gas, a C_4F_6 gas, a CF_4 gas, and a PF_3 gas.

Aspect 8

[0077] The plasma processing apparatus according to any one of aspects 1 to 7, wherein (b) includes providing a bias signal to the substrate support.

Aspect 9

[0078] The plasma processing apparatus according to any one of aspects 1 to 8, wherein (b) is performed with a substrate different from the substrate to be provided in (c) being placed on the substrate support.

Aspect 10

[0079] The plasma processing apparatus according to any one of aspects 1 to 8, wherein (b) is performed with a surface of the substrate support exposed to a space in the chamber.

Aspect 11

[0080] The plasma processing apparatus according to any one of aspects 1 to 10, wherein the component in the chamber is exposed to the plasma in (e).

Aspect 12

[0081] The plasma processing apparatus according to any one of aspects 1 to 11, wherein the second processing gas includes a hydrogen fluoride gas.

Aspect 13

[0082] The plasma processing apparatus according to aspect 12, wherein

the second processing gas includes more than or equal to 50 vol% of the hydrogen fluoride gas.

Aspect 14

[0083] A plasma processing method, comprising:

(a) supplying a first processing gas to a chamber, the first processing gas including an alkyne gas having three or more carbon atoms;

(b) generating a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber;

(c) providing a substrate on a substrate support in the chamber;

(d) supplying a second processing gas to the chamber; and

(e) generating a plasma from the second processing gas and performing plasma processing of the substrate.

Aspect 15

[0084] A precoat forming method, comprising:

(a) supplying a first processing gas to a chamber, the first processing gas including an alkyne gas having three or more carbon atoms; and

(b) generating a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber.

Aspect 16

[0085] A precoat being a carbon-containing film formed on a plasma exposed surface of a component in a chamber and formed using a plasma generated from a processing gas including an alkyne gas having three or more carbon atoms.

Aspect 17

[0086] A device manufacturing method, comprising:

(a) supplying a first processing gas to a chamber, the first processing gas including an alkyne gas having three or more carbon atoms;

(b) generating a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber;

(c) providing a substrate on a substrate support in the chamber;

(d) supplying a second processing gas to the chamber; and

(e) generating a plasma from the second processing gas and performing plasma processing of the substrate.

Aspect 18

[0087] A program executable by a computer included in a plasma processing apparatus including a chamber and a controller, the program causing the computer to perform control operations comprising:

(a) supplying a first processing gas to a chamber, the first processing gas including an alkyne gas having three or more carbon atoms;

(b) generating a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber;

(c) providing a substrate on a substrate support in the chamber;

(d) supplying a second processing gas to the chamber; and

(e) generating a plasma from the second processing gas and performing plasma processing of the substrate.

Aspect 19

[0088] A storage medium storing the program according to aspect 18.

[0089] The above embodiments are mere examples described for illustrative purposes and are not intended to limit the scope of the present disclosure. The embodiments may be modified in various manners without departing from the spirit and scope of the present disclosure. For example, one or more components in one embodiment may be added to the structure according to another embodiment. In some embodiments, some of the components

may be replaced with the corresponding components in other embodiments.

REFERENCE SIGNS LIST

[0090]

1 Plasma processing apparatus
2 Controller
10 Plasma processing chamber
10a Sidewall
10s Plasma processing space
11 Substrate support
112 Ring assembly
13 Showerhead
20 Gas supply
31a First RF generator
31b Second RF generator
32a First DC generator
32b Second DC generator
50 Shield
60 Baffle plate
70 GND block
CP Component
PC Precoat
W Substrate

CLAIMS

1. A plasma processing apparatus, comprising:

a chamber;

a gas supply;

a substrate support in the chamber;

a plasma generator configured to generate a plasma in the chamber; and

a controller configured to perform control operations including

(a) supplying a first processing gas from the gas supply to the chamber, the first processing gas including an alkyne gas having three or more carbon atoms,

(b) generating, with the plasma generator, a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber,

(c) providing a substrate on the substrate support,

(d) supplying a second processing gas from the gas supply to the chamber, and

(e) generating, with the plasma generator, a plasma from the second processing gas and performing plasma processing of the substrate.

2. The plasma processing apparatus according to claim 1, wherein

the alkyne gas includes at least one gas selected from the group consisting of a propyne gas, a butyne (1-butyne or 2-butyne) gas, and a pentyne (1-pentyne or 2-pentyne) gas.

3. The plasma processing apparatus according to claim 1, wherein

the first processing gas includes more than or equal to 50 vol% of the alkyne gas.

4. The plasma processing apparatus according to claim 1, wherein

the first processing gas includes more than or equal to 95 vol% of the alkyne gas.

5. The plasma processing apparatus according to any one of claims 1 to 4, wherein

the first processing gas further includes a halogen-containing gas.

6. The plasma processing apparatus according to claim 5, wherein

the halogen-containing gas is at least one of a chlorine-containing gas or a fluorine-containing gas.

7. The plasma processing apparatus according to claim 5, wherein

the halogen-containing gas is at least one gas selected from the group consisting of a Cl_2 gas, an HF gas, an NF_3 gas, a C_4F_6 gas, a CF_4 gas, and a PF_3 gas.

8. The plasma processing apparatus according to any one of claims 1 to 4, wherein

(b) includes providing a bias signal to the substrate support.

9. The plasma processing apparatus according to any one of claims 1 to 4, wherein

(b) is performed with a substrate different from the substrate to be provided in (c) being placed on the substrate support.

10. The plasma processing apparatus according to any one of claims 1 to 4, wherein

(b) is performed with a surface of the substrate support exposed to a space in the chamber.

11. The plasma processing apparatus according to any one of claims 1 to 4, wherein

the component in the chamber is exposed to the plasma in (e).

12. The plasma processing apparatus according to any one of claims 1 to 4, wherein the second processing gas includes a hydrogen fluoride gas.

13. The plasma processing apparatus according to claim 12, wherein the second processing gas includes more than or equal to 50 vol% of the hydrogen fluoride gas.

14. A plasma processing method, comprising:

(a) supplying a first processing gas to a chamber, the first processing gas including an alkyne gas having three or more carbon atoms;

(b) generating a plasma from the first processing gas and forming a precoat including a carbon-containing film on a component in the chamber;

(c) providing a substrate on a substrate support in the chamber;

(d) supplying a second processing gas to the chamber; and

(e) generating a plasma from the second processing gas and performing plasma processing of the substrate.