

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: at least one 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; 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 at least one 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; at least one temperature sensor installed outside the at least one process vessel and configured to detect a temperature of the at least one process vessel; and a control part configured to perform a control such that the temperature of the at least one process vessel detected by the at least one 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.

wafers W and execution of work instructed by the operator. Furthermore, the transfer system controller 31 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 221 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)

[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 O₂ 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 N₂ gas supply source as a nitrogen-containing gas supply source is installed instead of the O₂ 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) valve 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 valve 242, and the valve 243b. The vacuum pump 246 may also be included in the exhaust

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 valve 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.

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 O₂ gas which is an oxygen-containing gas, and an H₂ 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 O₂ gas and the H₂ gas into the process chamber 201 starts while flow rates of the O₂ gas and the H₂ gas are controlled by the MFCs 252a and 252b. At this time, the flow rate of the O₂ 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 H₂ 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 O₂ gas and the H₂ gas be set to 1,000 sccm, and a flow rate ratio thereof be set to O₂/H₂≥950/50. In addition, the exhaust in the process chamber 201 is controlled by adjusting the degree of opening of the APC valve 242 so that the internal

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 O₂ gas and the H₂ gas into the process chamber 201. Thus, the plasma processing process S140 is completed.

(Vacuum Exhaust Process S150)

[0065] When the supply of the O₂ gas and the H₂ gas is stopped, the interior of the process chamber 201 is vacuum-exhausted via the gas exhaust pipe 231. Thus, the O₂ gas and the H₂ 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 valve 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

[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 (at regular intervals) 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 S570)

[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. 6A, 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

WHAT IS CLAIMED IS:

1. A substrate processing apparatus, comprising:
 - at least one 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;
 - 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 at least one 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;
 - at least one temperature sensor installed outside the at least one process vessel and configured to detect a temperature of the at least one process vessel; and
 - a control part configured to control the plasma generation part and the gas supply part such that the temperature of the at least one process vessel detected by the at least one 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 at least one process vessel comprises an upper vessel and a lower vessel, and the at least one 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 at least one temperature sensor is lower than the lower limit value of a range 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 at least one process vessel.
6. The apparatus according to Claim 1, wherein, when the temperature detected by the at least one temperature sensor is higher than the upper limit value of the range 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 at least one process vessel when the temperature detected by the at least one temperature sensor is lower than the lower limit value of the range of the target temperature, while lowering the temperature of the at least one process vessel by turning off the high-frequency power source when the temperature detected by the at least one temperature sensor exceeds the upper limit value of the range of the target temperature.
8. The apparatus according to Claim 3, wherein, when the temperature detected by the at least one temperature sensor is higher than the lower limit value of the range of the target temperature and lower than the upper limit value of the range of the target temperature, the control part is configured to complete the pre-processing recipe.
9. The apparatus according to Claim 3, wherein the at least one process vessel includes a plurality of process vessels, and

wherein, when the temperature detected by the at least one temperature sensor installed in each of the process vessels is higher than the lower limit value of the range of the target temperature and lower than the upper limit value of the range 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 at least one process vessel includes a plurality of process vessels, and the at least one temperature sensor includes a plurality of temperature sensors, 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 range of the target temperature or when it is lower than the lower limit value of the range 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 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;

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.