DESCRIPTION

Title of Invention: PLASMA PROCESSING APPARATUS AND PROCESSING METHOD

Technical Field

[0001]

The present disclosure relates to a plasma processing apparatus and a processing method.

Background Art

[0002]

PTL 1 discloses a substrate processing apparatus including a stage that has a placement surface on which a substrate is to be placed, and that is provided with a gas supply pipe for supplying a heat transfer gas to a gap between the substrate and the placement surface.

Citation List

Patent Documents

[0003]

PTL 1: JP2020-120081A

Summary of Invention

Technical Problem

[0004]

The technique according to the present disclosure efficiently adjusts a temperature of a workpiece during plasma processing.

Solution to Problem

[0005]

An aspect of the present disclosure is a plasma processing apparatus including: a processing container configured to be depressurized, a support provided in the processing container and configured to support a workpiece, a heat transfer layer former configured to form, on a placement surface of the support on which the workpiece is placed, a deformable heat transfer layer formed of at least one of a liquid layer or a solid layer for the workpiece, an exhaust line configured to exhaust a processing space in the processing container, and a bypass line that detours the exhaust line, in which the bypass line is provided with a trap configured to retrieve the heat transfer layer in a gas form contained in exhaust of the processing space.

Advantageous Effects of Invention

[0006]

According to the present disclosure, it is possible to efficiently adjust a temperature of a workpiece during plasma processing.

Brief Description of Drawings

[0007]

[FIG.1] FIG.1 is a vertical sectional view schematically illustrating a configuration of a plasma processing apparatus according to a first embodiment.

[FIG.2] FIG.2 is a flowchart illustrating an example of wafer processing performed by the plasma processing apparatus illustrated in FIG.1.

[FIG.3] FIG.3 is a diagram illustrating a state of the plasma processing apparatus illustrated in FIG. 1 during the wafer processing performed by using the plasma processing apparatus.

[FIG.4] FIG.4 is a diagram illustrating a state of the plasma processing apparatus illustrated in FIG. 1 during the wafer processing performed by using the plasma processing apparatus.

[FIG.5] FIG.5 is a diagram illustrating a state of the plasma processing apparatus illustrated in FIG. 1 during the wafer processing performed by using the plasma processing apparatus.

[FIG.6] FIG.6 is a diagram illustrating a state of the plasma processing apparatus illustrated in FIG. 1 during the wafer processing performed by using the plasma processing apparatus.

[FIG.7] FIG.7 is a graph illustrating a vapor pressure curve of a constituent material of a heat transfer layer.

[FIG.8] FIG.8 is a diagram illustrating a state of the plasma processing apparatus illustrated in FIG. 1 during the wafer processing performed by using the plasma processing apparatus.

[FIG.9] FIG.9 is a diagram illustrating a state of the plasma processing apparatus illustrated in FIG. 1 during the wafer processing performed by using the plasma processing apparatus.

[FIG.10] FIG.10 is a partially-enlarged cross-sectional view of a wafer placement surface.

[FIG.11] FIG.11 is a partially-enlarged cross-sectional view of the wafer placement surface.

[FIG.12] FIG.12 is a diagram illustrating another example of a bypass line.

[FIG.13] FIG.13 is a diagram illustrating another example of a form in which a raw material gas of the heat transfer layer is condensed on a surface of a wafer support.

[FIG.14] FIG.14 is a diagram illustrating another example of the form in which the raw material gas of the heat transfer layer is condensed on the surface of the wafer support.

[FIG.15] FIG.15 is a diagram illustrating another example of the form in which the raw material gas of the heat transfer layer is condensed on the surface of the wafer support.

[FIG.16] FIG.16 is a diagram illustrating Modification 1 of a gas supply for a heat transfer layer formation gas.

[FIG.17] FIG.17 is a diagram illustrating another example of the raw material of the heat transfer layer.

[FIG.18] FIG.18 is a plan view schematically illustrating a modification of an electrode of an electrostatic chuck.

[FIG.19] FIG.19 is a sectional view schematically illustrating the modification of the electrode of the electrostatic chuck.

[FIG.20] FIG.20 is a sectional view schematically illustrating a modification of the electrode of the electrostatic chuck.

[FIG.21] FIG.21 is a sectional view schematically illustrating a modification of the electrode of an electrostatic chuck.

[FIG.22] FIG.22 is a plan view schematically illustrating a modification of an electrode of an electrostatic chuck.

[FIG.23] FIG.23 is a diagram illustrating an example of the heat transfer layer on the wafer placement surface.

[FIG.24] FIG.24 is a diagram illustrating an example in which a central portion of the electrostatic chuck has a diameter larger than that of a wafer.

[FIG.25] FIG.25 is a diagram illustrating another example of a wafer placement form on the wafer placement surface.

Description of Embodiments

[0008]

In a manufacturing process of a semiconductor device or the like, plasma processing, such as etching or film formation, is performed on a semiconductor wafer (hereinafter referred to as a “wafer”) serving as a workpiece using a plasma. The plasma processing is performed in a state in which a substrate is supported on a substrate support in a pressure-reduced processing container.

[0009]

Since a result of the plasma processing depends on a temperature of the substrate, a temperature of the substrate support is adjusted during the plasma processing, and the temperature of the substrate is adjusted via the substrate support.

In the related art, a heat transfer gas, such as a He gas, is supplied between the substrate support and the substrate such that the temperature of the substrate can be efficiently adjusted via the substrate support.

[0010]

However, when heat input from a plasma to the substrate during the plasma processing is large, the temperature of the substrate may not be sufficiently adjusted even when the heat transfer gas is used as described above.

A temperature of an object other than the substrate may be adjusted by the substrate support.

[0011]

Therefore, the technique according to the present disclosure efficiently adjusts a temperature of the workpiece, such as a substrate, via the support during the plasma processing.

[0012]

A plasma processing apparatus and a processing method according to an embodiment will be described below with reference to the drawings. Like reference numerals will be given to like parts having substantially the same functions throughout the specification and the drawings, and redundant description thereof will be omitted.

[0013]

(First embodiment)

Plasma Processing Apparatus 1

FIG. 1 is a vertical sectional view schematically illustrating a configuration of a plasma processing apparatus 1 according to a first embodiment.

The plasma processing apparatus 1 illustrated in FIG. 1 performs desired processing on a wafer W under a vacuum environment (vacuum atmosphere). Specifically, the plasma processing apparatus 1 performs the plasma processing, such as etching or film formation, on the wafer W.

[0014]

The plasma processing apparatus 1 includes a plasma processing chamber 100 as a processing container, gas supplies 120 and 130, a radio frequency (RF) power supply 140, and an exhaust system 150. The plasma processing apparatus 1 further includes a wafer support 101 as a support, and an upper electrode 102.

[0015]

The wafer support 101 is disposed in a lower region of a plasma processing space 100s

in the plasma processing chamber 100 configured to allow for internal pressure reduction. The upper electrode 102 is disposed above the wafer support 101. The upper electrode 102 can function as a part of a wall body defining the plasma processing space 100s, and specifically, can function as a part of a ceiling portion of the plasma processing chamber 100.

[0016]

The wafer support 101 is configured to support the wafer W in the plasma processing space 100s. In one embodiment, the wafer support 101 includes a lower electrode 103, an electrostatic chuck 104, an insulator 105, legs 106, and lifters 107. The wafer support 101 includes a temperature adjuster configured to adjust a temperature of the electrostatic chuck 104 (for example, a temperature of an upper surface 104_1 of a central portion thereof). The temperature adjuster includes, for example, a heater, a flow path, or a combination thereof. A temperature control fluid such as a coolant or a heat transfer gas flows through the flow path.

[0017]

The lower electrode 103 is formed of a conductive material such as aluminum, and is fixed to the insulator 105. In one embodiment, a flow path 108 of the temperature-controlled fluid, which constitutes a part of the temperature adjuster, is formed inside the lower electrode 103. The flow path 108 is supplied with the temperature-controlled fluid from, for example, a chiller unit (not illustrated) provided outside the plasma processing chamber 100. The temperature-controlled fluid supplied to the flow path 108 returns to the chiller unit. For example, by circulating a low-temperature brine in the flow path 108 as the temperature-controlled fluid, it is possible to cool the electrostatic chuck 104 and the wafer W and an edge ring E that are placed on the electrostatic chuck 104 to a predetermined temperature. For example, by circulating a high-temperature brine in the flow path 108 as the temperature-controlled fluid, the electrostatic chuck 104 and the wafer W and the edge ring E that are placed on the electrostatic chuck 104 can be heated to a predetermined temperature.

[0018]

The electrostatic chuck 104 is a member configured to attract and hold the wafer W by an electrostatic force, and is provided on the lower electrode 103. In one embodiment, in the electrostatic chuck 104, an upper surface of a central portion is formed to be higher than an upper surface of a peripheral edge. The upper surface 104_1 of the central portion of the electrostatic chuck 104 is a wafer placement surface on which the wafer W is to be placed, and an upper surface 104_2 of the peripheral edge of the electrostatic chuck 104 is a ring placement surface on which the edge ring E is to be placed. The edge ring E is a circular member viewed in plan, which surrounds the wafer W placed on the upper surface 104_1 of the central portion of the electrostatic chuck 104 and is disposed adjacent to the wafer W.

[0019]

The electrostatic chuck 104 is an example of a fixer that fixes the wafer W to the upper surface 104_1 of the central portion of the electrostatic chuck 104, that is, to the wafer placement surface. An electrode 109 is provided in the central portion of the electrostatic chuck 104.

[0020]

A direct-current voltage is applied to the electrode 109 from a direct-current power supply (not illustrated). Due to the electrostatic force thus generated, the wafer W is attracted and held on the upper surface 104_1 of the central portion of the electrostatic chuck 104.

In one embodiment, the electrostatic chuck 104 is configured to attract and hold the edge ring E by the electrostatic force. An electrode (not illustrated) for electrostatically attracting and holding the edge ring E on the wafer support 101 is provided.

In one embodiment, a gas supply hole (not illustrated) is formed in the upper surface 104_2 of the peripheral edge of the electrostatic chuck 104 to supply a heat transfer gas, such as a He gas, to a back surface of the edge ring E placed on the upper surface 104_2. The heat transfer gas from a gas supply (not illustrated) is supplied through the gas supply hole. The gas supply may include one or more gas sources and one or more pressure controllers. In one embodiment, for example, the gas supply is configured to supply the heat transfer gas from the gas source to the gas supply hole through the pressure controller.

[0021]

For example, the central portion of the electrostatic chuck 104 is formed to have a diameter less than a diameter of the wafer W. When the wafer W is placed on the upper surface 104_1 (hereafter referred to as the wafer placement surface) of the central portion of the electrostatic chuck 104, a peripheral edge of the wafer W protrudes outward from the central portion of the electrostatic chuck 104.

In the edge ring E, a step is formed on an upper portion thereof, and an upper surface of an outer peripheral portion is formed to be higher than an upper surface of an inner peripheral portion. The inner peripheral portion of the edge ring E is positioned below the peripheral portion of the wafer W that horizontally protrudes outward from the central portion of the electrostatic chuck 104.

[0022]

A heater (specifically, a resistive heat generator) constituting a part of the temperature adjuster may be provided inside the electrostatic chuck 104. By energizing the heater, the electrostatic chuck 104 and the wafers W placed on the electrostatic chuck 104 can be heated to a predetermined temperature. In this case, the electrostatic chuck 104 has a configuration in which the electrode 109 for wafer attracting and an electrode for edge ring-attracting are sandwiched between insulating members formed of an insulating material, with the heater embedded therein.

The central portion of the electrostatic chuck 104 provided with the electrode 109 for wafer attracting and the peripheral edge of the electrostatic chuck 104 provided with the electrode for edge ring-attracting may be integrally formed or separately formed.

[0023]

The insulator 105 is a disk-shaped member formed of ceramic or the like, and the lower electrode 103 is fixed thereto. The insulator 105 is formed to have the same diameter, for example, as that of the lower electrode 103.

[0024]

The leg 106 is a cylindrical member formed of ceramic or the like, and supports the electrostatic chuck 104 via the lower electrode 103 and the insulator 105. The leg 106 is formed to have, for example, an outer diameter equal to an outer diameter of the insulator 105, and supports a peripheral edge of the insulator 105.

[0025]

The lifter 107 is a lifting member that moves up and down with respect to the wafer placement surface 104_1 of the electrostatic chuck 104, and is formed in, for example, a columnar shape. When the lifter 107 is raised, an upper end thereof can protrude from the wafer placement surface 104_1 and support the wafer W. The wafer W can be transferred between the electrostatic chuck 104 and a transfer arm 71 of a transfer mechanism 70 by the lifter 107.

Three or more lifters 107 are provided at intervals from each other and are provided to extend in an up-down direction.

[0026]

The lifter 107 is connected to a support member 110 that supports the lifter 107. The support member 110 is connected to a driving unit 111 that generates a driving force for moving the support member 110 up and down to move the lifters 107 up and down. The driving unit 111 includes, for example, an actuator (not illustrated) as a driving source that generates the driving force.

[0027]

The lifter 107 is inserted into an insertion hole 112 having an upper end opening in the wafer placement surface 104_1 of the electrostatic chuck 104. The insertion hole 112 is formed to penetrate the central portion of the electrostatic chuck 104, the lower electrode 103 and the insulator 105.

The lifters 107, the support member 110 and the driving unit 111 constitute an elevation mechanism that moves the wafer W up and down with respect to the wafer placement surface 104_1.

[0028]

The upper electrode 102 described above also functions as a shower head for supplying

various gases from the gas supply 120 into the plasma processing space 100s. In one embodiment, the upper electrode 102 has a gas inlet 102a, a gas diffusion chamber 102b, and gas introduction ports 102c. For example, the gas inlet 102a is in fluid communication with the gas supply 120 and the gas diffusion chamber 102b. The gas introduction ports 102c are in fluid communication with the gas diffusion chamber 102b and the plasma processing space 100s. In one embodiment, the upper electrode 102 is configured to supply various gases into the plasma processing space 100s from the gas inlet 102a through the gas diffusion chamber 102b and the gas introduction ports 102c.

[0029]

The gas supply 120 may include one or more gas sources 121 and one or more flow rate controllers 122. In one embodiment, for example, the gas supply 120 is configured to supply one or more processing gases from the corresponding gas sources 121 to the gas inlet 102a through the corresponding flow rate controllers 122. For example, each of the flow rate controllers 122 may include a mass flow controller or a pressure-control type flow controller. Further, the gas supply 120 may include one or more flow modulation devices for modulating or pulsating the gas flow of one or more processing gases. In one embodiment, the gas supply 120 functions as an inert gas supply that supplies an inert gas, such as a N_2 gas, into the plasma processing space 100s.

[0030]

In one embodiment, a gas containing a raw material gas serving as a raw material of a heat transfer layer D to be described later from the gas supply 130, that is, a heat transfer layer formation gas is supplied from a sidewall of the plasma processing chamber 100 into the plasma processing space 100s. In this case, for example, a gas introduction port 100k in fluid communication with the plasma processing space 100s and in fluid communication with the gas supply 130 is provided in the sidewall of the plasma processing chamber 100. The heat transfer layer formation gas from the gas supply 130 is supplied into the plasma processing space 100s via the sidewall (specifically, the gas introduction port 100k).

[0031]

The gas supply 130 is configured to include one or more gas sources 131 and one or more flow rate controllers 132. In one embodiment, the gas supply 130 is configured to supply the heat transfer layer formation gas from the gas source 131 to the gas introduction port 100k through the flow rate controller 132.

The gas source 131 includes, for example, a tank 131a in which a raw material liquid of the heat transfer layer D is stored, and a vaporizer 131b that generates the raw material gas by vaporizing the raw material liquid. The gas source 131 may be connected to a supply path (not illustrated) of an inert gas as a carrier gas. In this case, for example, a mixed gas of the raw

material gas and the carrier gas is supplied from the gas source 131 as the heat transfer layer formation gas.

The flow rate controllers 132 may each include, for example, a mass flow controller or a pressure-control type flow controller. Further, the gas supply 130 may include one or more flow modulation devices for modulating or pulsing a gas flow of one or more heat transfer layer formation gases.

The heat transfer layer D in a liquid form is formed on the wafer placement surface 104_1 of the wafer support 101 from the heat transfer layer formation gas containing the raw material gas supplied from the gas supply 130. Therefore, the gas supply 130 may function as at least a part of a heat transfer layer former configured to form the heat transfer layer D on the wafer placement surface 104_1.

[0032]

The RF power supply 140 is configured to supply an RF power, for example, one or more RF signals, to one or more electrodes such as the lower electrode 103, the upper electrode 102, or both the lower electrode 103 and the upper electrode 102. The RF power supply 140 may be configured to supply the RF power, for example, one or more RF signals, to the electrode 109 provided in the electrostatic chuck 104 instead of the lower electrode 103. Therefore, plasma is generated from one or more processing gases supplied to the plasma processing space 100s. Therefore, the RF power supply 140 may function as at least a part of a plasma generator configured to generate a plasma from one or more processing gases in the plasma processing chamber 100.

[0033]

The RF power supply 140 includes, for example, two RF generation units, that is, RF generation units 141a and 141b and two matching circuits, that is, matching circuits 142a and 142b. In one embodiment, the RF power supply 140 is configured to supply a first RF signal from a first RF generation unit 141a to the lower electrode 103 via a first matching circuit 142a. For example, the first RF signal may have a frequency in a range of 27 MHz to 100 MHz.

[0034]

In one embodiment, the RF power supply 140 is configured to supply a second RF signal from a second RF generation unit 141b to the lower electrode 103 via a second matching circuit 142b. For example, the second RF signal may have a frequency in a range of 400 kHz to 13.56 MHz. A voltage pulse other than RF may be supplied instead of the second RF signal. The voltage pulse may be a negative-polarity direct-current voltage. In another example, the voltage pulse may be a triangular wave or an impulse.

[0035]

Although it is not illustrated, other embodiments may be considered in the present

disclosure. For example, in an alternative embodiment, the RF power supply 140 may be configured to supply the first RF signal from The RF generation unit to the lower electrode 103, supply the second RF signal from another RF generation unit to the lower electrode 103, and supply a third RF signal from the other RF generation unit to the lower electrode 103. In addition, in another alternative embodiment, a DC voltage may be applied to the upper electrode 102.

[0036]

Further, in various embodiments, amplitudes of one or more RF signals (that is, the first RF signal, the second RF signal, and the like) may be pulsated or modulated. The amplitude modulation may include pulsating the RF signal amplitude between an ON state and an OFF state, or between two or more different ON states.

[0037]

The exhaust system 150 includes an exhaust line 160 for exhausting a gas from the plasma processing space 100s, and a bypass line 170 that detours the exhaust line 160.

[0038]

An upstream end of the exhaust line 160 is connected to an exhaust port 100e provided in, for example, a bottom portion of the plasma processing chamber 100. A pump is interposed in the exhaust line 160, and specifically, for example, a turbo molecular pump 161 as a first exhaust pump and a dry pump 162 as a second exhaust pump are interposed in this order from an upstream side.

In one embodiment, an automatic pressure control (APC) valve 163 is interposed upstream of the turbo molecular pump 161 in the exhaust line 160. A shutoff valve 164 is provided between the turbo molecular pump 161 and the dry pump 162 in the exhaust line 160. The automatic pressure control valve 163 has, for example, a block function in addition to an automatic pressure control function.

[0039]

The bypass line 170 detours around the exhaust line 160 as described above. The bypass line 170 specifically detours around an upstream side of the exhaust line 160, and more specifically detours around a portion of the exhaust line 160 where the turbo molecular pump 161 is provided. An upstream end of the bypass line 170 is connected to a position in the exhaust line 160 upstream of the turbo molecular pump 161, and specifically, upstream of the automatic pressure control valve 163 in the exhaust line 160. For example, a downstream end of the bypass line 170 is connected between the turbo molecular pump 161 and the dry pump 162 in the exhaust line 160, and more specifically, is connected between the shutoff valve 164 and the dry pump 162 in the exhaust line 160. With this configuration, it is possible to exhaust the gas from the plasma processing space 100s through the bypass line 170.

[0040]

A trap 171 for retrieving the heat transfer layer D in a gas form contained in the exhaust of the plasma processing space 100s is provided in the bypass line 170. The heat transfer layer D in a gas form retrieved in the trap 171 is at least one of the raw material gas of the heat transfer layer D and a vaporized matter of the heat transfer layer D.

In one embodiment, a shutoff valve 172 is provided upstream of the trap 171 in the bypass line 170. A pressure control valve 173 and a shutoff valve 174 are provided in this order downstream of the bypass line 170 from an upstream side.

[0041]

The plasma processing apparatus 1 further includes a controller 200. In one embodiment, the controller 200 processes computer-executable instructions to cause the plasma processing apparatus 1 to perform various steps to be described in the present disclosure. The controller 200 may be configured to control other elements of the plasma processing apparatus 1 to execute various steps described herein. In one embodiment, a part or the whole controller 200 may be provided in the plasma processing apparatus 1. The controller 200 may include a processor 211, a storage unit 212, and a communication interface 213. The controller 200 is implemented by, for example, a computer 210. The processor 211 may be configured to read a program from the storage unit 212 and execute various control operations by executing the read program. The program may be stored in advance in the storage unit 212, or may be acquired via a medium when necessary. The acquired program is stored in the storage unit 212, and is read from the storage unit 212 and executed by the processor 211. The medium may be various recording media readable by the computer 210, or may be a communication line connected to the communication interface. The processor 211 may be a central processor unit (CPU), or may be one or more circuits. The storage unit 212 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 thereof. The communication interface 213 may communicate with the plasma processing apparatus 1 via a communication line such as a local area network (LAN).

[0042]

Wafer Processing in Plasma Processing Apparatus 1

Next, an example of wafer processing performed by using the plasma processing apparatus 1 will be described with reference to FIGS. 2 to 9. FIG. 2 is a flowchart illustrating an example of the wafer processing described above. FIGS. 3 to 6, 8, and 9 are diagrams illustrating a state of the plasma processing apparatus 1 during the wafer processing. In FIGS. 3 to 6, 8 and 9, valves in an open state are illustrated in white, valves in a closed state are illustrated in black, and pipes, such as exhaust lines through which a liquid or a gas flows, are illustrated by thick lines. FIG. 7 is a graph illustrating a vapor pressure curve of a constituent

material of the heat transfer layer D.

[0043]

The wafer processing described below is performed under the control of the controller 200. During the wafer processing, a temperature Tt (specifically, a temperature of a space in which the gas is liquefied and retrieved) of the trap 171 is maintained at a temperature at which the heat transfer layer D in a gas form is easily liquefied, for example, at a set temperature determined in advance within a range of -100°C to 25°C. During the wafer processing, a temperature Ts (specifically, the temperature of the wafer placement surface 104_1) of the wafer support 101 is maintained at a temperature during the plasma processing, for example, at a set temperature determined in advance within a range of -80°C to 80°C. During the wafer processing, the sidewall of the plasma processing chamber (hereinafter referred to as a "processing chamber") 100 that defines the plasma processing space (hereinafter referred to as a "processing space") 100s, or the upper electrode 102 is maintained at a temperature at which the heat transfer layer D in a gas form is difficult to be liquefied, for example, at a set temperature determined in advance within a range of 25°C to 150°C.

[0044]

Step S1: Formation of Heat Transfer Layer

For example, first, as illustrated in FIG. 2, the heat transfer layer D is formed on the wafer placement surface 104_1 of the wafer support 101.

[0045]

In the present embodiment, as illustrated in FIG. 7, at a temperature T1, the constituent material of the heat transfer layer D is a liquid at a pressure P2, and is a gas at a pressure P1. For practical use, a material in which a range of the temperature T1 is -80°C to 80°C, a range of the pressure P2 is 0.01 Torr to 10 Torr, and a range of the pressure P1 is less than 0.01 Torr is preferred as the constituent material of the heat transfer layer D. An example of the constituent material described above is methyl benzoate.

As to be described later, in the present embodiment, since the wafer W is placed on the wafer placement surface 104_1 via the heat transfer layer D, the heat transfer layer D is formed of a material having a high surface tension in the liquid state such that the heat transfer layer D in the liquid state does not flow around to the surface, such as the upper surface, of the wafer W during the placement. The term "liquid" includes a sol or gel in which the liquid is used as a dispersion medium.

[0046]

The raw material gas of the heat transfer layer D includes, for example, at least one of boron (B) and carbon (C), which are constituent atoms of the heat transfer layer D, and at least one of hydrogen (H), nitrogen (N), and oxygen (O), which constitute a gas component. The raw

material gas of the heat transfer layer D preferably contains a component that does not interfere with the plasma processing.

[0047]

In the formation of the heat transfer layer D, specifically, first, the gas is exhausted from an interior of the processing chamber 100, that is, from the processing space 100s.

More specifically, as illustrated in FIG. 3, the automatic pressure control valve 163 in the exhaust line 160 is fully opened and the shutoff valve 164 is opened, in a state in which the processing gas is not supplied from the gas supply 120 and the heat transfer layer formation gas is not supplied from the gas supply 130. Accordingly, the turbo molecular pump 161 and the dry pump 162 perform exhaust from the interior of the processing chamber 100, that is, from the processing space 100s. The interior of the processing chamber 100 is depressurized to, for example, an attainable vacuum degree.

At this time, the shutoff valve 172, the pressure control valve 173, and the shutoff valve 174 provided in the bypass line 170 are closed. That is, the processing space 100s is not exhausted through the bypass line 170.

[0048]

Next, the wafer W is loaded into the processing chamber 100.

Specifically, for example, as illustrated in FIG. 4, the automatic pressure control valve 163 and the shutoff valve 164 in the exhaust line 160 are switched to be closed such that exhaust of the processing space 100s through the exhaust line 160 stops. The shutoff valves 172 and 174 in the bypass line 170 are opened, and the pressure control valve 173 is fully opened. That is, exhaust of the processing space 100s through the bypass line 170 starts.

Thereafter, the wafer W is loaded into the processing chamber 100 by a transfer mechanism (not illustrated) outside the plasma processing apparatus 1, and is delivered to the raised lifters 107. After the delivery, the transfer mechanism retracts from the interior of the processing chamber 100.

[0049]

Subsequently, the raw material gas of the heat transfer layer D is supplied into the processing chamber 100.

Specifically, for example, as illustrated in FIG. 5, in a state in which the wafer W is supported by the lifters 107 and separated from the wafer placement surface 104_1 of the wafer support 101, and exhaust of the processing space 100s is performed through the bypass line 170, the heat transfer layer formation gas containing the raw material gas is supplied from the gas supply 130. In this case, in the illustrated example, the processing gas is not supplied from the gas supply 120. By supplying the heat transfer layer formation gas, an atmosphere in the processing space 100s is replaced by the heat transfer layer formation gas. During this

replacement, a pressure value in the processing space 100s is set to P1, and the temperature (specifically, the temperature of the wafer placement surface 104_1) Ts of the wafer support 101 is set to T1. The pressure value P1 is a pressure value at which the raw material gas of the heat transfer layer D is less than a saturation vapor pressure at the temperature T1. For example, the temperature T1 is -80°C to 80°C, and the P1 is less than 0.01 Torr. The temperature Ts of the wafer support 101 is set by the temperature adjuster of the wafer support 101, and the pressure in the processing space 100s is set by adjusting at least one of the flow rate of the heat transfer layer formation gas or an exhaust amount through the bypass line 170 (specifically, an opening degree of the pressure control valve 173).

[0050]

In the replacement described above, the raw material gas of the heat transfer layer D in the heat transfer layer formation gas that has reached the bypass line 170 is condensed and retrieved by the trap 171.

The temperature of the trap 171 is set to Tt to condense the raw material gas of the heat transfer layer D by the trap 171. The temperature Tt is a temperature lower than a temperature at which the raw material gas liquefies under the pressure P1, and is also a temperature lower than the temperature T1 (Ts).

[0051]

Thereafter, the pressure in the processing chamber 100 is increased to form the heat transfer layer D in a liquid form on the wafer placement surface 104_1 of the wafer support 101.

Specifically, for example, as illustrated in FIG. 6, the shutoff valves 172 and 174 in the bypass line 170 are switched to be closed in a state in which the wafer W is supported by the lifters 107 and separated from the wafer placement surface 104_1 of the wafer support 101, and the heat transfer layer formation gas is supplied from the gas supply 130. Accordingly, the exhaust of the processing space 100s, including the exhaust through the bypass line 170, stops, and the pressure value in the processing space 100s is increased to P2. The pressure value P2 is a pressure value higher than the saturation vapor pressure of the raw material gas of the heat transfer layer D at the temperature Ts of the wafer support 101, and is, for example, 0.01 Torr to 10 Torr. As a result of the pressure increase, the raw material gas of the heat transfer layer D is condensed on a surface of the wafer support 101, and the heat transfer layer D in a liquid form is at least formed on the wafer placement surface 104_1. After the heat transfer layer D is formed, the supply of the heat transfer layer formation gas from the gas supply 130 is stopped.

[0052]

A temperature of a region other than the wafer placement surface 104_1 may be set to Tw to prevent the heat transfer layer D from being formed in the region other than the wafer placement surface 104_1. For example, heaters may be provided on the sidewall and the upper

electrode 102 of the plasma processing chamber 100 to adjust the temperatures of the sidewall and the upper electrode 102 of the plasma processing chamber 100 to Tw. The temperature Tw is a temperature higher than the temperature at which the raw material gas liquefies under the pressure value P2, and is also a temperature higher than the temperature T1 (Ts).

[0053]

Step S2: Wafer Placement

Then, the wafer W is placed on the wafer placement surface 104_1 of the wafer support 101.

[0054]

Specifically, for example, first, the lifters 107 are lowered, and the wafer W is placed on the wafer placement surface 104_1 of the electrostatic chuck 104 via the heat transfer layer D in a liquid form as illustrated in FIG. 8.

Next, the heat transfer layer D formed on a portion of the wafer support 101 other than the wafer placement surface 104_1 is removed. Specifically, the shutoff valves 172 and 174 in the bypass line 170 are switched to be open such that exhaust of the processing space 100s through the bypass line 170 is performed. The pressure in the processing space 100s is less than the saturation vapor pressure of the raw material gas of the heat transfer layer D at the set temperature of the wafer placement surface 104_1 of the wafer support 101 by exhaust of the processing space 100s through the bypass line 170. For example, the pressure value in the processing space 100s is set to P1 while maintaining the temperature Ts of the wafer placement surface 104_1 at T1. Accordingly, the heat transfer layer D formed on a portion other than the wafer placement surface 104_1 is exposed to the vacuum environment, and as a result, is evaporated and removed. In this case, the wafer W may be fixed to the wafer placement surface 104_1 to prevent evaporation of the heat transfer layer D formed on the wafer placement surface 104_1. Specifically, a direct-current voltage may be applied to the electrode 109 of the electrostatic chuck 104 such that the wafer W is electrostatically attracted by the electrostatic force to the electrostatic chuck 104.

[0055]

When the heat transfer layer D is removed, a vaporized matter of the heat transfer layer D that has reached the bypass line 170 is condensed and retrieved by the trap 171.

The temperature of the trap 171 is set to Tt to condense the vaporized matter of the heat transfer layer D by the trap 171. The temperature Tt is a temperature lower than a temperature at which the raw material gas liquefies under the pressure P1, and is also a temperature lower than the temperature T1 (Ts).

[0056]

Step S3: Plasma Processing

Thereafter, the plasma processing such as etching or film formation is performed on the wafer W on the wafer placement surface 104_1 on which the heat transfer layer D is formed.

[0057]

Specifically, as illustrated in FIG. 9, first, the shutoff valves 172 and 174 in the bypass line 170 are switched to be open, and the shutoff valve 164 in the exhaust line 160 is switched to be open, such that the exhaust of the processing space 100s through the bypass line 170 stops, and the exhaust of the processing space 100s through the exhaust line 160 starts.

Then, the processing gas is supplied from the gas supply 120 into the processing space 100s by the upper electrode 102, and a radio-frequency power HF for plasma generation is supplied from the RF power supply 140 to the lower electrode 103. Accordingly, the processing gas is excited, and a plasma P is generated. Then, a radio-frequency power LF for ion extraction may be supplied from the RF power supply 140. Then, the plasma processing is performed on the wafer W by an action of the generated plasma P.

[0058]

During the plasma processing, the wafer placement surface 104_1 is adjusted to a predetermined temperature by the temperature-controlled fluid flowing through the flow path 108 to control the temperature of the wafer W. During the plasma processing, since the wafer W is placed on the wafer placement surface 104_1 via the heat transfer layer D in a liquid form, and the heat transfer layer D is formed of a deformable liquid, a lower surface, that is, a back surface of the wafer W is in close contact with the heat transfer layer D. Since the heat transfer layer D is a liquid, it has higher thermal conductivity than a heat transfer gas such as He. Therefore, when the heat transfer layer D in a liquid form is used, it is possible to efficiently adjust the temperature of the wafer W via the wafer placement surface 104_1, as compared with a case in which a heat transfer gas such as He flows between the wafer placement surface 104_1 and the back surface of the wafer W in the related art. Specifically, even when the heat input from the plasma P to the wafer W is large during the plasma processing, it is possible to maintain the temperature of the wafer W to be constant by the temperature control of the wafer placement surface 104_1.

[0059]

During the plasma processing, to make the heat transfer layer D and the lower surface of the wafer W to be closer contact with each other, the wafer W may be held, that is, fixed to the wafer support 101 (specifically, the wafer placement surface 104_1). For example, the wafer W may be attracted and held on the wafer placement surface 104_1 by the electrostatic force generated by the electrostatic chuck 104. More specifically, the direct-current voltage may be applied to the electrode 109 of the electrostatic chuck 104 such that the wafer W is electrostatically attracted by the electrostatic force to the electrostatic chuck 104. By being held

as described above, the temperature of the wafer W can be adjusted more efficiently.

When the wafer W is held on the wafer support 101 by the electrostatic force, a degree of close contact between the wafer W and the wafer support 101 may be controlled by the electrostatic force, thereby controlling an amount of heat removed from the wafer W by the wafer support 101.

[0060]

Similarly, during the plasma processing, the edge ring E may be held, that is, fixed to the wafer support 101. For example, a direct-current voltage may be applied to an electrode for edge ring-attracting (not illustrated) provided in the electrostatic chuck 104 such that the edge ring E is electrostatically attracted to the electrostatic chuck 104 by the electrostatic force.

During the plasma processing, the heat transfer gas may be supplied from a gas supply hole (not illustrated) formed in the upper surface 104_2 of the peripheral edge of the electrostatic chuck 104 toward the back surface of the edge ring E.

[0061]

When the plasma processing is ended, the supply of the radio-frequency power HF from the RF power supply 140 and the supply of the processing gas from the gas supply 130 are stopped. When the radio-frequency power LF is supplied during the plasma processing, the supply of the radio-frequency power LF is also stopped. When the wafer W is attracted and held by the electrostatic chuck 104 during the plasma processing, this attraction and holding is also stopped. In a case in which the edge ring E is attracted and held by the electrostatic chuck 104 and the heat transfer gas is supplied to the back surface of the edge ring E during the plasma processing, at least one of the attraction and holding and the supply may be stopped.

[0062]

Step S4: Wafer Separation

After the plasma processing, the wafer W is separated from the wafer placement surface 104_1.

[0063]

Specifically, for example, as illustrated in FIG. 4, the wafer W is raised by the lifters 107 and separated from the heat transfer layer D on the wafer placement surface 104_1.

The automatic pressure control valve 163 and the shutoff valve 164 in the exhaust line 160 are switched to be closed such that the exhaust of the processing space 100s through the exhaust line 160 is stopped. The shutoff valves 172 and 174 in the bypass line 170 are switched to be open such that the exhaust of the processing space 100s through the bypass line 170 is started.

[0064]

Step S5: Heat Transfer Layer Removal

Then, the heat transfer layer D is removed from the wafer placement surface 104_1 (step S6).

[0065]

Specifically, the exhaust of the processing space 100s through the bypass line 170 is continued, and the pressure in the processing space 100s is set to be less than the saturation vapor pressure of the raw material gas of the heat transfer layer D at the temperature Ts of the wafer support 101. Accordingly, the heat transfer layer D formed on the wafer placement surface 104_1 is exposed to the vacuum environment, and as a result, is evaporated and removed.

When the heat transfer layer D is removed, a vaporized matter of the heat transfer layer D that has reached the bypass line 170 is condensed and retrieved by the trap 171.

To condense the vaporized matter of the heat transfer layer D by the trap 171, adjustment is performed as follows. That is, the exhaust amount through the bypass line 170 is adjusted such that the pressure in the trap 171 exceeds the saturation vapor pressure of the raw material gas at the temperature Tt of the trap 171, specifically, 0.01 Torr.

[0066]

When the heat transfer layer D is removed from the wafer placement surface 104_1, the edge ring E may be held, that is, fixed to the wafer support 101. For example, a direct-current voltage may be applied to an electrode for edge ring-attracting (not illustrated) provided in the electrostatic chuck 104 such that the edge ring E is electrostatically attracted to the electrostatic chuck 104 by the electrostatic force.

When the heat transfer layer D is removed from the wafer placement surface 104_1, the heat transfer gas may be supplied from a gas supply hole (not illustrated) formed in the upper surface 104_2 of the peripheral edge of the electrostatic chuck 104 toward the back surface of the edge ring E.

[0067]

Step S6: wafer Unload

Thereafter, the wafer W is unloaded from the processing chamber 100.

Specifically, for example, in a state in which the exhaust of the processing space 100s through the bypass line 170 is continued, the wafer W is delivered to a transfer mechanism (not illustrated) outside the plasma processing apparatus 1 by the lifters 107, and then is unloaded from the processing chamber 100 by the transfer mechanism.

Thereafter, the processing returns to step S1, and the exhaust of the processing space 100s through the exhaust line 160 is performed. For example, the interior of the processing chamber 100 is depressurized to an attainable vacuum degree.

In this way, a series of wafer processing is completed.

[0068]

Other Examples of Heat Transfer Layer D

In the example described above, the heat transfer layer D in a liquid form is formed by condensing (liquefying) the raw material gas of the heat transfer layer D. However, the heat transfer layer D may be a solid layer as long as it is deformable. That is, the heat transfer layer D in a solid form, which is deformable, may be formed by subliming (solidifying) the raw material gas of the heat transfer layer D. Here, “deformable” means being deformable under a weight of the wafer W. When the wafer W is electrostatically attracted by the electrostatic chuck 104, “deformable” may mean being deformable when an electrostatic attraction force is applied to the wafer W.

The heat transfer layer D may be a combination of a liquid layer and a solid layer as long as it is deformable.

[0069]

That is, the heat transfer layer D is a layer formed of at least one of a liquid layer and a solid layer, and is deformable. The heat transfer layer D may be a solid layer in which the uppermost layer, which is deformable, in contact with the back surface of the wafer W is formed by a liquid layer, a solid layer, or a combination thereof, and other portions are non-deformable.

[0070]

A solid constituting the heat transfer layer D may have an elastic coefficient allowing deformation by the weight of the wafer W, and may also have an elastic coefficient allowing deformation when the electrostatic attraction force is applied to the wafer W. More specifically, the solid constituting the heat transfer layer D is, for example, an elastic polymer substance, that is, an elastomer.

[0071]

Effects

As described above, in the present embodiment, the deformable heat transfer layer D formed by at least one of a liquid layer and a solid layer is formed on the wafer placement surface 104_1 of the wafer support 101, and the plasma processing is performed on the wafer W on the wafer placement surface 104_1 on which the heat transfer layer D is formed. Since the heat transfer layer D is formed by at least one of the liquid layer and the solid layer, the heat transfer layer D has higher thermal conductivity than a heat transfer layer formed of the heat transfer gas, that is, a gas. Since the heat transfer layer D is deformable, the heat transfer layer D can be in close contact with the lower surface of the wafer W. Accordingly, according to the present embodiment, heat exchange can be efficiently performed between the wafer W and the wafer placement surface 104_1 via the heat transfer layer D. Therefore, the temperature of the wafer W can be efficiently adjusted via the wafer placement surface 104_1 during the plasma processing. Specifically, during the plasma processing, heat can be efficiently taken from the

wafer W via the heat transfer layer D by the wafer placement surface 104_1, or the wafer W can be efficiently heated via the heat transfer layer D by the wafer placement surface 104_1.

In the present embodiment, the bypass line 170, which detours around the exhaust line 160 through which exhaust of the processing space 100s is performed is provided. The trap 171 that retrieves the heat transfer layer D in a gas form included in the exhaust of the processing space 100s is provided in the bypass line 170. Therefore, the heat transfer layer in a gas form can be prevented from reaching the pumps in the exhaust line 160. Therefore, the heat transfer layer in a gas form can be prevented from adversely affecting the pumps in the exhaust line 160. Since a frequency of cleaning the pumps in the exhaust line 160 can be reduced compared to a case in which the bypass line 170 is not provided, improvement in throughput can be achieved.

[0072]

Specific Example of Wafer Placement Surface 104_1

FIGS. 10 and 11 are partially-enlarged cross-sectional views of the wafer placement surface 104_1.

For example, the entire wafer placement surface 104_1 is formed flat as illustrated in FIG. 10. The wafer placement surface 104_1 may be subjected to a roughening treatment as illustrated in FIG. 11. In this case, the roughening treatment is applied to the entire wafer placement surface 104_1, and a surface roughness of a portion subjected to the roughening treatment has, for example, an arithmetic mean roughness Ra of 1 μm to 10 μm. In the portion subjected to the roughening treatment, a surface area increases, and heat of the wafer placement surface 104_1 is more efficiently transferred to the wafer W via the heat transfer layer D. Therefore, the temperature of the wafer W can be adjusted more efficiently via the heat transfer layer D and the wafer placement surface 104_1.

The roughening treatment is performed, for example, by shot blasting or laser processing.

[0073]

As to be described later, the heat transfer layer D may be formed of a heat transfer medium formed of at least one of a liquid medium or a solid medium having fluidity. In this case, an annular projection concentric with the wafer placement surface 104_1 may be provided along a peripheral edge of the wafer placement surface 104_1 to prevent the heat transfer medium from leaking out of the wafer placement surface 104_1. In this embodiment, the roughening treatment may be performed only on a portion of the wafer placement surface 104_1 except for the peripheral edge where the annular projection is formed, that is, only on a portion where the heat transfer layer D is formed. Even when the annular projection is not provided, a portion subjected to the roughening treatment and a portion not subjected to the roughening treatment

may be provided on the wafer placement surface 104_1. For example, the central portion of the wafer placement surface 104_1 may be a region not subjected to the roughening treatment, and a peripheral portion thereof may be a region subjected to the roughening treatment. Accordingly, it is possible to provide a difference in temperature between the central portion and the peripheral portion of the wafer.

[0074]

Other Examples of Bypass Line 170

FIG. 12 is a diagram illustrating another example of the bypass line 170.

As illustrated in FIG. 12, a return line 180 may be connected to the bypass line 170. The return line 180 is configured to return the raw material gas of the heat transfer layer D retrieved by the trap 171 to the gas supply 130. Specifically, the return line 180 is configured to return the raw material liquid of the heat transfer layer D generated by condensing the raw material gas of the heat transfer layer D by the trap 171 back into the tank 131a of the gas supply 130. The return line 180 may be provided with a pump 181 that suctions the raw material liquid of the heat transfer layer D in the trap 171 and pressurizing the raw material liquid to the tank 131a of the gas supply 130. A filter 182 that removes foreign substances from the raw material liquid of the heat transfer layer D may be provided in the return line 180.

[0075]

The return of the raw material liquid of the heat transfer layer D from the trap 171 to the tank 131a is performed at a timing when the trap 171 does not communicate with the processing space 100s. Examples of the timing described above include during idling of the plasma processing apparatus 1 or during the plasma processing.

[0076]

By providing the return line 180 as described above, it is possible to effectively utilize the retrieved raw material gas of the heat transfer layer D.

[0077]

Modification of Form in Which Raw Material Gas is Condensed

FIGS. 13 to 15 are diagrams illustrating other examples of a form in which the raw material gas of the heat transfer layer D is condensed on the surface of the wafer support 101.

In the example described above, after replacing the atmosphere in the processing space 100s with the heat transfer layer formation gas, the supply of the heat transfer layer formation gas from the gas supply 130 is performed without supplying the processing gas from the gas supply 120, in a state in which exhaust of the processing space 100s is stopped, including exhaust through the bypass line 170. Accordingly, the pressure in the processing space 100s is increased, and the raw material gas of the heat transfer layer D is condensed on the surface of the wafer support 101. In this form, since the heat transfer layer formation gas is not exhausted

from the processing space 100s when forming the heat transfer layer D, it is possible to efficiently form the heat transfer layer D from the raw material gas of the heat transfer layer D supplied into the processing space 100s.

[0078]

The form in which the raw material gas of the heat transfer layer D is condensed on the surface of the wafer support 101 is not limited thereto. For example, as illustrated in FIG. 13, when the heat transfer layer D is formed, an inert gas (for example, a N_2 gas) may be supplied from the gas supply 120, in addition to supplying the heat transfer layer formation gas from the gas supply 130, in a state in which the exhaust of the processing space 100s is stopped, including exhaust through the bypass line 170. Even in this form, the pressure in the processing space 100s can be increased, and the raw material gas of the heat transfer layer D can be condensed on the surface of the wafer support 101. Specifically, even in this form, the raw material gas of the heat transfer layer D can be condensed on the surface of the wafer support 101, and the heat transfer layer D in the liquid form can be formed at least on the wafer placement surface 104_1 by increasing the pressure in the processing space 100s until it exceeds the saturation vapor pressure of the raw material gas of the heat transfer layer D at the temperature Ts of the wafer support 101. Even in this form, the heat transfer layer D can be efficiently formed from the raw material gas of the heat transfer layer D supplied into the processing space 100s.

[0079]

After the atmosphere in the processing space 100s is replaced with the heat transfer layer formation gas, as illustrated in FIG. 14, both the inert gas from the gas supply 120 and the heat transfer layer formation gas from the gas supply 130 may be supplied into the processing space 100s, in a state in which exhaust of the processing space 100s through the exhaust line 160 is not performed but exhaust through the bypass line 170 is performed. Even in this form, the pressure in the processing space 100s can be increased, and the raw material gas of the heat transfer layer D can be condensed on the surface of the wafer support 101. Specifically, even in this form, the raw material gas of the heat transfer layer D can be condensed on the surface of the wafer support 101, and the heat transfer layer D in the liquid form can be formed at least on the wafer placement surface 104_1 by increasing the pressure in the processing space 100s until it exceeds the saturation vapor pressure of the raw material gas of the heat transfer layer D at the temperature Ts of the wafer support 101.

In this form, it is difficult for the pressure in the supply path that connects the gas supply 130 and the processing chamber 100 to increase even when the pressure in the processing space 100s increases. Therefore, condensation of the raw material gas of the heat transfer layer D on an inner wall surface of the supply path can be prevented.

[0080]

After the atmosphere in the processing space 100s is replaced with the heat transfer layer formation gas, as illustrated in FIG. 15, only the inert gas from the gas supply 120 may be supplied into the processing space 100s, in a state in which exhaust of the processing space 100s through the exhaust line 160 is not performed but exhaust of the processing space 100s through the bypass line 170 is performed. Even in this form, the pressure in the processing space 100s can be increased, and the raw material gas of the heat transfer layer D can be condensed on the surface of the wafer support 101. Specifically, even in this form, the raw material gas of the heat transfer layer D can be condensed on the surface of the wafer support 101, and the heat transfer layer D in the liquid form can be formed at least on the wafer placement surface 104_1 by increasing the pressure in the processing space 100s until it exceeds the saturation vapor pressure of the raw material gas of the heat transfer layer D at the temperature Ts of the wafer support 101.

In this form, the pressure in the processing space 100s can be adjusted not only by the opening degree of the pressure control valve 173 downstream of the trap 171 but also by the flow rate of the inert gas from the gas supply 120, that is, the flow rate of the inert gas from the upper electrode 102. Since the upper electrode 102 is closer to the processing space 100s than the pressure control valve 173, responsiveness of the pressure adjustment in the processing space 100s can be improved in this form.

In this form, at a timing when the pressure in the processing space 100s increases, the supply path that connects the gas supply 130 and the processing chamber 100 is separated from the processing space 100s. Therefore, it is possible to prevent condensation of the raw material gas of the heat transfer layer D on the inner wall surface of the supply path at the timing when pressure in the processing space 100s increases.

[0081]

A heater (not illustrated) having a small heat capacity and being thin may be provided in a portion in the vicinity of the wafer placement surface 104_1 of the wafer support 101, for example, inside the electrostatic chuck 104, and it may be as follows.

That is, when the atmosphere in the processing space 100s is replaced with the heat transfer layer formation gas, the wafer placement surface 104_1 may be heated by the thin heater while cooling the entire electrostatic chuck 104 with low-temperature brine circulating through the flow path 108. In a stage of forming the heat transfer layer D, heating by the thin heater may be stopped while maintaining cooling of the entire electrostatic chuck 104. Accordingly, the temperature of the wafer placement surface 104_1 is instantaneously lowered. Therefore, it is possible to condense the raw material gas of the heat transfer layer D on the wafer placement surface 104_1 to form the heat transfer layer D. In this form, when the wafer W is placed on the

wafer placement surface 104_1 via the heat transfer layer D and the plasma processing is performed, the heating by the thin heater is restarted to adjust the temperature of the wafer placement surface 104_1 to a suitable temperature for the plasma processing.

[0082]

Modification 1 of Gas supply of Heat Transfer Layer Formation Gas

FIG. 16 is a diagram illustrating Modification 1 of the gas supply of the heat transfer layer formation gas.

As described above, the gas supply 130 of the heat transfer layer formation gas may include the flow rate controller 132. The gas supply of the heat transfer layer formation gas may include an automatic pressure control (APC) valve 133 as a pressure control valve instead of the flow rate controller 132, as a gas supply 130A in FIG. 16. The automatic pressure control valve 133 has, for example, a block function in addition to the automatic pressure control function. The gas supply of the heat transfer layer formation gas can control an amount of the raw material gas contained in the heat transfer layer formation gas supplied into the processing chamber 100 by including the flow rate controller 132 or the automatic pressure control valve 133.

[0083]

Modification 2 of Gas supply of Heat Transfer Layer Formation Gas

In the example described above, the mixed gas of the raw material gas and the carrier gas is supplied as the heat transfer layer formation gas from the gas source 131 including the tank 131a that stores the raw material liquid of the heat transfer layer D in the gas supply of the heat transfer layer formation gas. That is, the carrier gas is used for introducing the raw material gas into the processing chamber 100. However, the raw material gas may be introduced into the processing chamber 100 without using the carrier gas. In this case, for example, after the raw material liquid is vaporized by depressurization or the like in the tank 131a to generate the raw material gas, a valve (for example, the automatic pressure control valve 133) that separates the tank 131a and the processing chamber 100 is opened, and the raw material gas is then introduced from the tank 131a into the processing chamber 100 due to a pressure difference between the tank 131a and the processing chamber 100. When this introduction is performed, the exhaust of the processing chamber 100 may be stopped (that is, both of the automatic pressure control valve 163 and the shutoff valve 172 are closed), or may be performed (that is, only the shutoff valve 172 of the automatic pressure control valve 163 and the shutoff valve 172 is closed).

[0084]

Modification of Supply Form of Raw Material Gas

In the example described above, the supply of the raw material gas into the processing space 100s is performed through the sidewall of the processing chamber 100, but may be

performed through a wall body defining the processing space 100s different from the sidewall of the processing chamber 100. For example, the heat transfer layer formation gas containing the raw material gas may be supplied by the upper electrode 102 also used for supplying the processing gas. In this case, a gas outlet for supplying the processing gas and a gas outlet for supplying the heat transfer layer formation gas may be different or the same in the upper electrode 102.

[0085]

The supply of the raw material gas into the processing space 100s may be performed through a wafer support that supports the wafer W or a lifter that moves the wafer W up and down.

[0086]

Modification of Form in which Heat Transfer Layer D is Formed from Raw Material Gas

In the example described above, at least one of liquefaction or solidification (for example, condensation or sublimation) of the raw material gas is used to form the heat transfer layer D. However, the form in which the heat transfer layer D is formed from the raw material gas is not limited thereto. For example, the heat transfer layer D may be formed from the raw material gas using the plasma.

[0087]

Alternatively, the heat transfer layer D may be formed such that at least one of liquefaction or solidification of the raw material gas is generated by irradiating the raw material gas in the processing space 100s with a light.

[0088]

Modification of Form in which Heat Transfer Layer D Formed on Portion other than Wafer Placement Surface 104_1 is Removed

In the example described above, the heat transfer layer D formed on a portion other than the wafer placement surface 104_1 is removed by being exposed to a vacuum environment. However, a removal form is not limited thereto.

[0089]

For example, the heat transfer layer D formed on a portion other than the wafer placement surface 104_1 may be removed by using the plasma. Alternatively, the heat transfer layer D formed on a portion other than the wafer placement surface 104_1 may be irradiated with the light to vaporize and selectively remove the heat transfer layer D.

[0090]

Modification of Form in which Heat Transfer Layer D Formed on Wafer Placement Surface 104_1 is Removed

In the example described above, the heat transfer layer D formed on the wafer

placement surface 104_1 is removed by being exposed to a vacuum environment. However, a removal form is not limited thereto.

[0091]

For example, the heat transfer layer D formed on the wafer placement surface 104_1 may be removed by using the plasma. Alternatively, the heat transfer layer D formed on the wafer placement surface 104_1 may be irradiated with the light to vaporize and selectively remove the heat transfer layer D. The heat transfer layer D formed on the wafer placement surface may be vaporized and removed by heating the wafer placement surface 104_1 with the thin heater described above.

[0092]

Other Examples of State in Processing Chamber 100 when Heat Transfer Layer D is Formed

In the example described above, when forming the heat transfer layer D, the wafer W is positioned in the processing chamber 100. However, the wafer W may not be positioned in the processing chamber 100.

[0093]

Other Examples of Raw Material of Heat Transfer Layer D

In the example described above, the raw material of the heat transfer layer D supplied on the wafer placement surface 104_1 is a gas. However, the raw material of the heat transfer layer D may be a heat transfer medium formed by at least one of a liquid medium or a solid medium having fluidity.

[0094]

In this case, as illustrated in FIG. 17, the heat transfer medium is supplied to a wafer placement surface $104B_1$ via) a wafer support 101B. Specifically, for example, the heat transfer medium is supplied to a central portion of the wafer placement surface $104B_1$ through a supply port 300 formed in the wafer placement surface $104B_1$. A plurality of the supply ports 300 may be provided in the wafer placement surface $104B_1$.

[0095]

In this case, a flow path 310 is provided inside the wafer support 101B, with one end thereof in fluid communication with the supply port 300. The other end of the flow path 310 is fluidly connected to, for example, a gas supply 130B. The flow path 310 is formed such that an end on a wafer placement surface $104B_1$ side (specifically, for example, a portion positioned inside an electrostatic chuck 104B) is narrow. The heat transfer medium in the flow path 310 is supplied to the wafer placement surface $104B_1$ through the supply port 300 by capillary action. The flow path 310 is formed, for example, to span the electrostatic chuck 104B, a lower electrode 103B, and an insulator 105B.

[0096]

The gas supply 130B may include one or more gas sources 131B and one or more flow rate controllers 132B. In one embodiment, for example, the gas supply 130EB is configured to supply, from the corresponding gas sources 131B, one or more gases for generating the heat transfer medium described above (hereinafter referred to as heat transfer medium generation gases) to the wafer support 101B through the corresponding flow rate controllers 132B. For example, each of the flow rate controllers 132B may include a mass flow controller or a pressure-controlled flow rate controller. The gas supply 130B may further include one or more flow rate modulation devices that modulate or pulse flow rates of the one or more heat transfer medium generation gases.

[0097]

The heat transfer medium generation gas supplied from the gas supply 130B is cooled by, for example, the lower electrode 103B that is cooled with a temperature-controlled fluid in the flow path 310, is liquefied or solidified, and changes to a heat transfer medium formed by at least one of a liquid medium and a solid medium having fluidity. As described above, the heat transfer medium is supplied to the wafer placement surface $104B_1$ through the supply port 300 by capillary action, and the heat transfer layer D is formed. Therefore, the gas supply 130B can function as at least a part of a heat transfer layer former configured to form the heat transfer layer D on the wafer placement surface $104B_1$.

[0098]

In this example, for example, in a state in which the wafer W is supported on the wafer support 101B, the heat transfer medium is supplied to the wafer placement surface $104B_1$ to form, on the wafer placement surface $104B_1$, the deformable heat transfer layer D formed by at least one of the liquid layer and the solid layer.

[0099]

Specifically, first, for example, in the state in which the wafer W is supported on the wafer support 101B, the heat transfer medium generation gas is supplied from the gas supply 130B to the flow path 310 of the wafer support 101B. The heat transfer medium generation gas supplied to the flow path 310 is cooled in the flow path 310, and becomes the heat transfer medium formed by at least one of the liquid medium and the solid medium having fluidity. Then, for example, the heat transfer medium is supplied to the wafer placement surface $104B_1$ through the supply port 300 by capillary action.

After the heat transfer medium is supplied by a predetermined amount on the wafer placement surface $104B_1$, a direct-current voltage is applied to the electrode 109 of the electrostatic chuck 104B. Accordingly, the wafer W is electrostatically attracted to the electrostatic chuck 104B by the electrostatic force. At the same time, the heat transfer medium sandwiched between the wafer W and the electrostatic chuck 104B spreads along the wafer

placement surface $104B_1$ to form the heat transfer layer D.

[0100]

Modification of the Supply Form of Heat Transfer Medium

In the example described above, the heat transfer medium generation gas is supplied from outside to the wafer support 101B and changes into the heat transfer medium in the wafer support 101B. Alternatively, the heat transfer medium may be directly supplied from outside to the wafer support 101B.

[0101]

In the example described above, the supply of the heat transfer medium in the wafer support 101B to the wafer placement surface $104B_1$ is performed by capillary action. Alternatively, the heat transfer medium may be supplied to the wafer placement surface $104B_1$ of the wafer support 101B by a supply pressure of the heat transfer medium generation gas from outside to the wafer support 101B or a supply pressure of the heat transfer medium from outside to the wafer support 101B.

[0102]

Modification of Electrode of Electrostatic Chuck and Spreading Method of Heat Transfer Medium

FIGS. 18 and 19 are a plan view and a sectional view schematically illustrating a modification of an electrode of the electrostatic chuck.

In the example described above, a single electrode 109 is provided in the electrostatic chuck 104 to span between the central portion and the outer peripheral portion of the electrostatic chuck 104. Instead of this, as in an electrostatic chuck 104C illustrated in FIGS. 18 and 19, a plurality (three in the example of the drawing) of circular electrodes 109C viewed in plan may be disposed concentrically with respect to a center of the electrostatic chuck 104C. In the following description, the three electrodes 109C in the drawing may be referred to as an electrode 109C1, an electrode 109C2 and an electrode 109C3 from a center side of the electrostatic chuck 104C.

[0103]

Among the electrodes 109C, the electrode 109C provided in the central portion of the electrostatic chuck 104C may be closer to the wafer placement surface $104B_1$ than the electrode 109C provided in the outer peripheral portion of the electrostatic chuck 104C. In the example illustrated, the electrode 109C1 has a small distance to the wafer placement surface $104B_1$, whereas the electrodes 109C2 and C3 have small distances to the wafer placement surface $104B_1$.

In the example in the drawing, a common direct-current power supply (not illustrated) is provided for the three electrodes 109C, and switches 320 and 321 are provided to switch an

application destination of a voltage from the direct-current power supply. When the switch 320 is turned off, the voltage from the direct-current power supply is applied only to the electrode 109C1. When the switch 320 is turned on, and the switch 321 is turned off, the voltage from the direct-current power supply is applied to the electrodes 109C1 and 109C2. When both of the switches 320 and 321 are turned on, the voltage from the direct-current power supply is supplied to the electrodes 109C1, 109C2, and 109C3.

[0104]

For example, when a distance from the electrode 109C to the wafer placement surface $104B_1$ is smaller at the central portion of the electrostatic chuck 104 than at the outer peripheral portion thereof, when forming the heat transfer layer D, first, the voltage from the direct-current power supply is supplied only to the electrode 109C provided in the central portion of the electrostatic chuck 104. Accordingly, a central portion of the wafer W is attracted by a large electrostatic force to the central portion of the electrostatic chuck 104The heat transfer medium supplied to the central portion of the wafer placement surface $104B_1$ spreads up to an outer periphery of the wafer placement surface $104B_1$. Thereafter, the voltage from the direct-current power supply is also applied to the electrode 109C provided at the outer peripheral portion of the electrostatic chuck 104. Accordingly, the heat transfer medium spreading to the outer periphery of the wafer placement surface $104B_1$ spreads outside the wafer placement surface $104B_1$ by a small electrostatic force. Since the heat transfer medium spreads in this manner, it is possible to prevent retention of the heat transfer medium at the central portion of the wafer placement surface $104B_1$. The heat transfer medium spreading outside the wafer placement surface $104B_1$ is vaporized.

[0105]

In the case of the electrostatic chuck 104C illustrated in FIGS. 18 and 19, when forming the heat transfer layer D, it is possible to increase the number of electrodes 109C to which the voltage from the direct-current power supply is applied from a center side of the electrostatic chuck 104C.

[0106]

When the distance from the electrode 109C to the wafer placement surface $104B_1$ is smaller at the central portion of the electrostatic chuck 104C than at the outer peripheral portion thereof, when forming the heat transfer layer D, it may be as follows.

The voltage may be applied to all the electrodes 109C at the same time from a state in which the heat transfer medium is present only in the central portion of the wafer placement surface $104B_1$, that is, a large electrostatic force between the central portion of the wafer placement surface $104B_1$ and the wafer W, and a small electrostatic force between the outer peripheral portion of the wafer placement surface $104B_1$ and the wafer W may act

simultaneously. Even in this way, the heat transfer medium supplied to the central portion of the wafer placement surface $104B_1$ spreads over the outer periphery of the wafer placement surface $104B_1$ by a large electrostatic force, and spreads outside the wafer placement surface $104B_1$ by a small electrostatic force.

[0107]

When the circular electrodes 109C viewed in plan are concentrically disposed with respect to the center of the electrostatic chuck C, the distance to the wafer placement surface $104B_1$ may be equal between the electrodes 109C, and the direct-current power supply may be connected individually to each of the electrodes 109C. In the case of this form, first, a high voltage is applied only to the electrode 109C provided in the central portion of the electrostatic chuck 104. Accordingly, a central portion of the wafer W is attracted by a large electrostatic force to the central portion of the electrostatic chuck 104. The heat transfer medium supplied to the central portion of the wafer placement surface $104B_1$ spreads up to an outer periphery of the wafer placement surface $104B_1$. Thereafter, a low voltage is applied to the electrode 109C provided on the outer peripheral portion of the electrostatic chuck 104. Accordingly, the heat transfer medium spreading to the outer periphery of the wafer placement surface $104B_1$ spreads outside the wafer placement surface $104B_1$ by a small electrostatic force.

In a form in which the distance to the wafer placement surface $104B_1$ is equal between the electrodes 109C and the direct-current power supply is connected individually to each of the electrodes 109C, it may be as follows. That is, when forming the heat transfer layer D, a high voltage may be applied to the electrode 109C provided in the central portion of the electrostatic chuck 104, and a low voltage may be applied to the electrode 109C provided in the outer peripheral portion of the electrostatic chuck 104, from the state in which the heat transfer medium is present only in the central portion of the wafer placement surface $104B_1$.

[0108]

FIGS. 20 and 21 are sectional views schematically illustrating modifications of an electrode of an electrostatic chuck. FIG. 22 is a plan view schematically illustrating a modification of the electrode of the electrostatic chuck.

A single electrode 109 is provided in an electrostatic chuck 104D in FIG. 20 to span a central portion and an outer peripheral portion of the electrostatic chuck 104D. In the electrostatic chuck 104D, a wafer placement surface $104D_1$ is formed by a concave surface that is recessed downward, and the electrode 109 is formed in a horizontal flat plate shape. Therefore, a dielectric layer constituting the electrostatic chuck 104D is thinner in the central portion of the electrostatic chuck 104D compared to the outer peripheral portion of the electrostatic chuck 104D. In the electrostatic chuck 104D, when a voltage is applied to the electrode 109, a large electrostatic force between the central portion of the wafer placement

surface $104D_1$ and the wafer W, and a small electrostatic force between the outer peripheral portion of the wafer placement surface $104D_1$ and the wafer W act simultaneously. Therefore, in the electrostatic chuck 104D, by applying the voltage to the electrode 109, the heat transfer medium supplied to the central portion of the wafer placement surface $104B_1$ spreads to the outer peripheral portion of the wafer placement surface $104B_1$ by a large electrostatic force, and spreads to outside the wafer placement surface $104B_1$ by a small electrostatic force.

[0109]

Also in an electrostatic chuck 104E in FIG. 21, as in the electrostatic chuck 104D in FIG. 20, a single electrode 109E is provided to span a central portion and an outer peripheral portion of the electrostatic chuck 104E. In the electrostatic chuck 104E, unlike the electrostatic chuck 104D, the wafer placement surface $104B_1$ is formed as a horizontal plane, and a cross-sectional shape of the electrode 109E is formed in a triangular shape protruding toward the central portion of the wafer placement surface $104B_1$. Accordingly, a dielectric layer constituting the electrostatic chuck 104E is thinner in the central portion of the electrostatic chuck 104E compared to the outer peripheral portion of the electrostatic chuck 104E. In the electrostatic chuck 104E, when a voltage is applied to the electrode 109E, a large electrostatic force between the central portion of the wafer placement surface $104B_1$ and the wafer W, and a small electrostatic force between the outer peripheral portion of the wafer placement surface $104B_1$ and the wafer W act simultaneously. Therefore, even in the electrostatic chuck 104E, by applying the voltage to the electrode 109E, the heat transfer medium supplied to the central portion of the wafer placement surface $104B_1$ spreads to the outer peripheral portion of the wafer placement surface $104B_1$ by a large electrostatic force, and spreads to outside the wafer placement surface $104B_1$ by a small electrostatic force.

A cross-sectional shape of the electrode 109E may be any shape as long as it protrudes toward the central portion of the wafer placement surface $104B_1$, and may not be a triangular shape.

[0110]

Also in an electrostatic chuck 104F in FIG. 22, as in the electrostatic chuck 104D in FIG. 20, a single electrode 109F is provided to span a central portion and an outer peripheral portion of the electrostatic chuck 104E. However, in the electrostatic chuck 104F, unlike the electrostatic chuck 104F, the wafer placement surface $104B_1$ is formed as a horizontal plane, and a density of the electrode 109F is higher at the central portion of the electrode chuck 104F than that at the outer peripheral portion of the electrostatic chuck 104F. Therefore, in the electrostatic chuck 104F, when a voltage is applied to the electrode 109F, a large electrostatic force between the central portion of the wafer placement surface $104B_1$ and the wafer W, and a small electrostatic force between the outer peripheral portion of the wafer placement surface

$104B_1$ and the wafer W act simultaneously. Therefore, even in the electrostatic chuck 104F, by applying the voltage to the electrode 109F, the heat transfer medium supplied to the central portion of the wafer placement surface $104B_1$ spreads to the outer peripheral portion of the wafer placement surface $104B_1$ by a large electrostatic force, and spreads to outside the wafer placement surface $104B_1$ by a small electrostatic force.

A shape of the electrode 109F in a plan view is not limited to the shape in FIG. 22 as long as the density of the electrode 109F is higher at the central portion of the electrostatic chuck 104F compared to at the outer peripheral portion of the electrostatic chuck 104F.

[0111]

When a single electrode is provided to span between the central portion and the outer peripheral portion of the electrostatic chuck, and the wafer placement surface is formed as a horizontal plane, the dielectric constant may differ in the plane of the electrostatic chuck, and the dielectric constant at the central portion of the electrostatic chuck may be higher than that at the outer peripheral portion thereof. Even in this electrostatic chuck, when a voltage is applied to the electrode, a large electrostatic force between the central portion of the wafer placement surface and the wafer W, and a small electrostatic force between the outer peripheral portion of the wafer placement surface and the wafer W act simultaneously.

[0112]

Examples of a method of varying the dielectric constant in the plane of the electrostatic chuck, include a method of using different materials as a dielectric material in the central portion and the outer peripheral portion of the electrostatic chuck as a constituent material thereof, and a method of varying the concentration of the dielectric material in the constituent material of the electrostatic chuck in the plane of the electrostatic chuck.

[0113]

Example of Heat Transfer Layer D on Wafer Placement Surface 104_1

FIG. 23 is a diagram illustrating an example of the heat transfer layer D on the wafer placement surface 104_1. In FIG. 23, the flow path 108 is not illustrated.

For example, the heat transfer layer D is formed on the entire wafer placement surface 104_1, including the central region and a peripheral region of the wafer placement surface 104_1. However, the heat transfer layer D may be formed only in some regions of the wafer placement surface 104_1. For example, when it is necessary to actively cool or heat the peripheral edge of the wafer W, as illustrated in FIG. 16, the heat transfer layer D may be formed only in the peripheral region of the wafer placement surface 104_1 facing the peripheral edge of the wafer W. For example, when it is necessary to actively cool or heat the central portion of the wafer W, the heat transfer layer D may be formed only in the central region of the wafer placement surface 104_1 facing the central portion of the wafer W.

[0114]

For example, a method of forming the heat transfer layer D only on a part of the wafer placement surface 104_1 is as follows. That is, when the raw material of the heat transfer layer D is a gas, by providing the wafer placement surface 104_1 with both an oleophilic portion and an oil-repellent portion, it is possible to form the heat transfer layer D only on either the oleophilic portion or the oil-repellent portion.

A method of forming the wafer placement surface 104_1 having both the oleophilic portion and the oil-repellent portion is as follows. That is, for example, the method is such that an oleophilic treatment is performed on a part of the wafer placement surface 104_1 and an oil-repellent treatment is performed on another part. The oleophilic treatment is a treatment of coating with a substance having a hydrocarbon group, or a treatment of forming a predetermined shape in a nanometer order on the surface. The oil-repellent treatment is a treatment of coating with a silicon resin, a fluorine-based material, or a hydrophilic inorganic substance.

[0115]

When the raw material of the heat transfer layer D is the heat transfer medium formed by the liquid medium or the like as described above, for example, grooves can be formed only in some regions such as the peripheral region in the wafer placement surface 104_1 to form the heat transfer layer D only on these some regions.

[0116]

When the heat transfer layer D is formed only in some regions in the wafer placement surface 104_1 as described above, as illustrated in FIG. 23, a supply path 190 for supplying a heat transfer gas, such as a He gas, between a portion of the wafer placement surface 104_1 in which the heat transfer layer D is not formed and the wafer W may be provided in the wafer support 101. Accordingly, the temperature control ability for the wafer W by the wafer support 101 can be varied within the wafer placement surface 104_1, that is, a distribution can be given to the temperature control ability for the wafer W by the wafer support 101.

[0117]

A method of giving a distribution to the temperature control ability for the wafer W is not limited thereto. For example, when the raw material of the heat transfer layer D is the heat transfer medium formed by the liquid medium described above, it is possible to give a distribution in the temperature control ability for the wafer W by the wafer support 101 by forming grooves in each region and supplying the heat transfer medium having different thermal conductivity in each region.

[0118]

By providing a thick portion and a thin portion of the heat transfer layer D on the wafer placement surface 104_1, a distribution may be given to the temperature control ability for the

wafer W by the wafer support 101.

[0119]

By providing the wafer placement surface 104_1 with a portion with a large surface area and a portion with a small surface area, and forming the heat transfer layer D on the entire wafer placement surface 104_1, a distribution can be given to the temperature control ability (specifically, the temperature control ability for the wafer W via the wafer placement surface 104_1 and the heat transfer layer D) for the wafer W by the wafer support 101. For example, by performing the roughening treatment on the wafer placement surface 104_1, both a portion with a large surface area and a portion with a small surface area can be formed on the wafer placement surface 104_1.

[0120]

(Other Modifications)

In the example described above, a target whose temperature is adjusted via the wafer support 101 and the deformable heat transfer layer D is the wafer W. Alternatively or in addition thereto, the edge ring E may be the target. That is, in the present disclosure, a workpiece whose temperature is to be adjusted is at least one of the wafer W and the edge ring E.

The forms of removing the heat transfer layer formed on each portion described above may be combined. For example, when removing the heat transfer layer formed on a portion other than on the wafer placement surface, two or more of a form in which the processing chamber 100 is depressurized, a form using the plasma, and a form in which the light is emitted may be combined.

[0121]

In the example described above, the central portion of the electrostatic chuck 104 on which the wafer W is placed has a diameter less than that of the wafer W. However, it may be formed to have a larger diameter than that of the wafer W. In the example described above, the central portion of the electrostatic chuck 104, which has a diameter less than that of the wafer W is formed to be higher than the upper surface of the peripheral edge, but may have the same height as that of the upper surface. FIG. 24 is a diagram illustrating an example in which the central portion of the electrostatic chuck 104 has a diameter larger than that of the wafer W. In the example illustrated in FIG. 24, the central portion having a diameter larger than that of the wafer W and the peripheral edge of the electrostatic chuck 104 are formed at the same height. However, as illustrated in FIG. 1, the upper surface of the central portion may be formed to be higher than the upper surface of the peripheral edge.

[0122]

In the example illustrated in FIG. 24, the central portion (that is, the wafer placement surface 104_1) of the electrostatic chuck 104 is formed to have a diameter larger than that of the

wafer W. Therefore, the peripheral edge of the wafer W is not projected from the central portion of the electrostatic chuck 104 and is placed on the wafer placement surface 104_1 via the heat transfer layer D. Therefore, the temperature uniformity of the wafer W can be improved. Since the heat transfer layer D is also formed in an end region of the wafer placement surface 104_1 on which no wafer W is placed, the electrostatic chuck 104 is not exposed to the processing space 100s even in the end region on which no wafer W is placed. Accordingly, the electrostatic chuck 104 can be protected from the plasma in the end region of the wafer placement surface 104_1 on which no wafer W is placed.

[0123]

As illustrated in FIG. 25, a tray T on which the wafer W is placed and on which the heat transfer layer D is formed between the wafer W and the tray T may be placed on the wafer placement surface 104_1.

In this example, under the control of the controller 200, the tray T is placed on the wafer placement surface 104_1 of the wafer support 101 via the lifters 107 to form the heat transfer layer D on the wafer placement surface 104_1 via the tray T. Accordingly, in the present embodiment, the elevation mechanism of the wafer W (the tray T on which the wafer is placed) including the controller 200 and the lifters 107 can function as a part of the heat transfer layer former that forms the heat transfer layer D on the wafer placement surface 104_1.

[0124]

The tray T is held by the electrostatic chuck 104 by electrostatic attracting. The heat transfer layer D is formed in a central portion of the tray T, and the wafer W is placed thereon via the heat transfer layer D. The edge ring E is placed on a peripheral edge of the tray T, and by loading and unloading the tray, not only the wafer W but also the edge ring E can be replaced. The heat transfer layer D may also be formed between the edge ring E and the tray T.

[0125]

In the example illustrated in FIG. 25, the peripheral edge of the wafer W is also placed on the tray T via the heat transfer layer D. Therefore, the temperature uniformity of the wafer W can be improved. The heat transfer layer D is formed on an upper surface of the tray T on which neither the wafer W nor the edge ring E is placed. Accordingly, the upper surface of the tray T is not exposed to the processing space 100s even in a region where no wafer W or edge ring E is placed, and the tray T can be protected from the plasma.

[0126]

The heat transfer layer D may be formed between the tray T and the electrostatic chuck 104. Only the wafer W may be placed on the tray T, and the edge ring E may be placed on the electrostatic chuck 104. In this case, the placement surface of the edge ring E on the peripheral edge of the electrostatic chuck 104 may be formed at a height equal to that of the central portion

(a placement surface of the tray T) of the electrostatic chuck 104 as illustrated in FIG. 24, or may be formed lower than the central portion (the placement surface of the tray T) as illustrated in FIG. 1.

[0127]

In the example described above, plasma etching is performed as the plasma processing. However, the technique of the present disclosure can also be applied to cases in which processing other than etching (for example, film formation processing) is performed as the plasma processing.

[0128]

It shall be understood that the embodiments disclosed herein are illustrative and are not restrictive in all aspects. The embodiment described above may be omitted, replaced, or modified in various forms without departing from the scope and spirit of the appended claims. For example, the components of the embodiments described above may be combined as desired. From the desired combination, functions and effects of each component related to the combination can be obtained as a matter of course, and other functions and effects apparent to those skilled in the art can be obtained from the description herein.

[0129]

The effects described herein are merely illustrative or exemplary, and are not limited. In other words, the technique according to the present disclosure may have other effects apparent to those skilled in the art from the description herein, in addition to or in place of the effects described above.

[0130]

The following configuration examples also fall within the technical scope of the present disclosure.

(1) A plasma processing apparatus includes:

a processing container configured to be depressurized,

a support provided in the processing container and configured to support a workpiece,

a heat transfer layer former configured to form, on a placement surface of the support on which the workpiece is placed, a deformable heat transfer layer formed of at least one of a liquid layer or a solid layer for the workpiece,

an exhaust line configured to exhaust a processing space in the processing container, and

a bypass line that detours the exhaust line, in which

the bypass line is provided with a trap configured to retrieve the heat transfer layer in a gas form contained in exhaust from the processing space.

(2) The plasma processing apparatus according to (1), in which

the heat transfer layer former supplies a raw material gas serving as a raw material of the heat transfer layer to the processing space in the processing container, and

the heat transfer layer in the gas form retrieved by the trap is the raw material gas.

(3) The plasma processing apparatus according to (2), in which

the trap also retrieves a vaporized matter of the heat transfer layer formed on the placement surface as the heat transfer layer in the gas form.

(4) The plasma processing apparatus according to (2) or (3), further including:

a return line configured to allow the raw material gas of the heat transfer layer retrieved by the trap to be returned to the heat transfer layer former.

(5) The plasma processing apparatus according to any one of (2) to (4), in which

the placement surface includes a oleophilic portion and an oil-repellent portion, and the heat transfer layer is formed only on one of the portions.

(6) The plasma processing apparatus according to (5), in which

the support has a supply path through which a heat transfer gas is supplied between the workpiece and a portion of the placement surface where the heat transfer layer is not formed.

(7) The plasma processing apparatus according to any one of (1) to (6), in which

the placement surface has a portion with a large surface area and a portion with a small surface area.

(8) The plasma processing apparatus according to any one of (1) to (7), in which

the placement surface is roughened.

(9) The plasma processing apparatus according to any one of (2) to (6), further including:

an inert gas supply configured to supply an inert gas to the processing space in the processing container, and

a controller configured to supply both the raw material gas and the inert gas into the processing space to form the heat transfer layer, in a state in which exhaust of the processing space through the exhaust line is not performed and exhaust of the processing space through the bypass line is performed.

(10) The plasma processing apparatus according to any one of (2) to (6), further including:

a controller configured to

supply the raw material gas into the processing space, in a state in which exhaust of the processing space through the exhaust line is not performed and exhaust of the processing space through the bypass line is performed, and

then continue the supply of the raw material gas into the processing space to form the heat transfer layer, in a state in which exhaust of the processing space, including the

exhaust through the bypass line, is not performed.

(11) The plasma processing apparatus according to (10), further including:

an inert gas supply configured to supply an inert gas into the processing space in the processing container, in which

in forming the heat transfer layer, the inert gas is also supplied into the processing space.

(12) The plasma processing apparatus according to any one of (2) to (6), further including:

an inert gas supply configured to supply an inert gas into the processing space in the processing container, and

a controller configured to

supply the raw material gas into the processing space in a state in which exhaust of the processing space through the exhaust line is not performed and exhaust of the processing space through the bypass line is performed, and

then supply the inert gas into the processing space instead of the raw material gas to form the heat transfer layer, in a state in which the exhaust of the processing space through the exhaust line is not performed and the exhaust of the processing space through the bypass line is performed.

(13) The plasma processing apparatus according to any one of (1) to (12), in which

a first exhaust pump and a second exhaust pump are provided in this order from an upstream side in the exhaust line, and

a downstream end of the bypass line is connected between the first exhaust pump and the second exhaust pump in the exhaust line.

(14) The plasma processing apparatus according to (13), in which

a pressure control valve is connected downstream of the trap in the bypass line.

(15) The plasma processing apparatus according to (14), in which

shutoff valves are provided upstream of the trap in the bypass line and downstream of the pressure control valve, and

a shutoff valve is provided between the first exhaust pump and a portion of the exhaust line to which the downstream end of the bypass line is connected.

(16) A processing method of performing plasma processing on a substrate, the processing method including:

(A) forming a deformable heat transfer layer formed by at least one of a liquid layer and a solid layer for a workpiece on a placement surface of a support in a processing container configured to be depressurized,

(B) placing the substrate on the heat transfer layer formed on the placement surface of

the support,

(C) performing the plasma processing on the substrate,

(D) separating the substrate from the heat transfer layer and removing the heat transfer layer formed on the placement surface, and

(E) retrieving the heat transfer layer in a gas form contained in exhaust of a processing space by a trap provided in a bypass line that detours an exhaust line configured to exhaust the processing space in the processing container.

(17) The processing method according to claim (16), further including:

before (A),

closing a valve provided in the exhaust line,

opening a valve provided in the bypass line and exhausting the processing space in the processing container from the bypass line, and

supplying a raw material gas serving as a raw material of the heat transfer layer into the processing space.

(18) The processing method according to (16) or (17), further including:

between (B) and (C),

closing the valve provided in the bypass line, and

opening the valve provided in the exhaust line to exhaust the processing space in the processing container through the exhaust line.

(19) The processing method according to any one of (16) to (18), in which

(A) includes increasing pressure in the processing container or lowering a temperature of the placement surface.

Reference Signs List

[0131]

1: plasma processing apparatus

100: plasma processing chamber

100s: plasma processing space

101: wafer support

130: gas supply

160: exhaust line

170: bypass line

171: trap

104_1: wafer placement surface

104_2: upper surface of peripheral edge of electrostatic chuck

D: heat transfer layer

E: edge ring

W: wafer

CLAIMS

[Claim 1]

A plasma processing apparatus comprising:

a processing container configured to be depressurized,

a support provided in the processing container and configured to support a workpiece,

a heat transfer layer former configured to form, on a placement surface of the support on which the workpiece is placed, a deformable heat transfer layer formed of at least one of a liquid layer or a solid layer for the workpiece,

an exhaust line configured to exhaust a processing space in the processing container, and

a bypass line that detours the exhaust line, wherein

the bypass line is provided with a trap configured to retrieve the heat transfer layer in a gas form contained in exhaust from the processing space.

[Claim 2]

The plasma processing apparatus according to claim 1, wherein

the heat transfer layer former supplies a raw material gas serving as a raw material of the heat transfer layer to the processing space in the processing container, and

the heat transfer layer in the gas form retrieved by the trap is the raw material gas.

[Claim 3]

The plasma processing apparatus according to claim 2, wherein

the trap also retrieves a vaporized matter of the heat transfer layer formed on the placement surface as the heat transfer layer in the gas form.

[Claim 4]

The plasma processing apparatus according to claim 2, further comprising:

a return line configured to allow the raw material gas of the heat transfer layer retrieved by the trap to be returned to the heat transfer layer former.

[Claim 5]

The plasma processing apparatus according to claim 2, wherein

the placement surface includes an oleophilic portion and an oil-repellent portion, and the heat transfer layer is formed only on one of the portions.

[Claim 6]

The plasma processing apparatus according to claim 5, wherein

the support has a supply path through which a heat transfer gas is supplied between the workpiece and a portion of the placement surface where the heat transfer layer is not formed.

[Claim 7]

The plasma processing apparatus according to claim 1, wherein

the placement surface has a portion with a large surface area and a portion with a small surface area.

[Claim 8]

The plasma processing apparatus according to any one of claims 1 to 7, wherein

the placement surface is roughened.

[Claim 9]

The plasma processing apparatus according to any one of claims 2 to 6, further comprising:

an inert gas supply configured to supply an inert gas to the processing space in the processing container, and

a controller configured to supply both the raw material gas and the inert gas into the processing space to form the heat transfer layer, in a state in which exhaust of the processing space through the exhaust line is not performed and exhaust of the processing space through the bypass line is performed.

[Claim 10]

The plasma processing apparatus according to any one of claims 2 to 6, further comprising:

a controller configured to

supply the raw material gas into the processing space, in a state in which exhaust of the processing space through the exhaust line is not performed and exhaust of the processing space through the bypass line is performed, and

then continue the supply of the raw material gas into the processing space to form the heat transfer layer, in a state in which exhaust of the processing space, including the exhaust through the bypass line, is not performed.

[Claim 11]

The plasma processing apparatus according to claim 10, further comprising:

an inert gas supply configured to supply an inert gas into the processing space in the processing container, wherein

in forming the heat transfer layer, the inert gas is also supplied into the processing space.

[Claim 12]

The plasma processing apparatus according to any one of claims 2 to 6, further comprising:

an inert gas supply configured to supply an inert gas into the processing space in the processing container, and

a controller configured to

supply the raw material gas into the processing space in a state in which exhaust of the processing space through the exhaust line is not performed and exhaust of the processing space through the bypass line is performed, and

then supply the inert gas into the processing space instead of the raw material gas to form the heat transfer layer, in a state in which the exhaust of the processing space through the exhaust line is not performed and the exhaust of the processing space through the bypass line is performed.

[Claim 13]

The plasma processing apparatus according to any one of claims 1 to 7, wherein

a first exhaust pump and a second exhaust pump are provided in this order from an upstream side in the exhaust line, and

a downstream end of the bypass line is connected between the first exhaust pump and the second exhaust pump in the exhaust line.

[Claim 14]

The plasma processing apparatus according to claim 13, wherein

a pressure control valve is connected downstream of the trap in the bypass line.

[Claim 15]

The plasma processing apparatus according to claim 14, wherein

shutoff valves are provided upstream of the trap in the bypass line and downstream of the pressure control valve, and

a shutoff valve is provided between the first exhaust pump and a portion of the exhaust

line to which the downstream end of the bypass line is connected.

[Claim 16]

A processing method of performing plasma processing on a substrate, the processing method comprising:

(A) forming a deformable heat transfer layer formed by at least one of a liquid layer and a solid layer for a workpiece on a placement surface of a support in a processing container configured to be depressurized,

(B) placing the substrate on the heat transfer layer formed on the placement surface of the support,

(C) performing the plasma processing on the substrate,

(D) separating the substrate from the heat transfer layer and removing the heat transfer layer formed on the placement surface, and

(E) retrieving the heat transfer layer in a gas form contained in exhaust of a processing space by a trap provided in a bypass line that detours an exhaust line configured to exhaust the processing space in the processing container.

[Claim 17]

The processing method according to claim 16, further comprising:

before (A),

closing a valve provided in the exhaust line,

opening a valve provided in the bypass line and exhausting the processing space in the processing container from the bypass line, and

supplying a raw material gas serving as a raw material of the heat transfer layer into the processing space.

[Claim 18]

The processing method according to claim 17, further comprising:

between (B) and (C),

closing the valve provided in the bypass line, and

opening the valve provided in the exhaust line to exhaust the processing space in the processing container through the exhaust line.

[Claim 19]

The processing method according to claim 16, wherein

(A) includes increasing pressure in the processing container or lowering a temperature

of the placement surface.