SUBSTRATE PROCESSING APPARATUS, METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE, AND PROGRAM

TECHNICAL FIELD

[0001] The present invention relates to a substrate processing apparatus, a method of manufacturing a semiconductor device, and a program.

BACKGROUND

[0002] Recently, semiconductor devices such as flash memories tend to be highly integrated, and patterns have been remarkably miniaturized accordingly. When forming these patterns, a process of performing predetermined processing such as oxidizing or nitriding process on a substrate is often carried out as a manufacturing process.

[0003] For example, Patent Document 1 discloses that a surface of a pattern formed on a substrate is modified using a plasma-excited processing gas.

[0004] Patent Document 1: Japanese laid-open publication No. 2014-75579

SUMMARY OF INVENTION

PROBLEMS TO SOLVED BY INVENTION

[0005] However, since a temperature of a quartz dome is raised and then a product lot (a group of product substrates) is processed by processing a plurality of dummy substrates in pre-processing of substrate processing at present, productivity may be deteriorated.

[0006] The present invention provides a recipe execution control which executes pre-processing without using a dummy substrate before processing a product lot.

MEANS TO SOLVE THE PROBLEM

[0007] According to one embodiment of the present invention, there is provided a configuration that includes: a process vessel forming a plasma generation space in which a processing gas is

plasma-excited and a substrate processing space communicating with the plasma generation space; a plasma generation part including a coil disposed to surround the plasma generation space and installed to be wound around an outer periphery of the process vessel, and a high-frequency power source configured to supply high-frequency power to the coil; a gas supply part configured to supply the processing gas to the plasma generation space; a temperature sensor installed outside the process vessel and configured to detect a temperature of the process vessel; and a control part configured to perform a control such that the temperature of the process vessel detected by the temperature sensor falls within a range of a target temperature defined by a preset upper limit value and a preset lower limit value, prior to execution of a process recipe for processing substrates.

EFFECTS OF THE INVENTION

[0008] According to the present invention, it is possible to suppress deterioration of productivity by shortening a time spent for pre-processing before a process recipe for processing a product lot.

BRIEF DESCRIPTION OF DRAWINGS

[0009] FIG. 1 is a configuration diagram (top view) of a substrate processing apparatus according to an embodiment of the present invention.

FIG. 2 is a schematic cross-sectional view of a substrate processing apparatus according to an embodiment of the present invention.

FIG. 3 is a diagram illustrating a configuration of a control part (control means) of a substrate processing apparatus according to one embodiment of the present invention.

FIG. 4 is a flowchart illustrating substrate processing process according to an embodiment of the present invention.

FIG. 5 is an illustrative example of a sequence recipe editing screen according to an embodiment of the present invention.

FIG. 6A is an example of a flow of a pre-processing recipe according to an embodiment of the present invention.

FIG. 6B is an example of a flow of a pre-processing recipe according to an embodiment of the present invention.

FIG. 7 is an example of a flow of a pre-processing recipe according to an embodiment of the present invention.

MODE FOR CARRYING OUT THE INVENTION

[0010] <First Embodiment of the Present Invention>

(1) Configuration of the Substrate Processing Apparatus

A substrate processing apparatus according to a first embodiment of the present invention will now be described with reference to FIG. 1.

[0011] The substrate processing apparatus illustrated in FIG. 1 includes a vacuum side configuration for handling substrates (wafers W made of, e.g., silicon or the like) in a depressurized state, and an atmospheric pressure side configuration for handling the wafers W in an atmospheric pressure state. The vacuum side configuration mainly includes a vacuum transfer chamber TM, load lock chambers LM1 and LM2, and processing modules (processing mechanisms) PM1 to PM4 for processing the wafers W. The atmospheric pressure side configuration mainly includes an atmospheric pressure transfer chamber EFEM and load ports LP1 to LP3. Carriers CA1 to CA3 storing the wafers W are transferred from the outside of the substrate processing apparatus and held on the load ports LP1 to LP3, and are also transferred to the outside of the substrate processing apparatus. According to this configuration, an unprocessed wafer W is discharged from, for example, the carrier CA1 on the load port LP1, and is loaded into the processing module PM1 via the load lock chamber LM1 and is processed, and thereafter, the processed wafer W is returned to the carrier CA1 on the load port LP1 in reverse order thereof.

(Vacuum Side Configuration)

[0012] The vacuum transfer chamber TM is configured to have a vacuum-sealable structure capable of withstanding a negative pressure (reduced pressure) lower than an atmospheric pressure, such as a vacuum state. Furthermore, in the present embodiment, a housing of the vacuum transfer chamber TM is formed in a box shape having a pentagonal shape in a plane view with both its upper and lower ends closed. The load lock chambers LM1 and LM2 and the processing modules PM1 to PM4 are disposed to surround the outer periphery of the vacuum transfer chamber TM. The processing modules PM1 to PM4 will be generally or representatively referred to as processing modules PM. The load lock chambers LM1 and LM2 will be generally or representatively referred to as load lock chambers LM. The same rules apply to other components (a vacuum robot VR, an arm VRA, and the like which will be described later).

[0013] For example, one vacuum robot VR as a transfer means for transferring a wafer W in a depressurized state is installed in the vacuum transfer chamber TM. The vacuum robot VR is configured to transfer the wafer W between the load lock chambers LM and the processing modules PM by placing the wafer W on two sets of substrate support arms (hereinafter, referred to as arms) VRA, which are substrate mounting parts. The vacuum robot VR is also configured to be moved up and down while maintaining airtightness of the vacuum transfer chamber TM. Furthermore, the two sets of arms VRA are installed to be vertically separated from each other so as to be each expanded and contracted in a horizontal direction, and are configured to move rotatably in the relevant horizontal plane.

[0014] The processing modules PM respectively include substrate mounting parts on which the wafers W are held, and are configured as, for example, single-wafer-type process chambers capable of processing the wafers W one by one in a depressurized state. That is, each of the processing modules PM serves as a process chamber which gives additional values to the wafers W, such as etching or ashing using plasma or the like, or film formation by chemical reaction.

[0015] The processing modules PM are each connected to the vacuum transfer chamber TM by

gate valves PGV as opening/closing valves. Therefore, the wafers W can be transferred into and out of the vacuum transfer chamber TM under a reduced pressure by opening the gate valves PGV. Furthermore, various substrate processing can be performed on the wafers W while maintaining an internal pressure of the processing modules PM and a processing gas atmosphere, by closing the gate valves PGV.

[0016] The load lock chambers LM serve as spare chambers for loading the wafers W into the vacuum transfer chamber TM or as spare chambers for unloading the wafers W from the interior of the vacuum transfer chamber TM. Buffer stages (not shown) as substrate mounting parts for temporarily supporting the wafers W when loading and unloading the wafers W are respectively installed in the load lock chambers LM. The buffer stages may be configured as a multi-stage slot which holds a plurality of (e.g., two) wafers W.

[0017] Furthermore, the load lock chambers LM are each connected to the vacuum transfer chamber TM by gate valves LGV as opening/closing valves, and are each connected to the atmospheric pressure transfer chamber EFEM as described below by gate valves LD as opening/closing valves. Therefore, the wafers W can be transferred between the load lock chambers LM and the atmospheric pressure transfer chamber EFEM under an atmospheric pressure while the interior of the vacuum transfer chamber TM being vacuum-sealed, by opening the gate valves LD on the atmospheric pressure transfer chamber EFEM side while keeping the gate valves LGV on vacuum transfer chamber TM side closed.

[0018] In addition, the load lock chambers LM are configured to withstand a reduced pressure lower than an atmospheric pressure, such as a vacuum state, such that the interior of the load lock chambers LM can be vacuum-exhausted. Therefore, after the interior of the load lock chambers LM is vacuum-exhausted by closing the gate valves LD on the atmospheric pressure transfer chamber EFEM side, the wafers W can be transferred between the load lock chambers LM and the vacuum transfer chamber TM under a reduced pressure while keeping the interior of the vacuum transfer chamber TM in a vacuum state, by opening the gate valves LGV on the vacuum transfer chamber TM side. In this manner, the load lock chambers LM are configured

to be switched between the atmospheric pressure state and the depressurized state.

(Atmospheric Pressure Side Configuration)

[0019] On the other hand, as described above, the atmospheric pressure transfer chamber EFEM (equipment front end module), which is a front module connected to the load lock chambers LM1 and LM2, and the load ports LP1 to LP3 as carrier loading parts for loading the carriers CA1 to CA3 as wafer storage vessels each storing, for example, 25 wafers W for one lot, which are connected to the atmospheric pressure transfer chamber EFEM, are installed at the atmospheric pressure side of the substrate processing apparatus. As these carriers CA1 to CA3, for example, front opening unified pods (FOUPs) are used. The load ports LP1 to LP3 will be generally or representatively referred herein to as load ports LP. The carriers CA1 to CA3 will be generally or representatively referred herein to as carriers CA. The same rules apply to the atmospheric pressure side configuration (such as carrier doors CAH1 to CAH3, carrier openers CP1 to CP3 and the like as described below), like the vacuum side configuration.

[0020] For example, one atmospheric pressure robot AR as a transfer means is installed in the atmospheric pressure transfer chamber EFEM. The atmospheric pressure robot AR is configured to transfer the wafer W between the load lock chamber LM1 and the carrier CA on the load port LP1. The atmospheric pressure robot AR also has two sets of arms ARA, which are substrate mounting parts, like the vacuum robot VR.

[0021] A carrier door CAH which is a cap (lid) for the carrier CA is installed at the carrier CA1. The wafer W is stored in the carrier CA by the atmospheric pressure robot AR via a substrate loading/unloading port CAA1 with the door CAH of the carrier CA loaded on the load port LP opened, and the wafer W in the carrier CA is unloaded by the atmospheric pressure robot AR.

[0022] In addition, the carrier openers CP for opening and closing the carrier doors CAH are respectively installed adjacent to the load ports LP in the atmospheric pressure transfer chamber EFEM. That is, the atmospheric pressure transfer chamber EFEM is installed adjacent to the load ports LP via the carrier openers CP.

[0023] The carrier openers CP each have a closure which can be brought into close contact with the carrier door CAH, and a driving mechanism which operates the closure horizontally and vertically. The carrier opener CP opens and closes the carrier door CAH by moving the closure horizontally and vertically together with the carrier door CAH while the closure is in close contact with the carrier door CAH.

[0024] Furthermore, an aligner AU, which is an orientation flat alignment device for aligning the crystal orientation of the wafer W, as a substrate position correction device is installed in the atmospheric pressure transfer chamber EFEM. In addition, a clean air unit (not shown) for supplying clean air into the atmospheric pressure transfer chamber EFEM is installed in the atmospheric pressure transfer chamber EFEM.

[0025] The load ports LP are configured so that the carriers CA1 to CA3 storing the plurality of substrates W are respectively loaded on the load ports LP. In the respective carriers CA, slots (not shown), for example, 25 slots for one lot, as storage parts for storing the wafers W are installed. Each of the load ports LP is configured to read and store a bar code or the like indicating a carrier ID attached to and identifying the carrier CA when the carrier CA is loaded thereon.

[0026] Next, a control part 10 which controls the overall substrate processing apparatus is configured to control the respective parts of the substrate processing apparatus. The control part 10 includes at least a device controller 11 as an operation part, a transfer system controller 31 as a transfer control part, and a process controller 221 as a process control part.

[0027] The device controller 11 is an interface with an operator together with an operation display part (not shown), and is configured to receive an operation by the operator or an instruction from the operator via the operation display part. The operation display part displays an operation screen or information such as various data or the like. The data displayed on the operation display part is stored in a storage part of the device controller 11.

[0028] The transfer system controller 31 includes a robot controller which controls the vacuum robot VR and the atmospheric pressure robot AR, and is configured to control the transfer of the

wafers W and execution of work instructed by the operator. Furthermore, the transfer system controller 13 is also configured to control the transfer of the wafers W in the substrate processing apparatus by outputting control data (control instructions) for transferring the wafers W to the vacuum robot VR or the atmospheric pressure robot AR, various valves, switches, and the like based on, for example, a transfer recipe created or edited by the operator via the device controller 11. Details of the process controller 221 will be described later. The hardware configuration of each of the controllers 11, 31 and 222 of the control part 10 is like that of the process controller 221 as described below, and therefore, a description thereof will be omitted here.

[0029] The control part 10 may be installed not only inside the substrate processing apparatus as illustrated in FIG. 1 but also outside the substrate processing apparatus. Furthermore, the process controller 221 as the process control part which controls the device controller 11, the transfer system controller 31, and the processing modules PM may be configured as a general-purpose computer such as, e.g., a personal computer or the like. In this case, each controller may be configured by installing a program on the general-purpose computer by using a computer-readable recording medium (a USB memory, a DVD, or the like) storing various programs.

[0030] In addition, means for supplying a program for executing the aforementioned processing may be arbitrarily selected. In addition to supplying the program via a predetermined recording medium as described above, the program may be supplied via, for example, a telecommunication line, a communication network, a communication system, or the like. In this case, for example, the program may be posted on a bulletin board of the communication network and may be supplied by superimposing the program over a carrier wave via the network. Then, the aforementioned processing may be executed by activating the program provided in this way and executing the program, like other application programs, under the control of an operating system (OS) of the substrate processing apparatus.

(Processing Chamber)

[0031] Next, the processing module PM as the processing mechanism according to the first embodiment of the present invention will be described with reference to FIG. 2. The processing mechanism PM includes a process furnace 202 configured to plasma-process a wafer W. A process vessel 203 constituting a process chamber 201 is installed in the process furnace 202. The process vessel 203 includes a dome-shaped upper vessel 210 made of quartz as a first vessel (hereinafter, referred to as a quartz dome), and a bowl-shaped lower vessel 211 as a second vessel. The process chamber 201 is formed by the upper vessel 210 covering the lower vessel 211. In addition, a temperature sensor 280 such as a thermocouple is installed in the upper vessel 210 and is configured to detect the temperature of the upper vessel 210. The upper vessel 210 is made of a non-metallic material such as, e.g., aluminum oxide (Al_2O_3) or quartz (SiO_2), and the lower vessel 211 is made of, e.g., aluminum (Al).

[0032] In addition, a gate valve 244 is installed at a lower sidewall of the lower vessel 211. The gate valve 244 is configured to load and unload the wafer W into and from the process chamber 201 via a loading/unloading port 245 by using a transfer mechanism (not shown) when the gate valve 244 is opened. The gate valve 244 is configured to be a gate valve which maintains airtightness in the process chamber 201 when the gate valve 244 is closed.

[0033] The process chamber 201 includes a plasma generation space 201a (above an alternate long and short dash line in FIG. 2) around which a coil 212 is installed, and a substrate processing space 201b which communicates with the plasma generation space 201a and in which the wafer W is processed. The plasma generation space 201a is a space in which plasma is generated, and is a space above a lower end of the coil 212 and below an upper end of the coil 212 in the process chamber 201. On the other hand, the substrate processing space 201b (below the alternate long and short dash line in FIG. 2) is a space in which the substrate is processed by using plasma, and is a space below the lower end of the coil 212. In the present embodiment, the plasma generation space 201a and the substrate processing space 201b are configured to have substantially the same horizontal diameter.

(Susceptor)

[0034] A susceptor 217 serving as a substrate mounting part for holding the wafer W is disposed at the center on the bottom side of the process chamber 201. The susceptor 217 is made of a non-metallic material such as, e.g., aluminum nitride (AlN), ceramics, quartz or the like, and is configured to reduce metal contamination on a film or the like formed on the wafer W.

[0035] A heater 217b as a heating mechanism is integrally embedded in the susceptor 217. The heater 217b is configured to heat the surface of the wafer W, for example, from about 25 to 750 degrees C, when electric power is supplied.

[0036] The susceptor 217 is electrically insulated from the lower vessel 211. An impedance adjustment electrode 217c is installed inside the susceptor 217 to further improve the uniformity of density of plasma generated on the wafer W held on the susceptor 217, and is grounded through an impedance variable mechanism 275 serving as an impedance adjustment part. The impedance variable mechanism 275 is configured by a coil and a variable capacitor, and is configured to vary the impedance within the range of about 0 Ω to a parasitic impedance value of the process chamber 201 by controlling the inductance value and the resistance value of the coil and the capacitance value of the variable capacitor.

[0037] A susceptor elevating mechanism 268 including a driving mechanism for elevating the susceptor is installed at the susceptor 217. In addition, through-holes 217a are formed in the susceptor 217, and wafer push-up pins 266 are installed at the bottom surface of the lower vessel 211. When the susceptor 217 is lowered by the susceptor elevating mechanism 268, the wafer push-up pins 266 are configured to pass through the through-holes 217a in a non-contact state with the susceptor 217. The substrate mounting part according to the present embodiment is mainly configured by the susceptor 217, the heater 217b, and the electrode 217c.

(Gas Supply Part)

[0038] A gas supply head 236 is installed above the process chamber 201, namely above the upper vessel 210. The gas supply head 236 is configured to include a cap-like lid 233, a gas

introduction port 234, a buffer chamber 237, an opening 238, a shielding plate 240, and a gas outlet 239, so as to supply a reaction gas into the process chamber 201. The buffer chamber 237 serves as a distribution space for distributing the reaction gas introduced from the gas introduction port 234.

[0039] A downstream end of an oxygen-containing gas supply pipe 232a for supplying an oxygen (O_2) gas as an oxygen-containing gas, a downstream end of a hydrogen-containing gas supply pipe 232b for supplying a hydrogen (H_2) gas as a hydrogen-containing gas, and an inert gas supply pipe 232c for supplying am argon (Ar) gas as an inert gas are connected to the gas introduction port 234 so that they join. An O_2 gas supply source 250a, a mass flow controller (MFC) 252a, which is a flow rate control device, and a valve 253a, which is an opening/closing valve, are installed at the oxygen-containing gas supply pipe 232a sequentially from the corresponding upstream side. An H_2 gas supply source 250b, an MFC 252b, and a valve 253b are installed at the hydrogen-containing gas supply pipe 232b sequentially from the corresponding upstream side. An Ar gas supply source 250c, an MFC 252c, and a valve 253c are installed ate the inert gas supply pipe 232c sequentially from the corresponding upstream side. A valve 243a is installed at the downstream side at which the oxygen-containing gas supply pipe 232a, the hydrogen-containing gas supply pipe 232b, and the inert gas supply pipe 232c joined, and is connected to an upstream end of the gas introduction port 234. A processing gas such as an oxygen-containing gas, a hydrogen-containing gas or an inert gas may be supplied into the process chamber 201 via the gas supply pipes 232a, 232b and 232c while adjusting the flow rate of each gas by the MFCs 252a, 252b and 252c by opening and closing the valves 253a, 253b, 253c and 243a.

[0040] A gas supply part (gas supply system) according to the present embodiment is mainly configured by the gas supply head 236 (the lid 233, the gas introduction port 234, the buffer chamber 237, the opening 238, the shielding plate 240, the gas outlet 239), the oxygen-containing gas supply pipe 232a, the hydrogen-containing gas supply pipe 232b, the inert gas supply pipe 232c, the MFCs 252a, 252b and 252c, and the valves 253a, 253b, 253c and 243a.

[0041] In addition, an oxygen-containing gas supply system according to the present embodiment is configured by the gas supply head 236, the oxygen-containing gas supply pipe 232a, the MFC 252a, and the valves 253a and 243a. Furthermore, a hydrogen gas supply system according to the present embodiment is configured by the gas supply head 236, the hydrogen-containing gas supply pipe 232b, the MFC 252b, and the valves 253b and 243a. Moreover, an inert gas supply system according to the present embodiment is configured by the gas supply head 236, the inert gas supply pipe 232c, the MFC 252c, and the valves 253c and 243a.

[0042] Furthermore, the substrate processing apparatus according to the present embodiment is configured to perform an oxidizing process by supplying an O_2 gas as an oxygen-containing gas from the oxygen-containing gas supply system, but a nitrogen-containing gas supply system for supplying a nitrogen-containing gas into the process chamber 201 may be installed instead of the oxygen-containing gas supply system. According to the substrate processing apparatus configured in this way, a nitriding process may be performed instead of the oxidizing process of the substrate. In this case, for example, an N_2 gas supply source as a nitrogen-containing gas supply source is installed instead of the O_2 gas supply source 250a, and the oxygen-containing gas supply pipe 232a is configured as a nitrogen-containing gas supply pipe.

(Exhaust Part)

[0043] A gas exhaust port 235 configured to exhaust the reaction gas from the interior of the process chamber 201 is installed at a sidewall of the lower vessel 211. The upstream end of the gas exhaust pipe 231 is connected to the gas exhaust port 235. An auto pressure controller (APC) 242 as a pressure regulator (pressure regulation part), a valve 243b as an opening/closing valve, and a vacuum pump 246 as a vacuum exhaust device are installed at the gas exhaust pipe 231 sequentially from the corresponding upstream side. An exhaust part according to the present embodiment is mainly configured by the gas exhaust port 235, the gas exhaust pipe 231, the APC 242, and the valve 243b. The vacuum pump 246 may also be included in the exhaust

part.

(Plasma Generation Part)

[0044] A spiral resonance coil 212 as a first electrode is installed at an outer peripheral portion of the process chamber 201, namely at an outer side of the sidewall of the upper vessel 210, so as to surround the process chamber 201. An RF sensor 272, a high-frequency power source 273, and a matcher 274 for matching an impedance or an output frequency of the high-frequency power source 273 are connected to the resonance coil 212. A plasma generation part according to the present embodiment is mainly configured by the resonance coil 212, the RF sensor 272, and the matcher 274. The high-frequency power source 273 may also be included as the plasma generation part.

[0045] The high-frequency power source 273 is configured to supply high-frequency power (RF power) to the resonance coil 212. The RF sensor 272 is installed at an output side of the high-frequency power source 273 to monitor information on a traveling wave or a reflected wave of the supplied high-frequency power. The reflected wave power monitored by the RF sensor 272 is input to the matcher 274, which controls the impedance of the high-frequency power source 273 or the frequency of the output high-frequency power so that the reflected wave is minimized, based on the information on the reflected wave input from the RF sensor 272.

[0046] The high-frequency power source 273 includes a power source control means (control circuit) including a high-frequency oscillation circuit and a pre-amplifier for defining an oscillation frequency and an output, and an amplifier (output circuit) for amplifying the same to a predetermined output. The power control means controls the amplifier based on output conditions of preset frequency and electric power through an operation panel. The amplifier supplies constant high-frequency power to the resonance coil 212 via a transmission line.

[0047] A winding diameter, a winding pitch, and the number of turns of the resonance coil 212 are set to resonate at a certain wavelength so as to form a standing wave having a predetermined wavelength. That is, an electrical length of the resonance coil 212 is set to a length equivalent

to an integral multiple (1 time, 2 times,...) of one wavelength at a predetermined frequency of the high-frequency power supplied from the high-frequency power source 273.

[0048] As a material constituting the resonance coil 212, a copper pipe, a copper thin plate, an aluminum pipe, an aluminum thin plate, a material in which copper or aluminum is deposited on a polymer belt, or the like is used. The resonance coil 212 has a flat plate shape made of an insulating material, and is supported by a plurality of supports (not shown) vertically erected on an upper end surface of a base plate 248.

(Control Part)

[0049] As illustrated in FIG. 3, the controller 221 as a control part is configured to control the APC 242, the valve 243b and the vacuum pump 246 via a signal line A, the susceptor elevating mechanism 268 via a signal line B, the heater power adjustment mechanism 276 and the impedance variable mechanism 275 via a signal line C, the gate valve 244 via a signal line D, the RF sensor 272, the high-frequency power source 273 and the matcher 274 via a signal line E, and the MFCs 252a to 252c and the valves 253a to 253c and 243a via a signal line F, respectively.

[0050] The controller 221 as the process control part is configured as a computer including a central processing unit (CPU) 221a, a random access memory (RAM) 221b, a memory device 221c, and an I/O port 221d. The RAM 221b, the memory device 221c, and the I/O port 221d are configured to exchange data with the CPU 221a via an internal bus 221e. An input/output device 222 formed of, e.g., a touch panel or a display, is connected to the controller 221.

[0051] The memory device 221c is configured by, for example, a flash memory, a hard disk drive (HDD), or the like. A control program for controlling operations of a substrate processing apparatus, a program recipe specifying sequences and conditions of substrate processing as described below, or the like is readably stored in the memory device 221c. A process recipe (processing recipe) or various program recipes such as a chamber condition recipe as a pre-processing recipe and the like as described below function as a program combined such that the process control part 221 executes each sequence so as to obtain a predetermined result.

Hereinafter, the program recipe and the control program will be generally and simply referred to as a "program." Furthermore, when the term "program" is used herein, it may indicate a case of including only the program recipe, a case of including only the control program, or a case of including both the program recipe and the control program. Furthermore, the RAM 221b is configured as a memory area (work area) in which a program, data or the like read by the CPU 221a is temporarily stored.

[0052] The I/O port 221d is connected to the MFCs 252a to 252c, the valves 253a to 253c and 243a and 243b, the gate valve 244, the APC valve 242, the vacuum pump 246, the RF sensor 272, the high-frequency power source 273, the matcher 274, and the susceptor elevating mechanism 268, the impedance variable mechanism 275, the heater power adjustment mechanism 276, and the like, as described above.

[0053] The CPU 221a is configured to read the control program from the memory device 221c and execute the same, and reads the process recipe from the memory device 221c according to an input of an operation command from the input/output device 222. In addition, the CPU 221a is configured to control, according to the contents of the process recipe thus read, the opening degree adjusting operation of the APC valve 242, the opening/closing operation of the valve 243b, the driving and stopping of the vacuum pump 246 via the I/O port 221d and the signal line A, the operation of moving the susceptor elevating mechanism 268 up via the signal line B, the operation of adjusting the amount of electric power supplied to the heater 217b with the heater power adjustment mechanism 276 (temperature adjusting operation) and the operation of adjusting the impedance value with the impedance variable mechanism 275 via the signal line C, the opening/closing operation of the gate valve 244 via the signal line D, the operation of the RF sensor 272, the matcher 274, and the high-frequency power source 273 via the signal line E, the flow rate adjusting operation of various kinds of gases by the MFCs 252a to 252c and the opening/closing operation of the valves 253a to 253c and 243a via the signal line F, and the like.

[0054] The process control part 221 may be configured by installing, on the computer, the aforementioned program stored in an external memory device 223 (for example, a semiconductor

memory such as a USB memory or a memory card). The memory device 221c or the external memory device 223 is configured as a computer-readable recording medium. Hereinafter, the memory device 221c and the external memory device 223 will be generally and simply referred to as a "recording medium." When the term "recording medium" is used herein, it may indicate a case of including only the memory device 221c, a case of including only the external memory device 223, or a case of including both the memory device 221c and the external memory device 223. Furthermore, the program may be supplied to the computer by using a communication means such as the Internet or a dedicated line, instead of using the external memory device 223.

(2) Substrate Processing

[0055] FIG. 4 is a flowchart illustrating substrate processing as the process recipe according to the present embodiment. The substrate processing process according to the present embodiment, which is one of the processes for manufacturing a semiconductor device, is performed by, for example, the aforementioned processing mechanism PM. In the following descriptions, the operations of the respective parts constituting the processing mechanism PM are controlled by the process control part 221.

(Substrate Loading Process S110)

[0056] First, the susceptor elevating mechanism 268 lowers the susceptor 217 to a transfer position of a wafer W so as to pass the wafer push-up pins 266 through the through-holes 217a of the susceptor 217. As a result, the wafer push-up pins 266 protrude from the surface of the susceptor 217 by a predetermined height.

[0057] Subsequently, the gate valve 244 is opened, and the wafer W is loaded into the process chamber 201 from the vacuum transfer chamber adjacent to the process chamber 201 by using a wafer transfer mechanism (not shown). The loaded wafer W is supported in a horizontal posture on the wafer push-up pins 266 protruding from the surface of the susceptor 217. When the wafer W is loaded into the process chamber 201, the wafer transfer mechanism is retracted to

the outside of the process chamber 201 and the gate valve 244 is closed to seal the interior of the process chamber 201. Then, the susceptor elevating mechanism 268 raises the susceptor 217 such that the wafer W is supported on the upper surface of the susceptor 217.

(Temperature Rising and Vacuum Exhaust Process S120)

[0058] Subsequently, the temperature of the wafer W carried into the process chamber 201 is raised. The heater 217b, which is heated in advance, heats the wafer W to a predetermined value which falls within a range of, for example, 150 to 750 degrees C, by holding the wafer W on the susceptor 217 in which the heater 217b is embedded. At this time, the wafer W is heated such that the temperature of the wafer W becomes equal to 600 degrees C. In addition, the interior of the process chamber 201 is vacuum-exhausted by the vacuum pump 246 via the gas exhaust pipe 231 such that the internal pressure of the process chamber 201 becomes a predetermined value, while the temperature of the wafer W is raised. The vacuum pump 246 is operated at least until a substrate unloading process S160 as described below is completed.

(Reaction Gas Supply Process S130)

[0059] Next, an O_2 gas which is an oxygen-containing gas, and an H_2 gas which is a hydrogen-containing gas starts to be supplied as reaction gases. Specifically, the valves 253a and 253b are opened, and the supply of the O_2 gas and the H_2 gas into the process chamber 201 starts while flow rates of the O_2 gas and the H_2 gas are controlled by the MFCs 252a and 252b. At this time, the flow rate of the O_2 gas may be set at a predetermined value which falls within a range of, for example, 20 to 2,000 sccm, or preferably 20 to 1,000 sccm in some embodiments. Furthermore, the flow rate of the H_2 gas may be set at a predetermined value which falls within a range of, for example, 20 to 1,000 sccm, or preferably 20 to 500 sccm. As a more suitable example, it is desirable that a total flow rate of the O_2 gas and the H_2 gas be set to 1,000 sccm, and a flow rate ratio thereof be set to $O_2/H_2 \geqq 950/50$. In addition, the exhaust in the process chamber 201 is controlled by adjusting the degree of opening of the APC 242 so that the internal

pressure of the process chamber 201 becomes equal to a predetermined pressure which falls in a range of, for example, 1 to 250 Pa, preferably 50 to 200 Pa, or more preferably about 150 Pa. In this manner, the supply of the O_2 gas and the H_2 gas is continuously performed until a plasma processing process S140 as described below is completed while exhausting the inside of the process chamber 201 appropriately.

(Plasma Processing Process S140)

[0060] When the internal pressure of the process chamber 201 is stabilized, the application of high-frequency power to the resonance coil 212 from the high-frequency power source 273 via the RF sensor 272 begins. In the present embodiment, high-frequency power of 27.12 MHz is supplied from the high-frequency power source 273 to the resonance coil 212. The high-frequency power supplied to the resonance coil 212 may be set at predetermined electric power which falls within a range of, for example, 100 to 5,000 W, preferably 100 to 3,500 W, or more preferably 3,500 W. When the electric power is lower than 100 W, it is difficult to stably generate plasma discharge.

[0061] Therefore, high-frequency electric field is formed in the plasma generation space 201a to which the O_2 gas and the H_2 gas are supplied, and due to the electric field, doughnut-shaped induction plasma having the highest plasma density is excited at a height position corresponding to the electrical midpoint of the resonance coil 212 in the plasma generation space. The plasma-like O_2 gas and H_2 gas are dissociated to generate reactive species such as oxygen radicals containing oxygen (oxygen active species) or oxygen ions, hydrogen radicals containing hydrogen (hydrogen active species) or hydrogen ions, or the like.

[0062] As described above, when the electrical length of the resonance coil 212 is equal to the wavelength of the high-frequency power, the doughnut-shaped induction plasma having a very low electric potential is excited near the electrical midpoint of the resonance coil 212 in the plasma generation space 201a, with almost no capacitive coupling with the process chamber wall and the substrate mounting stand. Since the plasma having the very low electric potential is

generated, it is possible to prevent a sheath from being generated on the wall of the plasma generation space 201a or on the susceptor 217. Thus, in the present embodiment, the ions in the plasma are not accelerated.

[0063] The radicals generated by the induction plasma and the ions in a non-accelerated state are uniformly supplied into a groove 301 of the wafer W held on the susceptor 217 in the substrate processing space 201b. The supplied radicals and ions uniformly react with the sidewalls 301a and 301b to modify a silicon layer on the surface into a silicon oxide layer having good step coverage.

[0064] Thereafter, after lapse of a predetermined processing time, for example, 10 to 300 seconds, the output of the electric power from the high-frequency power source 273 is stopped, and the plasma discharge in the process chamber 201 is stopped. Furthermore, the valves 253a and 253b are closed to stop the supply of the O_2 gas and the H_2 gas into the process chamber 201. Thus, the plasma processing process S140 is completed.

(Vacuum Exhaust Process S150)

[0065] When the supply of the O_2 gas and the H_2 gas is stopped, the interior of the process chamber 201 is vacuum-exhausted via the gas exhaust pipe 231. Thus, the O_2 gas and the H_2 gas in the process chamber 201, an exhaust gas generated by the reaction of these gases, or the like is exhausted to the outside of the process chamber 201. Thereafter, the internal pressure of the process chamber 201 is adjusted to a pressure (e.g., 100 Pa) equal to that of the vacuum transfer chamber (a destination for unloading the wafer W, not shown) adjacent to the process chamber 201 by adjusting the opening degree of the APC 242.

(Substrate Unloading Process S160)

[0066] When the interior of the process chamber 201 reaches a predetermined pressure, the susceptor 217 is lowered to the transfer position of the wafer W to support the wafer W on the wafer push-up pins 266. Then, the gate valve 244 is opened and the wafer W is unloaded to the

outside of the process chamber 201 by using the wafer transfer mechanism. Thus, the substrate processing process according to the present embodiment is completed.

[0067] Next, execution control of a pre-processing recipe (chamber condition recipe) by the control part 10 will be described with reference to FIGS. 5 to 7.

[0068] First, setting of the pre-processing recipe will be described. Various recipes including the pre-processing recipe may be specified on a sequence recipe editing screen illustrated in FIG. 5.

[0069] The sequence recipe editing screen is configured to include a column for entering a name of a sequence recipe, an area for setting a pre-processing recipe for each processing mechanism PM, a warm-up recipe as an idle recipe for each processing apparatus, a process recipe as a substrate process recipe, an area for setting a post-processing recipe for each processing mechanism PM, and an area for selecting an operation type of the substrate processing apparatus.

[0070] In the area for setting a pre-processing recipe for each processing mechanism PM, a column for setting a pre-processing recipe for setting a target temperature for each processing mechanism PM is provided. In addition, a column (automatic execution setting column) for automatically setting specification of checking the target temperature before the process recipe in all the processing mechanisms PM is provided. When this column is checked, the pre-processing recipe is continuously executed until the temperature of the upper vessel 210 constituting the process chamber 201 of all the processing mechanisms PM reaches the target temperature. When all the processing mechanisms PM reach the target temperature, the pre-processing recipe is completed.

[0071] In the sequence recipe editing screen illustrated in FIG. 5, when there is execution setting of the pre-processing recipe and there is no automatic execution setting (when the automatic execution setting column is not checked), the pre-processing recipe is executed in each processing mechanism PM after completion of the idle recipe, and when a recipe completion report is issued from the processing mechanism PM specified to be executed, automatic operation processing (execution of the process recipe) is performed. As described above, when

the pre-processing recipe of the processing mechanism PM1 is completed, the process proceeds to next processing (substrate processing), enabling adaptation for a case where priority is given to the throughput over the temperature of the upper vessel 210 constituting the process chamber 201.

[0072] Hereinafter, respective processes constituting pre-processing process as the pre-processing recipe will be described with reference to FIG. 6A. The pre-processing process may also be performed with the wafer W as a dummy substrate held on the susceptor 217, but an example in which a dummy substrate is not used will be described herein.

(Vacuum Exhaust Process S410)

[0073] First, the process chamber 201 is vacuum-exhausted by the vacuum pump 246 such that the pressure of the process chamber 201 becomes a predetermined value. The vacuum pump 246 is operated at least until an exhaust and pressure regulation process S440 is completed. The heater 217b is also controlled to heat the susceptor 217.

(Discharge Gas Supply Process S420)

[0074] Next, similar to the reaction gas in the process recipe illustrated in FIG. 4, a mixture gas of the O_2 gas and the H_2 gas is supplied into the process chamber 201 as a discharge gas. Specific conditions such as the gas supply sequences, the supply gas flow rates, the pressure of the process chamber 201 or the like may be similar to those of the process recipe illustrated in FIG. 4.

[0075] Further, another gas such as an Ar gas or the like may be supplied or at least one of the O_2 gas and the H_2 gas may not be supplied for the purpose of promoting plasma discharge at a plasma discharge step S430 and the like as described below. In addition, different conditions may be set for the conditions such as the supply gas flow rates, the pressure of the process chamber 201 or the like. However, since the aspect of using the same discharge gas as the reaction gas in the process recipe illustrated in FIG. 4 has an effect of bringing the environment

of the process chamber 201 closer to the stable state of a next process recipe, in addition to heating the upper vessel 210, this is one of preferred aspects.

(Plasma Discharge Process S430)

[0076] Next, the application of high-frequency power from the high-frequency power source 273 to the resonance coil 212 starts. The magnitude of the high-frequency power supplied to the resonance coil 212 may be similar to that of the process recipe illustrated in FIG. 4. However, the magnitude of the high-frequency power may be set larger than that of the process recipe illustrated in FIG. 4, or may be differently set within the range of 100 to 5,000 W according to other processing conditions, in order to promote plasma discharge.

[0077] Therefore, the plasma discharge is intensively generated, particularly at respective height positions of the upper end, the midpoint, and the lower end of the resonance coil 212, within the plasma generation space 201a. The generated plasma discharge heats the upper vessel 210 from the inside. In particular, portions of the upper vessel 210 corresponding to the aforementioned height positions at which the plasma discharge is intensively generated, and surroundings thereof are intensively heated.

[0078] The controller 221 measures (monitors) the temperature of the outer peripheral surface of the upper vessel 210 (the temperature of the plasma generation space 201a) at least during this process by the temperature sensor 280, thereby maintaining the plasma discharge by continuously applying the high-frequency power to the resonance coil 212 until the measured temperature becomes equal to or higher than the target temperature (first temperature). When it is detected that the measured temperature has become equal to or higher than the target temperature, the controller 221 stops the supply of the high-frequency power from the high-frequency power source 273, stops the supply of the discharge gas to the process chamber 201, and completes this step.

[0079] As described above, the plasma discharge is generated and the upper vessel 210 and the like are heated until the measured temperature of the temperature sensor 280 becomes equal to or

higher than the target temperature such that the thickness of a film formed in the process recipe illustrated in FIG. 4 subsequent to this process can fall within a predetermined deviation range. In this case, it is desirable that the value of a stable temperature at that time be obtained as the target temperature by continuously executing the process recipe illustrated in FIG. 4 in advance. In short, the stable temperature is set as the target temperature.

(Exhaust and Pressure Regulation Process S440)

[0080] The gas in the process chamber 201 is exhausted to the outside of the process chamber 201. Thereafter, the opening degree of the APC valve 242 is adjusted so that the pressure of the process chamber 201 becomes equal to that of the vacuum transfer chamber. Thus, the pre-processing is completed, and lot processing illustrated in FIG. 4 is subsequently executed.

[0081] Next, a flow of the pre-processing recipe when the target temperature has a range with two threshold values (an upper limit value and a lower limit value) is illustrated in FIG. 6B. When a lot processing start request is made, the controller 221 is configured to start a pre-processing recipe illustrated in FIG. 6B. Further, temperature detection of the quartz dome 210 by the temperature sensor 280 also starts. Thereafter, the temperature detection is performed at least until the pre-processing recipe is completed.

(Pre-preparation Process S510)

[0082] First, a pre-preparation step before plasma generation is executed. Specifically, the vacuum exhaust process S410 and the discharge gas supply process S420 illustrated in FIG. 4 are executed. Thus, details thereof will be omitted.

(Comparison Process S520)

[0083] Comparison is performed as to whether the temperature (detected temperature) of the temperature sensor 280 is equal to or lower than the upper limit value of the target temperature. When the temperature is lower than the upper limit value of the target temperature, the high-

frequency power source 273 is turned on to supply the high-frequency power to the process chamber 201 so that the plasma processing is performed (S530), and the process proceeds to the next step (S550). Details of the plasma processing have already been described at the plasma discharge step S430, and therefore, they will be omitted. Thus, the temperature of the quartz dome 210 is raised.

[0084] Further, when the temperature exceeds the upper limit value of the target temperature, the plasma processing is not performed with the high-frequency power source 273 kept turned off, and the process as it is goes to the next process (S560).

[0085] FIG. 6B is only an embodiment, and when the temperature (detected temperature) of the temperature sensor 280 is equal to or lower than the lower limit value of the target temperature, the high-frequency power source 273 is turned on to supply the high-frequency power to the process chamber 201 so that the plasma processing is performed (S530), and the process proceeds to the next process (S550). When the temperature is higher than the lower limit value of the target temperature, the process may proceed to the next process (S560) with the high-frequency power source 273 kept turned off.

(Monitoring Process S550)

[0086] The controller 221 waits until the detected temperature of the temperature sensor 280 exceeds the upper limit value of the target temperature.

[0087] Further, when the temperature of the quartz dome 210 is raised by the plasma processing (S530), the high-frequency power source 273 is turned off at the time when the detected temperature reaches the upper limit value of the target temperature, and the process proceeds to the next process (S560). Although not illustrated in FIG. 6B, the pre-processing recipe may be stopped when the temperature does not reach the upper limit value of the target temperature even after the lapse of a predetermined period.

(Temperature Holding Process S560)

[0088] The controller 221 performs control so that the detected temperature falls within the range of the upper and lower limit values of the target temperature, and notifies the transfer system controller 31 that the process has proceeded to the temperature holding process S560.

[0089] For example, when the temperature reaches the upper limit value of the target temperature (S550) by the plasma processing (S530), the plasma processing is stopped (the high-frequency power source 273 is turned off). On the other hand, the temperature of the quartz dome 210 is lowered with the high-frequency power source 273 kept turned off, and when the detected temperature of the temperature sensor 280 is lowered to the target temperature, the plasma processing illustrated at S530 is performed.

[0090] At this process, the controller 221 compares the detected temperature with the upper and lower limit values of the target temperature on a regular cycle and turns on and off the high-frequency power source 273, and when the plasma detected temperature becomes lower than the lower limit value of the target temperature, the plasma processing (S530) is performed. Thereafter, as described above, the high-frequency power source 273 is turned on and off in order to keep the detected temperature within the range of the upper and lower limit values of the target temperature.

[0091] When the transfer system controller 31 receives, from the controllers 221 of all the connected processing mechanisms PM (PM1 to PM4), the notification that the process has proceeded to the processing of the temperature holding process S560, the controller 31 instructs the controller 221 of all the processing mechanisms PM (PM1 to PM4) to proceed to the processing of a post-processing process S580. On the other hand, for one of all the processing mechanisms PM, when the temperature of the quartz dome 210 in the processing mechanism PM does not fall within the range of the upper and lower limit values of the target temperature, the pre-processing recipe is continuously executed. In this case, the controller 221 of the processing mechanism PM in which the temperature of the quartz dome 210 falls within the range of the upper and lower limit values of the target temperature is configured to continuously execute the temperature holding process (S560). In addition, the controller 221 of the

processing mechanism PM, which falls within the range of the upper and lower limit values of the target temperature, may simply wait until the temperature of the quartz dome 210 in other processing mechanisms PM reaches the upper and lower limit values of the target temperature, by continuously executing the temperature holding process (S560).

(Post-processing Process S580)

[0092] The controller 221 performs post-processing upon receipt of an instruction from the transfer system controller 31 to proceed to the processing of the post-processing process S580. The contents of the post-processing have already been described at the exhaust and pressure regulation step S440 illustrated in FIG. 4, and therefore, they will be omitted. When the post-processing is completed, the pre-processing recipe is completed. Then, the controller 221 notifies the transfer system controller 31 that the pre-processing recipe has been completed.

[0093] When the pre-processing recipe for all the PMs (PM1 to PM4) is completed, the transfer system controller 31 transfers product wafers to be processed in the lot processing to the process chamber 201, and thereafter, the process recipe is executed.

[0094] In this case, in order that the temperature of the quartz dome 210 may be lowered and not deviate from the target temperature until the process recipe starts, the controller 221 may spontaneously monitor the temperature of the quartz dome 210, automatically control ON/OFF of the high-frequency power source to generate discharge plasma, and monitor the temperature of the quartz dome 210 on a regular cycle so that the temperature of the quartz dome 210 may fall within the range of the upper and lower limit values of the target temperature,.

[0095] As described above, according to the pre-processing recipe illustrated in FIG. 6B, the plasma discharge is generated until the measured temperature of the temperature sensor 280 becomes equal to or higher than the target temperature or until the temperature converges within the range of the upper and lower limit values of the target temperature, and the quartz dome 210 or the like is then heated such that the thickness of the film formed in the process recipe illustrated in FIG. 4 subsequent to this process (execution of the pre-processing recipe) can fall

within a predetermined deviation range.

[0096] Furthermore, according to the pre-processing recipe illustrated in FIGS. 6A and 6B which do not use the dummy wafer, since the internal temperature of the quartz dome is raised by the plasma processing by processing several dummy wafers and a production process is then performed, it is possible to reduce the deterioration of productivity and any inconvenience of having to use the dummy wafers.

[0097] FIG. 7 illustrates a flow of the pre-processing recipe for the entire substrate processing apparatus. In FIG. 7, when the execution setting of the pre-processing recipe and the automatic execution setting are made, the pre-processing recipe is executed until the target temperature is reached in each processing mechanism PM after the completion of the idle recipe, and when the completion report of the pre-processing recipe is issued from the processing mechanism PM specified to be executed, the automatic operation processing (execution of the process recipe) is performed.

[0098] In this case, the idle recipe is executed when the processing mechanism PM is in an idle (standby) state. On the other hand, the process recipe is executed when the processing mechanism PM is in a run (execution) state. After the idle recipe is completed, since the state of the processing mechanism PM is changed from the standby state to the execution state via the preparation state (standby state) until the process recipe is executed, the atmosphere of the process chamber 201 of the processing mechanism PM is at a high temperature to some extent after the completion of the idle recipe. However, it was not clear whether the atmosphere of the process chamber 201 was at a high temperature when executing the process recipe.

[0099] Furthermore, the idle recipe was executed at a predetermined time period, but the temperature of the plasma generation space 201a could not be recognized. In the present embodiment, the pre-processing recipe can be executed immediately before the execution of the process recipe such that the temperature of the plasma generation space 201a of each processing mechanism PM is controlled within the range of the upper and lower limit values of the target temperature. Moreover, in the present embodiment, the pre-processing recipe may be executed

before the execution of the process recipe when the processing mechanism PM is in a run (execution) state.

[0100] The control in each processing mechanism PM is as illustrated in FIGS. 6A and 6B described above. In the present invention, the controller 221 which controls the processing mechanism PM1 is described as PMC1, the controller 221 which controls the processing mechanism PM2 is described as PMC2, the controller 221 which controls the processing mechanism PM3 is described as PMC3, and the controller 221 which controls the processing mechanism PM4 is described as PMC4. At this time, the device controller 11 is described as OU, and the transfer system controller 31 is described as CC.

[0101] The CC, which receives a lot start request from the device controller 11 by the operation of the operator or a higher controller such as a host computer, confirms the completion of the idle recipe such as warm-up recipe or the like to the controller 221 which controls each processing mechanism PM. Furthermore, a request to execute the pre-processing recipe is held off when the idle recipe is under execution, and such a request is issued to each processing mechanism PM after the idle recipe is completed. In the illustrated example, it is illustrated when the temperature of the upper vessel 210 is lower than the target temperature.

[0102] The CC waits for the temperature of the upper vessel 210 constituting the process chamber 201 to reach the target temperature. Each PMC executes processing (executes a pre-processing recipe) according to a recipe name specified in FIG. 5. Furthermore, when the temperature of the upper vessel 210 reaches the target temperature during execution of the pre-processing recipe, each processing mechanism PM reports an event to the CC, and temporarily stops the corresponding step.

[0103] Upon receipt of a temperature reach event in which the temperatures of the upper vessel 210 in all the processing mechanisms PM have reached the target temperature, the CC requests each PMC to proceed to the processing of the next step. Each PMC resumes pre-processing. Upon receipt of a pre-processing recipe completion event from all the PMCs, the CC causes the process control part to execute the process recipe so as to start lot processing.

[0104] According to the present embodiment, in order that the temperature of the quartz dome 210 may be lowered and not deviate from the target temperature until the process recipe starts, the controller 221 spontaneously monitors the temperature of the quartz dome 210, automatically controls ON/OFF of the high-frequency power source to generate discharge plasma, and monitors the temperature of the quartz dome 210 on a regular cycle so that the temperature of the quartz dome 210 may fall within the range of the upper and lower limit values of the target temperature, and therefore the thickness of the film formed in the process recipe can fall within a predetermined deviation range.

[0105] Further, according to the present embodiment, in all the processing mechanisms PM, the temperature of the quartz dome 210 is controlled so as to fall within the range of the upper and lower limit values of the target temperature, and therefore no difference due to the atmosphere of the processing mechanism PM (process chamber 201) occurs in the processing result of the substrate W formed in each processing mechanism PM and processed in the process chamber 201 at the next process (execution of process recipe). Thus, it is possible to improve the quality of the processing result of the substrate W.

<Other Embodiments of the Invention>

[0106] In the aforementioned embodiments, there has been described examples in which the oxidizing process and the nitriding process are performed on the surface of the substrate using plasma. However, the present invention is not limited thereto and may be applied to any technique for processing a substrate using plasma. For example, the present invention may be applied to a modification process or a doping process for a film formed on a surface of a substrate using plasma, a reduction process for an oxide film, an etching process for the film, an ashing process for a resist, or the like.

[0107] This application claims the benefit of priority based on Japanese Patent Application No. 2017-179484 filed on September 20, 2017, the entire invention of which is incorporated herein by reference.

INDUSTRIAL USE OF THE INVENTION

[0108] The present invention can be in a processing apparatus which performs processing on a substrate using plasma, and thus has industrial applicability.

EXPLANATION OF REFERENCE NUMERALS

[0109] W: wafer (substrate), 10: control part, 201: process chamber, 221: process controller (process control part)

WHAT IS CLAIMED IS:

1. A substrate processing apparatus, comprising:

a process vessel forming a plasma generation space in which a processing gas is plasma-excited and a substrate processing space communicating with the plasma generation space;

a plasma generation part including a coil disposed to surround the plasma generation space and installed to be wound around an outer periphery of the process vessel, and a high-frequency power source configured to supply high-frequency power to the coil;

a gas supply part configured to supply the processing gas to the plasma generation space;

a temperature sensor installed outside the process vessel and configured to detect a temperature of the process vessel; and

a control part configured to control the plasma generation part and the gas supply part such that the temperature of the process vessel detected by the temperature sensor falls within a range of a target temperature defined by a preset upper limit value and a preset lower limit value, prior to execution of a process recipe for processing substrates .

2. The apparatus according to Claim 1, wherein the process vessel comprises an upper vessel and a lower vessel, and the temperature sensor is configured to be installed in the upper vessel.

3. The apparatus according to Claim 1, wherein the control part is configured to execute a pre-processing recipe before the process recipe is executed, and

wherein the pre-processing recipe is configured to supply the high-frequency power for plasma-exciting the processing gas to the coil.

4. The apparatus according to Claim 3, wherein the pre-processing recipe is configured not to transfer the substrates.

5. The apparatus according to Claim 1, wherein, when the temperature detected by the temperature sensor is lower than the lower limit value of the target temperature, the control part is configured to supply the high-frequency power to the coil so as to raise the temperature of the process vessel.

6. The apparatus according to Claim 1, wherein, when the temperature detected by the temperature sensor is higher than the upper limit value of the target temperature, the control part is configured not to supply the high-frequency power to the coil.

7. The apparatus according to Claim 1, wherein the control part is configured to supply the high-frequency power to the coil by turning on the high-frequency power source so as to raise the temperature of the process vessel when the temperature detected by the temperature sensor is lower than the lower limit value of the target temperature, while lowering the temperature of the process vessel by turning off the high-frequency power source when the temperature detected by the temperature sensor exceeds the upper limit value of the target temperature.

8. The apparatus according to Claim 3, wherein, when the temperature detected by the temperature sensor is higher than the lower limit value of the target temperature and lower than the upper limit value of the target temperature, the control part is configured to complete the pre-processing recipe.

9. The apparatus according to Claim 3, wherein the process vessel includes a plurality of process vessels, and

wherein, when the temperature detected by the temperature sensor installed in each of the process vessels is higher than the lower limit value of the target temperature and lower than the upper limit value of the target temperature, the control part is configured to complete the pre-

processing recipe.

10. The apparatus according to Claim 9, wherein the control part is configured to distributively transfer the substrates to respective substrate process chambers in the process vessels so as to execute the process recipe for each of the substrates.

11. The apparatus according to Claim 3, wherein the process vessel includes a plurality of process vessels, and

wherein, when the temperature detected by at least one of the temperature sensors respectively installed in the process vessels is higher than the upper limit value of the target temperature or when it is lower than the lower limit value of the target temperature, the control part is configured to continue the pre-processing recipe.

12. The apparatus according to Claim 9, wherein the control part is configured to execute an idle recipe, and

wherein the pre-processing recipe is configured to be executed after the idle recipe.

13. A method of manufacturing a semiconductor device, comprising:

executing a pre-processing recipe including:

detecting a temperature of a process vessel including a plasma generation space in which a processing gas is plasma-excited and a substrate processing space communicating with the plasma generation space;

supplying the processing gas to the plasma generation space; and

plasma-exciting the processing gas supplied to the plasma generation space by supplying high-frequency power to a coil disposed to surround the plasma generation space and installed to be wound around an outer periphery of the process vessel; and

processing a substrate disposed in the substrate processing space while supplying the

processing gas to the substrate via the plasma generation space, by executing a process recipe,

wherein the act of executing the pre-processing recipe further includes performing a control so that a temperature of the process vessel falls within a range of a target temperature defined by a preset upper limit value and a preset lower limit value.

14. A program that causes, by a computer, a substrate processing apparatus to perform a pre-processing recipe, the pre-processing recipe comprising:

detecting a temperature of a process vessel forming a plasma generation space in which a processing gas is plasma-excited and a substrate processing space communicating with the plasma generation space;

supplying the processing gas to the plasma generation space;

plasma-exciting the processing gas supplied to the plasma generation space by supplying high-frequency power to a coil disposed to surround the plasma generation space and installed to be wound around an outer periphery of the process vessel; and

causing a temperature of the process vessel to fall within a range of a target temperature defined by a preset upper limit value and a preset lower limit value.