

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

TECHNICAL FIELD

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

BACKGROUND

[0002] Generally, a tungsten (W) film is used for a control gate of a NAND flash memory having a three-dimensional structure and for an electrode for a word line of a MOSFET (Metal Oxide Semiconductor Field Effect Transistor). The W film is finally buried in a hole. At the time of forming the W film, W is completely embedded and closed in the hole. At this time, the W film is formed also on an unnecessary portion. Therefore, an etching-back process is performed after the W film-forming process, thereby leaving the W film only on a desired portion.

[Prior Art Documents]

[0003] Patent Document

Patent Document 1: Japanese laid-open publication No. 2015-109419

[0004] Conventionally, wet cleaning has been mainly used for etching-back of a W film. In recent years, etching-back by dry etching has been studied. However, for example, when the W film is etched back, an other film may be exposed at the portion where the W film is not embedded, because the thickness of the W film to be etched back is larger (thicker) than the thickness of the formed W film. The other exposed film may react with an etching gas and may be shaved off or may form a foreign substance.

[0005] The present disclosure provides a technique capable of suppressing reaction of an etching gas with a film other than an etching target film exposed during etching-back.

SUMMARY

[0006] According to one or more embodiments of the present disclosure, there is provided a technique that includes: etching back a second metal film by supplying an oxygen-containing gas and a fluorine-containing etching gas to a substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and removing the oxygen-containing gas and the fluorine-containing etching gas.

[0007] According to the present disclosure, it is possible to suppress reaction of an etching gas with a film other than an etching target film exposed during etching-back.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. 1 is a view schematically showing a device according to embodiments of the present disclosure.

FIG. 2 is a vertical sectional view schematically showing a vertical process furnace of a substrate processing apparatus according to embodiments of the present disclosure.

FIG. 3 is a schematic horizontal sectional view taken along line A-A in FIG. 2.

FIG. 4 is a schematic configuration diagram of a controller of the substrate processing apparatus according to embodiments of the present disclosure, in which a control system of the controller is shown in a block diagram.

FIG. 5 is a view showing gas supply timings in embodiments of the present disclosure.

FIG. 6 is a view showing types of substrates accommodated in a process chamber of the substrate processing apparatus and a positional relationship between respective substrates at the time of evaluation according to embodiments of the present disclosure.

FIG. 7 is a view showing the results of evaluation (XPS analysis of a Si wafer) according to embodiments of the present disclosure.

FIGS. 8A to 8F are views showing modifications of the gas supply timings according to embodiments of the present disclosure, where FIG. 8A is a view showing modification 1, FIG. 8B is a view showing modification 2, FIG. 8C is a view showing modification 3, FIG. 8D is a view showing modification 4, FIG. 8E is a view showing modification 5, and FIG. 8F is a view showing modification 6.

DETAILED DESCRIPTION

[0009] In a NAND flash memory, for example, as described above, when a W film is etched back, an other film may be exposed at a portion where the W film is not embedded. Examples of the other film may include a silicon film (Si film), a silicon oxide film (SiO film), a silicon nitride film (SiN film), and an aluminum oxide film (AlO film). There are also portions, which are exposed from the beginning, such as the back surface of the substrate and the like. For example, in the case of a silicon (Si) substrate, Si is exposed at the back surface thereof. In the case of the Si substrate, silicon 601 corresponds to the Si substrate. For example, as shown in FIG. 1, an aluminum oxide film 603 and a titanium nitride film 602 may form on silicon 601, and tungsten 604 may be embedded therein.

[0010] For example, when Si is exposed, Si may be shaved off by reacting with an etching gas, or etched W may react with Si such that W penetrates into Si. For example, when AlO is exposed, it may react with an element contained in the etching gas to form a foreign substance, and the foreign substance may remain in AlO. When a halogen-based etching gas is used as the etching gas, the foreign substance mainly contains Al and a halogen element. For example, when a nitrogen trifluoride (NF₃) gas, which is a fluorine-containing gas, is used as the etching gas, Al and F react to form AlF. AlF has a low vapor pressure and may possibly remain in AlO as a solid.

[0011] Thus, the present inventors have conducted intensive research and have conceived to allow an oxygen-containing gas to flow together with an etching gas during etching-back. For example, by allowing an oxygen-containing gas to flow, Si and O react with each other to form SiO at a portion where Si is exposed. This makes it possible to suppress reaction of Si with the etching gas and to suppress shaving-off of Si. In addition, it is possible to suppress the reaction between etched W and Si and to suppress entry of W into Si. This is because Si reacts with W to form a tungsten silicon film (tungsten silicide or WSi), but SiO does not react with W. In addition, it is possible to suppress reaction of AlO with the etching gas and to suppress formation of a foreign substance due to the reaction of AlO with the element contained in the etching gas.

Details will be described below.

<One or more embodiments of the Present Disclosure>

[0012] Hereinafter, one or more embodiments of the present disclosure will be described with reference to FIGS. 2 to 4. The substrate processing apparatus 10 is configured as an example of an apparatus to be used in a semiconductor-device-manufacturing process.

(1) Configuration of Substrate Processing Apparatus

[0013] The substrate processing apparatus 10 includes a process furnace 202 provided with a heater 207 as a heating means (heating mechanism or heating system). The heater 207 has a cylindrical shape, and is vertically installed by being supported by a heater base (not shown) as a holding plate.

[0014] Inside the heater 207, there is installed an outer tube 203 which constitutes a reaction container (process container) concentrically with the heater 207. The outer tube 203 is made of a heat-resistant material such as quartz (SiO_2) or silicon carbide (SiC), and is formed in a cylindrical shape with its upper end closed and its lower end opened. Below the outer tube 203, there is installed a manifold (inlet flange) 209 concentrically with the outer tube 203. The manifold 209 is made of, for example, a metal such as stainless steel (SUS), and is formed in a cylindrical shape with both of its upper and lower ends opened. An O-ring 220a as a seal member is installed between the upper end of the manifold 209 and the outer tube 203. As the manifold 209 is supported by the heater base, the outer tube 203 comes into a vertically installed state.

[0015] Inside the outer tube 203, there is installed an inner tube 204 that constitutes a reaction container. The inner tube 204 is made of a heat-resistant material such as quartz (SiO_2) or silicon carbide (SiC), and is formed in a cylindrical shape its upper end closed and its lower end opened. A process container (reaction container) mainly includes the outer tube 203, the inner tube 204, and the manifold 209. A process chamber 201 is formed at a hollow portion of the process container (inside the inner tube 204).

[0016] The process chamber 201 is configured to accommodate wafers 200 as substrates in a state in which the wafers 200 are arranged in a horizontal posture and in multiple stages along a vertical direction by a boat 217 described below.

[0017] In the process chamber 201, nozzles 410, 420, and 430 are installed so as to penetrate the side wall of the manifold 209 and the inner tube 204. Gas supply pipes 310, 320, and 330 as gas supply lines are connected to the nozzles 410, 420, and 430, respectively. As described above, the substrate processing apparatus 10 is provided with the three nozzles 410, 420, and 430 and the three gas supply pipes 310, 320, and 330, and is configured to supply a plurality of types of gases into the process chamber 201. However, the process furnace 202 of the present embodiments is not limited to the above-described form.

[0018] MFCs (Mass flow controllers) 312, 322, and 332, which are flow rate controllers (flow rate control units), and valves 314, 324, and 334, which are opening/closing valves, are installed at the gas supply pipes 310, 320, and 330, respectively, sequentially from the upstream side. Gas supply pipes 610, 620, and 630 for supplying an etching gas are connected to the gas supply pipes 310, 320, and 330 at the downstream side of the valves 314, 324, and 334, respectively. MFCs 612, 622, and 632, which are flow rate controllers (flow rate control units), and valves 614, 624, and 634, which are opening/closing valves, are installed at the gas supply pipes 610, 620, and 630, respectively, sequentially from the upstream side. Furthermore, gas supply pipes 510, 520, and 530 for supplying an inert gas are connected to the gas supply pipes 310, 320, and 330 at the downstream side of the valves 314, 324, and 334, respectively. MFCs 512, 522, and 532, which are flow rate controllers (flow rate control units), and valves 514, 524, and 534, which are opening/closing valves, are installed at the gas supply pipes 510, 520, and 530, respectively, sequentially from the upstream side.

[0019] Nozzles 410, 420, and 430 are connected to the distal ends of the gas supply pipes 310, 320, and 330, respectively. The nozzles 410, 420, and 430 are configured as L-shaped nozzles. The horizontal portions of the nozzles 410, 420, and 430 are installed to penetrate the side wall of the manifold 209 and the inner tube 204. The vertical portions of the nozzles 410, 420, and 430 are installed inside a channel-shaped (groove-shaped) spare chamber 201a that protrudes

radially outward of the inner tube 204 and extends in the vertical direction. In the spare chamber 201a, the vertical portions of the nozzles 410, 420, and 430 are installed to extend upward (upward in the arrangement direction of the wafers 200) along the inner wall of the inner tube 204.

[0020] The nozzles 410, 420, and 430 are installed so as to extend from a lower region of the process chamber 201 to an upper region of the process chamber 201. The nozzles 410, 420, and 430 have a plurality of gas supply holes 410a, 420a, and 430a, respectively, which are formed at positions facing the wafers 200. Thus, processing gases are supplied to the wafers 200 from the gas supply holes 410a, 420a, and 430a of the nozzles 410, 420, and 430, respectively. The gas supply holes 410a, 420a, and 430a are formed in plural over a region from the lower portion to the upper portion of the inner tube 204. The gas supply holes 410a, 420a, and 430a have the same opening area, and are provided at the same opening pitch. However, the gas supply holes 410a, 420a, and 430a are not limited to the above-described form. For example, the opening area may be gradually increased from the lower portion to the upper portion of the inner tube 204. By doing so, the flow rates of the gases supplied from the gas supply holes 410a, 420a, and 430a can be made more uniform.

[0021] The gas supply holes 410a, 420a, and 430a of the nozzles 410, 420, and 430 are formed in plural at height positions from the bottom to the top of the boat 217, which will be described below. Therefore, the processing gases supplied into the process chamber 201 from the gas supply holes 410a, 420a, and 430a of the nozzles 410, 420, and 430 are supplied to the entire arrangement region of the wafers 200 accommodated from the lower portion to the upper portion of the boat 217, i.e., the wafers 200 accommodated in the boat 217. The nozzles 410, 420, and 430 may be installed so as to extend from the lower region to the upper region of the process chamber 201, but are preferably installed so as to extend to the vicinity of the ceiling of the boat 217.

[0022] A precursor gas containing a metal element (metal-containing gas, precursor gas) as a processing gas is supplied from the gas supply pipe 310 to the process chamber 201 via the MFC 312, the valve 314, and the nozzle 410. The precursor may contain, for example, tungsten (W)

as a metal element. Tungsten hexafluoride (WF_6), which is a halogen-based precursor (halide), may be used as a fluorine-containing precursor gas.

[0023] A reducing gas is supplied from the gas supply pipe 320 to the process chamber 201 via the MFC 322, the valve 324, and the nozzle 420. As the reducing gas, for example, a hydrogen (H_2) gas as an H-containing gas containing a hydrogen element (H) may be used.

[0024] An oxidizing gas is supplied from the gas supply pipe 330 to the process chamber 201 via the MFC 332, the valve 334, and the nozzle 430. As the oxidizing gas, for example, an oxygen (O_2) gas as an O-containing gas containing an oxygen element (O) may be used.

[0025] An inert gas, for example, a nitrogen (N_2) gas, is supplied from the gas supply pipes 510, 520, and 530 to the process chamber 201 via the MFCs 512, 522, and 532, the valves 514, 524, and 534, and the nozzles 410, 420, and 430. An example in which the N_2 gas is used as an inert gas will be described below. However, as the inert gas, in addition to the N_2 gas, it may be possible to use, for example, a rare gas such as an argon (Ar) gas, a helium (He) gas, a neon (Ne) gas, a xenon (Xe) gas, or the like.

[0026] An etching gas is supplied from the gas supply pipes 610, 620, and 630 to the process chamber 201 via the MFCs 612, 622, and 632, the valves 614, 624, and 634, and the nozzles 410, 420, and 430, respectively. As the etching gas, it may be possible to use a halogen-based etching gas containing a halogen element, for example, nitrogen trifluoride (NF_3) which is a fluorine-containing etching gas containing a fluorine element.

[0027] A gas supply system mainly includes the gas supply pipes 310, 320, 330, 610, 620, and 630, the MFCs 312, 322, 332, 612, 622, and 632, the valves 314, 324, 334, 614, 624, and 634, and the nozzles 410, 420, and 430. However, only the nozzles 410, 420, and 430 may be considered as the gas supply system. When the precursor gas is supplied from the gas supply pipes 310 and 330, a precursor gas supply system mainly includes the gas supply pipes 310 and 330, the MFCs 312 and 332, and the valves 314 and 334. The nozzles 410 and 430 may be included in the precursor gas supply system. When the reducing gas is supplied from the gas supply pipe 320, a reducing gas supply system mainly includes the gas supply pipe 320, the MFC 322, and the valve 324. The nozzle 420 may be included in the reducing gas supply

system. When the etching gas is supplied from the gas supply pipes 610, 620, and 630, an etching gas supply system mainly includes the gas supply pipes 610, 620, and 630, the MFCs 612, 622, and 632, and the valves 614, 624, and 634. The nozzles 410, 420, and 430 may be included in the etching gas supply system. An inert gas supply system mainly includes the gas supply pipes 510, 520, and 530, the MFCs 512, 522, and 532, and the valves 514, 524, and 534. The inert gas supply system may be referred to as a purge gas supply system, a dilution gas supply system, or a carrier gas supply system.

[0028] In the gas supply method according to the present embodiments, the gases are transported via the nozzles 410, 420, and 430 arranged in the spare chamber 201a in an annular vertically-elongated space, i.e., a cylindrical space defined by the inner wall of the inner tube 204 and the end portions of the plurality of wafers 200. The gases are injected into the inner tube 204 from the gas supply holes 410a, 420a, and 430a installed at the nozzles 410, 420, and 430 at the positions facing the wafers. More specifically, the precursor gas and the like are injected in a direction parallel to the surfaces of the wafers 200, i.e., in a horizontal direction, from the gas supply holes 410a of the nozzle 410, the gas supply holes 420a of the nozzle 420, and the gas supply holes 430a of the nozzle 430.

[0029] The exhaust hole (exhaust port) 204a is a through hole formed on the side wall of the inner tube 204 at a position facing the nozzles 410, 420, and 430, i.e., at a position 180 degrees opposite to the spare chamber 201a. The exhaust hole is, for example, a slit-shaped through hole elongated in the vertical direction. Therefore, the gas supplied from the gas supply holes 410a, 420a, and 430a of the nozzles 410, 420, and 430 to the process chamber 201 and flowing on the surfaces of the wafers 200, i.e., the remaining gas (residual gas), flows into an exhaust path 206 defined by a gap formed between the inner tube 204 and the outer tube 203 via the exhaust hole 204a. Then, the gas flowing into the exhaust path 206 flows into an exhaust pipe 231 and is discharged out of the process furnace 202.

[0030] The exhaust hole 204a is formed at a position facing the plurality of wafers 200 (preferably at a position facing a region from the upper portion to the lower portion of the boat 217). The gas supplied from the gas supply holes 410a, 420a, and 430a to the vicinity of the

wafers 200 in the process chamber 201 flows in the horizontal direction, i.e., in the direction parallel to the surfaces of the wafers 200, and then flows into the exhaust path 206 through the exhaust hole 204a. That is, the gas remaining in the process chamber 201 is exhausted in parallel with the main surfaces of the wafers 200 through the exhaust hole 204a. In addition, the exhaust hole 204a is not limited to being configured as a slit-shaped through hole, and may be configured by a plurality of holes.

[0031] The manifold 209 is provided with an exhaust pipe 231 for exhausting the atmosphere in the process chamber 201. A pressure sensor 245 as a pressure detector (pressure detection part) for detecting the pressure in the process chamber 201, an APC (Automatic Pressure Controller) valve 243, and a vacuum pump 246 as a vacuum exhaust device are connected to the exhaust pipe 231 sequentially from the upstream side. By opening and closing the APC valve 243 while operating the vacuum pump 246, it is possible to perform evacuation of the process chamber 201 and to stop the evacuation of the process chamber 201. Furthermore, by adjusting the opening degree of the APC valve 243 while operating the vacuum pump 246, it is possible to adjust the pressure in the process chamber 201. An exhaust system, i.e., an exhaust line, mainly includes the exhaust hole 204a, the exhaust path 206, the exhaust pipe 231, the APC valve 243, and the pressure sensor 245. The vacuum pump 246 may be included in the exhaust system.

[0032] Below the manifold 209, there is installed a seal cap 219 as a furnace port lid capable of hermetically closing the lower end opening of the manifold 209. The seal cap 219 is configured to make contact with the lower end of the manifold 209 from below in the vertical direction. The seal cap 219 is made of, for example, a metal such as SUS or the like, and is formed in a disk shape. On the upper surface of the seal cap 219, there is installed an O-ring 220b as a seal member that makes contact with the lower end of the manifold 209. On the opposite side of the seal cap 219 from the process chamber 201, there is installed a rotation mechanism 267 for rotating a boat 217 that accommodates the wafers 200. A rotation shaft 255 of the rotation mechanism 267 is connected to the boat 217 through the seal cap 219. The rotation mechanism 267 is configured to rotate the boat 217 to rotate the wafers 200. The seal cap 219 is configured to be moved up and down in the vertical direction by a boat elevator 115 as an elevating

mechanism installed vertically outside the outer tube 203. The boat elevator 115 is configured to load and unload the boat 217 into and from the process chamber 201 by moving the seal cap 219 up and down. The boat elevator 115 is configured as a transfer device (transfer mechanism) that transfers the boat 217 and the wafers 200 accommodated in the boat 217 into and out of the process chamber 201.

[0033] The boat 217 as a substrate support is configured to support a plurality of, for example, 25 to 200, wafers 200 in a horizontal posture and in multiple stages in a vertically-aligned state with the centers thereof aligned with each other, i.e., to arrange the wafers 200 at intervals. The boat 217 is made of, for example, a heat-resistant material such as quartz or SiC. Under the boat 217, heat-insulating plates 218 made of, for example, a heat-resistant material such as quartz or SiC, are supported in a horizontal posture and in multiple stages (not shown). This configuration makes it difficult for the heat from the heater 207 to be transferred toward the seal cap 219. However, the present embodiments are not limited to the above-described form. For example, instead of installing the heat-insulating plates 218 under the boat 217, a heat-insulating tube configured as a tubular member made of a heat-resistant material such as quartz or SiC may be installed.

[0034] As shown in FIG. 3, a temperature sensor 263 as a temperature detector is installed at the inner tube 204. By adjusting the amount of supplying electric power to the heater 207 based on the temperature information detected by the temperature sensor 263, the inside of the process chamber 201 has a desired temperature distribution. The temperature sensor 263 is formed in an L shape in a similar manner as the nozzles 410, 420, and 430, and is installed along the inner wall of the inner tube 204.

[0035] As shown in FIG. 4, a controller 121 as a control part (control means) is configured as a computer including a CPU (Central Processing Unit) 121a, a RAM (Random Access Memory) 121b, a memory device 121c, and an I/O port 121d. The RAM 121b, the memory device 121c, and the I/O port 121d are configured to exchange data with the CPU 121a via an internal bus. An input/output device 122 configured as, for example, a touch panel or the like is connected to the controller 121.

[0036] The memory device 121c is configured by, for example, a flash memory, a HDD (Hard Disk Drive), or the like. The memory device 121c readably stores a control program for controlling the operation of the substrate processing apparatus, a process recipe in which procedures and conditions of a below-described method of manufacturing a semiconductor device are written, and the like. The process recipe is a combination that can obtain a predetermined result by causing the controller 121 to execute the respective processes (respective steps) in a below-described method of manufacturing a semiconductor. The process recipe functions as a program. Hereinafter, the process recipe, the control program, and the like are collectively and simply referred to as a program. As used herein, the term "program" may refer to a case of including only the process recipe, a case of including only the control program, or a case of including a combination of the process recipe and the control program. The RAM 121b is configured as a memory area (work area) in which the program read by the CPU 121a, data, and the like are temporarily held.

[0037] The I/O port 121d is connected to the MFCs 312, 322, 332, 512, 522, 532, 612, 622, and 632, the valves 314, 324, 334, 514, 524, 534, 614, 624, and 634, the pressure sensor 245, the APC valve 243, the vacuum pump 246, the heater 207, the temperature sensor 263, the rotation mechanism 267, the boat elevator 115, and the like.

[0038] The CPU 121a is configured to read the control program from the memory device 121c and execute the control program thus read. The CPU 121a is also configured to read the recipe from the memory device 121c in response to an operation command inputted from the input/output device 122 or the like. The CPU 121a is configured to control, according to the contents of the recipe thus read, the operation of adjusting the flow rates of various gases by the MFCs 312, 322, 332, 512, 522, 532, 612, 622, and 632, the opening/closing operation of the valves 314, 324, 334, 514, 524, 534, 614, 624, and 634, the opening/closing operation of the APC valve 243, the pressure regulation operation by the APC valve 243 based on the pressure sensor 245, the temperature adjustment operation of the heater 207 based on the temperature sensor 263, the start and stop of the vacuum pump 246, the rotation and rotation speed adjustment operation of the boat 217 by the rotation mechanism 267, the operation of raising and

lowering the boat 217 by the boat elevator 115, the operation of storing the wafers 200 in the boat 217, and the like.

[0039] The controller 121 may be configured by installing, in a computer, the aforementioned program stored in an external memory device (e.g., a magnetic tape, a magnetic disk such as a flexible disk or hard disk, an optical disk such as a CD or a DVD, a magneto-optical disk such as a MO or the like, or a semiconductor memory such as a USB memory or a memory card) 123. The memory device 121c and the external memory device 123 are configured as computer-readable recording media. Hereinafter, the memory device 121c and the external memory device 123 are collectively and simply referred to as a recording medium. As used herein, the term "recording medium" may refer to a case of including only the memory device 121c, a case of including only the external memory device 123, or a case of including both the memory device 121c and the external memory device 123. The provision of the program to the computer may be performed using a communication means such as the Internet or a dedicated line without using the external memory device 123.

(2) Substrate-Processing Process

[0040] As a process of manufacturing a semiconductor device, an example of a W film formation step of embedding a W film into a hole of a pattern formed on a wafer 200 as a silicon substrate and having a surface at which an AlO film and a titanium nitride film (TiN film) are sequentially formed and an example of an etching-back step of etching back the W film will be described with reference to FIG. 5. The W film formation step and the etching-back step are performed using the process furnace 202 of the substrate processing apparatus 10 described above. In the following description, the operations of the respective parts constituting the substrate processing apparatus 10 are controlled by the controller 121.

[0041] A process of manufacturing a semiconductor device (substrate-processing process) according to the present embodiments includes:

an etching-back step of etching back a W film by supplying an oxygen-containing gas (e.g., an O₂ gas) and a fluorine-containing gas (e.g., an NF₃ gas) to a wafer 200 having a surface

at which a first metal film (e.g., a TiN film) is formed at an opening part (hole) in which a second metal film (e.g., a W film) is embedded; and

a removal step of removing the O₂ gas and the NF₃ gas.

[0042] When the term "wafer" is used herein, it may refer to "a wafer itself" or "a laminated body (aggregation) of a wafer and a predetermined layer or film formed on the surface of the wafer" (i.e., a wafer including a predetermined layer or film formed on the surface thereof). In addition, when the term "wafer surface" is used herein, it may refer to "a surface (exposed surface) of a wafer itself" or "a surface of a predetermined layer or a film formed on a wafer, i.e., an outermost surface of a wafer as a laminated body." In addition, when the term "substrate" is used herein, it may be synonymous with the word "wafer."

(Wafer Loading)

[0043] When a plurality of wafers 200 having a surface with a pattern hole in which an AlO film and a titanium nitride film (TiN film) are sequentially formed is charged into a boat 217 (wafer charging), as shown in FIG. 1, the boat 217 supporting the plurality of wafers 200 is lifted by the boat elevator 115 and loaded into the process chamber 201 (boat loading). In this state, the seal cap 219 closes the lower end opening of the outer tube 203 via the O-ring 220.

(Pressure Regulation and Temperature Adjustment)

[0044] The inside of the process chamber 201 is evacuated by the vacuum pump 246 so as to have a desired pressure (degree of vacuum). At this time, the pressure in the process chamber 201 is measured by the pressure sensor 245, and the APC valve 243 is feedback-controlled based on the measured pressure information (pressure regulation). The vacuum pump 246 keeps operating at least until the processing to the wafers 200 is completed. Furthermore, the inside of the process chamber 201 is heated by the heater 207 so as to reach a desired temperature. At this time, the amount of supplying electric power to the heater 207 is feedback-controlled based on the temperature information detected by the temperature sensor 263 so that the inside of the process chamber 201 has a desired temperature distribution (temperature adjustment). The

heating of the inside of the process chamber 201 by the heater 207 is continuously performed at least until the processing to the wafers 200 is completed.

[W Film Formation Step (W Deposition)]

[0045] A step of forming a W film is performed.

(WF₆ Gas and H₂ Gas Supply)

[0046] The valves 314 and 324 are opened to allow a WF₆ gas and a H₂ gas to flow through the gas supply pipes 310 and 320, respectively. The flow rates of the WF₆ gas and the H₂ gas are adjusted by the MFCs 312 and 322, respectively. The WF₆ gas and the H₂ gas are supplied to the process chamber 201 from the gas supply holes 410a and 420a of the nozzles 410 and 420, respectively, and are exhausted from the exhaust pipe 231. At this time, the WF₆ gas and the H₂ gas are supplied to the wafers 200. At the same time, the valves 514 and 524 may be opened to allow an inert gas such as a N₂ gas or the like to flow through the gas supply pipes 510 and 520. The flow rates of the N₂ gas flowing through the gas supply pipes 510 and 520 are adjusted by the MFCs 512 and 522. The N₂ gas is supplied to the process chamber 201 together with the WF₆ gas and the H₂ gas, and is exhausted from the exhaust pipe 231. At this time, in order to prevent the WF₆ gas and the H₂ gas from entering the nozzle 430, the valve 534 is opened to allow the N₂ gas to flow into the gas supply pipe 530. The N₂ gas is supplied to the process chamber 201 through the gas supply pipe 330 and the nozzle 430, and is exhausted from the exhaust pipe 231.

[0047] At this time, the APC valve 243 is controlled to set the pressure in the process chamber 201 to a pressure falling within a range of, for example, 10 to 6630 Pa. The supply flow rate of the WF₆ gas controlled by the MFC 312 is set to a flow rate falling within a range of, for example, 0.01 to 5 slm, and the supply flow rate of the H₂ gas controlled by the MFC 322 is set to a flow rate falling within a range of, for example, 0.1 to 50 slm. However, the supply flow rate of the WF₆ gas and the supply flow rate of the H₂ gas may be determined according to a desired film thickness. The time for supplying the WF₆ gas and the H₂ gas to the wafers 200,

i.e., the gas supply time (irradiation time), is determined according to the desired film thickness. At this time, the temperature of the heater 207 is set such that the temperature of the wafers 200 becomes a temperature falling within a range of, for example, 100 to 500 degrees C and preferably within a range of 150 to 450 degrees C.

[0048] The WF_6 gas and the H_2 gas flowing into the process chamber 201 react with each other in the gas phase (gas phase reaction) or react with each other at the substrate surface (surface reaction), whereby a W film is formed at the wafer 200. At this time, the W film is embedded in the hole formed on the wafer 200. The W film is also formed on the TiN film formed at the surface of the wafer 200.

(Removal of Residual Gas)

[0049] After the W film having a predetermined thickness is formed, the valves 314 and 324 are closed to stop the supply of the WF_6 gas and the H_2 gas. At this time, while the APC valve 243 is kept open, the inside of the process chamber 201 is evacuated by the vacuum pump 246 to remove the WF_6 gas and the H_2 gas remaining in the process chamber 201 from the process chamber 201. At this time, the valves 514, 524, and 534 are kept open to maintain the supply of the N_2 gas into the process chamber 201. The N_2 gas acts as a purge gas and may enhance the effect of removing the WF_6 gas and the H_2 gas unreacted or contributed to the formation of the W film, which remain in the process chamber 201, from the process chamber 201.

[Etching-back Step]

[0050] Next, a step of etching back the W film is performed.

(O_2 Gas Supply (Continuous Supply))

[0051] The valve 334 is opened to allow the O_2 gas to flow through the gas supply pipe 330. The flow rate of the O_2 gas is adjusted by the MFC 332. The O_2 gas is supplied into the process chamber 201 from the gas supply holes 430a of the nozzle 430, and is exhausted from the exhaust pipe 231. At this time, the O_2 gas is supplied to the wafers 200. At the same time, the

valve 534 may be opened to allow an inert gas such as a N_2 gas or the like to flow through the gas supply pipe 530. The flow rate of the N_2 gas flowing through the gas supply pipe 530 is adjusted by the MFC 532. The N_2 gas is supplied to the process chamber 201 together with the WF_6 gas and the H_2 gas, and is exhausted from the exhaust pipe 231. At this time, in order to prevent the WF_6 gas and the H_2 gas from entering the nozzle 430, the valves 514 and 524 are opened to allow the N_2 gas to flow through the gas supply pipes 510 and 520. The N_2 gas is supplied into the process chamber 201 through the gas supply pipes 310 and 320 and the nozzles 410 and 420, and is exhausted from the exhaust pipe 231.

[0052] At this time, the APC valve 243 is controlled to set the pressure in the process chamber 201 to a pressure falling within a range of, for example, 1 to 399 Pa. The supply flow rate of the O_2 gas controlled by the MFC 332 is set to a flow rate falling within a range of, for example, 0.1 to 30 slm. The time for supplying the O_2 gas to the wafers 200, i.e., the gas supply time (irradiation time) is set to a time falling within a range of, for example, 1 to 3600 seconds. At this time, the temperature of the heater 207 is set such that the temperature of the wafers 200 becomes a temperature falling within a range of, for example, 300 to 600 degrees C and preferably within a range of 350 to 500 degrees C.

(NF_3 Gas Supply (Intermittent Supply))

[0053] While the O_2 gas is flowing, the NF_3 gas is intermittently (like pulses) supplied a plurality of times. Specifically, the valves 614, 624, and 634 are opened to allow a NF_3 gas to flow through the gas supply pipes 610, 620, and 630, respectively. The flow rate of the NF_3 gas is adjusted by the MFCs 612, 622, and 632. The NF_3 gas is supplied into the process chamber 201 from the gas supply holes 410a, 420a, and 430a of the nozzles 410, 420, and 430, and is exhausted from the exhaust pipe 231. At this time, the O_2 gas and the NF_3 gas are supplied to the wafers 200. At this time, when the N_2 gas is flowing through the gas supply pipes 510, 520, and 530, the N_2 gas is supplied to the process chamber 201 together with the O_2 gas and the NF_3 gas, and is exhausted from the exhaust pipe 231.

[0054] At this time, the APC valve 243 is controlled such that the pressure in the process

chamber 201 during the supply of the NF_3 gas is set to a pressure falling within a range of, for example, 1 to 3990 Pa. The supply flow rate of the NF_3 gas controlled by the MFCs 612, 622, and 632 is set to a flow rate falling within a range of, for example, 0.1 to 10 slm. The time for supplying the NF_3 gas to the wafers 200, i.e., the gas supply time (irradiation time), is set such that one pulse is maintained for a time falling within a range of, for example, 0.1 to 60 seconds. The cumulative irradiation time (total irradiation time) of the NF_3 gas is set to a time falling within a range of, for example, 0.1 to 3600 seconds. At this time, the temperature of the heater 207 is set to be equal to the temperature in the O_2 supply step.

[0055] When the etching-back to a predetermined film thickness is completed, the valves 614, 624, and 634 are closed to stop the supply of the NF_3 gas. Finally, the above-described O_2 supply step is performed.

(After-Purging and Atmospheric Pressure Return)

[0056] A N_2 gas is supplied into the process chamber 201 from each of the gas supply pipes 510, 520, and 530, and is exhausted from the exhaust pipe 231. The N_2 gas acts as a purge gas, whereby the inside of the process chamber 201 is purged with the inert gas, and the gases and by-products remaining in the process chamber 201 are removed from the inside of the process chamber 201 (after-purging). Thereafter, the atmosphere in the process chamber 201 is replaced with the inert gas (inert gas replacement), and the pressure in the process chamber 201 is returned to the atmospheric pressure (atmospheric pressure return).

(Wafer Unloading)

[0057] Thereafter, the seal cap 219 is lowered by the boat elevator 115, and the lower end of the outer tube 203 is opened. Then, the boat 217 is unloaded from the lower end of the outer tube 203 to the outside of the outer tube 203 while the processed wafers 200 are supported by the boat 217. Thereafter, the processed wafers 200 are taken out from the boat 217 (wafer discharging).

[0058] The results of evaluation will be described with reference to FIGS. 6 and 7. As shown

in FIG. 6, in the evaluation according to the present embodiments, a Si wafer (bare wafer) for evaluation was accommodated in the boat 217 so as to be located near the center of the process chamber 201. A SiO₂/Si wafer obtained by forming a SiO₂ film on a Si wafer was accommodated at the upper stage of the Si wafer. A W/TiN/Si wafer obtained by sequentially forming a TiN film and a W film on a Si wafer was accommodated at the lower stage of the Si wafer. Furthermore, a TiN/Si wafer obtained by forming a TiN film on a Si wafer was accommodated at the lower stage of the W/TiN/Si wafer. Dummy wafers (Dummy) were accommodated at the upper stage of the SiO₂/Si wafer and at the lower stage of the TiN/Si wafer. In this state, evaluation was conducted.

[0059] FIG. 7 shows a XPS (X-ray Photoelectron Spectroscopy) analysis result for the Si wafer. The evaluation in the case where the oxygen-containing gas was not used (not added) at the time of etching-back is shown as a comparative example (indicated by a dotted line) for comparison with the evaluation according to the present embodiments (indicated by a solid line). FIG. 7 shows a XPS spectrum of W_{4f}. The horizontal axis indicates the binding energy (B.E. (eV)), and the vertical axis indicates the intensity of tungsten (W_{4f}). From these results, it can be seen that when etching was performed only with the NF₃ gas, W adheres onto Si. This means that the W-containing material (W-based gas) gasified by etching the W/TiN/Si wafer reacts with the exposed Si so that W adheres onto Si. On the other hand, when the O₂ gas was added to the evaluation (NF₃ gas) according to the present embodiments, W was not detected on Si. This is presumably because Si was oxidized by the added O₂ gas to form SiO, thereby suppressing the reaction with the gasified W-containing material mentioned above. As described above, by adding the oxygen-containing gas to the etching gas, it is possible to prevent the W-containing material gasified by reacting with the etching gas from reacting with another exposed film.

(3) Effects of the Present Embodiments

[0060] According to the present embodiments, one or more effects described below may be obtained.

(a) By adding the oxygen-containing gas at the time of supplying the etching gas, it is

possible to enhance the etching-back efficiency and to improve the throughput.

(b) When Si is exposed at the time of etching-back, by reacting Si and O to form SiO, it is possible to suppress the reaction with the etching gas and to suppress the shaving-off of Si.

(c) When AlO is exposed at the time of etching-back, it is possible to suppress the reaction of AlO with the etching gas and to suppress the formation of a foreign substance due to the reaction of AlO with the elements contained in the etching gas.

(d) By continuously supplying the oxygen-containing gas at the time of etching-back, even if a film other than the etching target film is shaved off by the etching gas, it is possible to immediately oxidize the shaved film to minimize the reaction with the etching gas.

(e) By supplying the oxygen-containing gas at the time of etching-back, it is possible to assure high safety.

(f) Since the etching can be performed little by little by intermittently supplying the oxygen-containing gas at the time of the etching-back, even if a film other than the etching target film is shaved off by the etching gas, it is possible to immediately oxidize the shaved film to minimize the reaction with the etching gas.

(g) By supplying the oxygen-containing gas into the process chamber prior to the etching gas at the start of the etching-back, it is possible to oxidize the exposed Si so as to become SiO that does not react with W. It is also possible to suppress the reaction of the W-containing material (W, W_x, WF₆, or the like) generated during the irradiation (supply) of the etching gas with Si.

(h) At the end of the etching-back, by supplying the oxygen-containing gas into the process chamber after stopping the supply of the etching gas, it is possible to maintain Si as SiO to suppress formation of WF_x (WF₆ or the like) due to the reaction of the remaining etching gas with W and to suppress reaction of the WF_x with Si.

(i) By supplying the etching gas from all the nozzles into the process chamber, it is possible to improve the uniformity of the etching gas distribution in the process chamber. Even in a process furnace that accommodates a plurality of substrates, it is possible to improve the uniformity of etching-back between the substrates.

[0061] Hereinafter, modifications of the above-described embodiments will be described.

Detail description of the parts similar to those of the above-described embodiments will be omitted, and different parts will be described.

<Modification 1>

[0062] In modification 1 of the above-described embodiments, as shown in FIG. 8A, the O₂ gas supply (continuous supply) step in the above-described etching-back step is performed, and the NF₃ gas is supplied once. That is, the O₂ gas is allowed to flow in a state in which the NF₃ gas is not flowing into the process chamber 201. The supply of the NF₃ gas is started after a predetermined time has elapsed. The supply of the NF₃ gas is stopped after a predetermined time has elapsed. The O₂ gas is supplied into the process chamber 201 again in a state in which the NF₃ gas is not flowing into the process chamber 201. The time for supplying the NF₃ gas is shorter than the time for supplying the O₂ gas. According to this modification, it is possible to obtain one or more of the effects of the above-described embodiments.

<Modification 2>

[0063] In modification 2 of the above-described embodiments, as shown in FIG. 8B, the O₂ gas supply (continuous supply) step in the above-described etching-back step is performed, and the NF₃ gas is supplied once. That is, the NF₃ gas and the O₂ gas are started to flow into the process chamber 201 at the same timing. The supply of the NF₃ gas is stopped after a predetermined time has elapsed. The O₂ gas is supplied into the process chamber 201 in a state in which the NF₃ gas is not flowing into the process chamber 201. The time for supplying the NF₃ gas is shorter than the time for supplying the O₂ gas.

[0064] According to this modification, one or more of the effects of the above-described embodiments may be obtained, and the following effect may be further obtained.

(j) The processing time can be shortened by starting to supply the etching gas and the oxygen-containing gas at the same timing.

<Modification 3>

[0065] In modification 3 of the above-described embodiments, as shown in FIG. 8C, the supply of the O₂ gas and the supply of the NF₃ gas are alternately repeated n₁ times. At this time, during the supply of each gas, the residual gas in the process chamber 201 is removed by the same procedure as the residual gas removal step of the W film formation step. That is, the O₂ gas and the NF₃ gas are intermittently supplied so as not to be mixed with each other.

[0066] According to this modification, one or more of the effects of the above-described embodiments may be obtained, and the following effect may be further obtained.

(k) By intermittently supplying the oxygen-containing gas and the etching gas, there is a timing at which the etching gas flows into the process chamber 201 in a state in which the oxygen-containing gas is not flowing. It is therefore possible to enhance the etching efficiency.

<Modification 4>

[0067] In modification 4 of the above-described embodiments, as shown in FIG. 8D, the O₂ gas supply (continuous supply) step of the above-described etching-back step is performed, and the NF₃ gas is supplied once. That is, the O₂ gas is allowed to flow in a state in which the NF₃ gas is not flowing into the process chamber 201. The supply of the NF₃ gas is started after a predetermined time has elapsed. After a predetermined time has elapsed, the supply of the NF₃ gas and the supply of the O₂ gas are stopped at the same timing. The time for supplying the NF₃ gas is shorter than the time for supplying the O₂ gas.

[0068] According to this modification, one or more of the effects of the above-described embodiments may be obtained, and the following effect may be further obtained.

(l) The processing time can be shortened by stopping the supply of the etching gas and the supply of the oxygen-containing gas at the same timing.

<Modification 5>

[0069] In modification 5 of the above-described embodiments, as shown in FIG. 8E, modification 4 is repeated n₂ times. At this time, the residual gas in the process chamber 201 is

removed in each cycle by the same procedure as the residual gas removal step of the W film formation step. That is, the O₂ gas is allowed to flow in a state in which the NF₃ gas is not flowing into the process chamber 201. The supply of the NF₃ gas is started after a predetermined time has elapsed. After a predetermined time has elapsed, the supply of the NF₃ gas and the supply of the O₂ gas are stopped at the same timing. After removing the residual gas in the process chamber 201, the O₂ gas is started to flow again in a state in which the NF₃ gas is not flowing in the process chamber 201. The time for supplying the NF₃ gas is shorter than the time for supplying the O₂ gas.

[0070] According to this modification, one or more of the effects of the above-described embodiments may be obtained, and the following effect may be further obtained.

(m) It is possible to efficiently discharge WF_x (WF₆ or the like) generated by the reaction with the etching gas.

<Modification 6>

[0071] In modification 6 of the above-described embodiments, as shown in FIG. 8F, the O₂ gas supply (continuous supply) step of the above-described etching-back step is performed, and the NF₃ gas is continuously supplied. That is, the NF₃ gas and the O₂ gas are started to flow into the process chamber 201 at the same timing. After a predetermined time has elapsed, the supply of the NF₃ gas and the supply of the O₂ gas are stopped at the same timing. The time for supplying the NF₃ gas and the time for supplying the O₂ gas have the same length of time. According to this modification, one or more of the effects of the above-described embodiments may be obtained.

[0072] In the above-described embodiments, there has been described the example in which the W film is etched back. However, the present disclosure is not limited thereto. The present disclosure may also be applied to the etching of a TiN film, a tantalum nitride film (TaN film), a cobalt film (Co film), and other films containing a metal element, such as a metal film, a metal nitride film, a metal carbide film, and the like.

[0073] In the above-described embodiments, there has been described the example in which the

O₂ gas is used as the oxygen-containing gas. However, the present disclosure is not limited thereto. Nitric oxide (NO), nitrous oxide (N₂O), water (H₂O), ozone (O₃), and the like may also be used.

[0074] In the above-described embodiments, there has been described the example in which the NF₃ gas, which is a fluorine-containing gas, is used as the etching gas. However, the present disclosure is not limited thereto. Other gases containing a halogen element may also be used. In particular, a gas having a low etching rate for an oxide film is preferable.

[0075] In the above-described embodiments, there has been described the example in which the present disclosure is applied to a control gate of a NAND-type flash memory. However, the present disclosure is not limited thereto. The present disclosure may also be applied to an electrode for a word line of a MOSFET (Metal Oxide Semiconductor Field Effect Transistor).

[0076] While various exemplary embodiments and modifications of the present disclosure have been described above, the present disclosure is not limited to the embodiments and the modifications. The embodiments and the modifications may be used in appropriate combinations.

INDUSTRIAL USE OF THE PRESENT DISCLOSURE

[0077] According to the present disclosure, it is possible to suppress the reaction of a film other than an etching target film, which is exposed at the time of etching-back, with an etching gas.

EXPLANATION OF REFERENCE NUMERALS

[0078] 10: substrate processing apparatus, 121: controller, 200: wafer (substrate), 201: process chamber

WHAT IS CLAIMED IS:

1. A method of manufacturing a semiconductor device, comprising:
etching back a second metal film by supplying an oxygen-containing gas and a fluorine-containing etching gas to a substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and
removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein in the act of etching back, the oxygen-containing gas is continuously supplied to the substrate, and the fluorine-containing etching gas is intermittently supplied to the substrate a plurality of times.
2. A method of manufacturing a semiconductor device, comprising:
etching back a second metal film by supplying an oxygen-containing gas and a fluorine-containing etching gas to a substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and
removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially performs:
supplying the oxygen-containing gas to the substrate;
simultaneously supplying the oxygen-containing gas and the fluorine-containing etching gas to the substrate; and
supplying the oxygen-containing gas to the substrate.
3. The method of Claim 1, wherein the act of etching back sequentially performs:
simultaneously supplying the oxygen-containing gas and the fluorine-containing etching gas to the substrate; and
supplying the oxygen-containing gas to the substrate.
4. A method of manufacturing a semiconductor device, comprising:
etching back a second metal film by supplying an oxygen-containing gas and a

fluorine-containing etching gas to a substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially and repeatedly performs, a plurality of times:

supplying the oxygen-containing gas to the substrate;

removing the oxygen-containing gas;

supplying the fluorine-containing etching gas to the substrate; and

removing the fluorine-containing etching gas.

5. The method of Claim 1, wherein the act of etching back sequentially performs:
supplying the oxygen-containing gas to the substrate; and
simultaneously supplying the oxygen-containing gas and the fluorine-containing etching gas to the substrate.

6. A method of manufacturing a semiconductor device, comprising:
etching back a second metal film by supplying an oxygen-containing gas and a fluorine-containing etching gas to a substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and
removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially and repeatedly performs, a plurality of times:

supplying the oxygen-containing gas to the substrate;

simultaneously supplying the oxygen-containing gas and the fluorine-containing etching gas to the substrate; and

removing the oxygen-containing gas and the fluorine-containing etching gas.

7. The method of any one of Claims 1 to 6, wherein the substrate is a silicon substrate, and in the act of etching back, the silicon substrate is oxidized to form a silicon oxide film at

a back surface of the substrate at which the first metal film and the second metal film are not formed.

8. The method of any one of Claims 1 to 7, wherein the first metal film is a titanium nitride film, and the second metal film is a tungsten film.

9. The method of any one of Claims 1 to 8, wherein the oxygen-containing gas is an oxygen gas, and the fluorine-containing etching gas is a nitrogen trifluoride gas.

10. A substrate processing apparatus, comprising:
a process chamber configured to accommodate a substrate;
a gas supply system configured to supply an oxygen-containing gas and a fluorine-containing etching gas to the process chamber;
an exhaust system configured to exhaust the process chamber; and
a controller configured to control the gas supply system and the exhaust system so as to perform:

etching back a second metal film by supplying the oxygen-containing gas and the fluorine-containing etching gas to the process chamber that accommodates the substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and
removing the oxygen-containing gas and the fluorine-containing etching gas, wherein in the act of etching back, the oxygen-containing gas is continuously supplied to the substrate, and the fluorine-containing etching gas is intermittently supplied to the substrate a plurality of times.

11. A program that causes, by a computer, a substrate processing apparatus to perform a process comprising:

etching back a second metal film by supplying an oxygen-containing gas and a fluorine-containing etching gas to a substrate accommodated in a process chamber of the

substrate processing apparatus, the substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein in the act of etching back, the oxygen-containing gas is continuously supplied to the substrate, and the fluorine-containing etching gas is intermittently supplied to the substrate a plurality of times.

12. A substrate processing apparatus, comprising:

a process chamber configured to accommodate a substrate;
a gas supply system configured to supply an oxygen-containing gas and a fluorine-containing etching gas to the process chamber;
an exhaust system configured to exhaust the process chamber; and
a controller configured to control the gas supply system and the exhaust system so as to perform:

etching back a second metal film by supplying the oxygen-containing gas and the fluorine-containing etching gas to the process chamber that accommodates the substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially performs:

supplying the oxygen-containing gas to the substrate;
simultaneously supplying the oxygen-containing gas and the fluorine-containing etching gas to the substrate; and
supplying the oxygen-containing gas to the substrate.

13. A substrate processing apparatus, comprising:

a process chamber configured to accommodate a substrate;
a gas supply system configured to supply an oxygen-containing gas and a fluorine-containing etching gas to the process chamber;

an exhaust system configured to exhaust the process chamber; and
a controller configured to control the gas supply system and the exhaust system so as
to perform:

etching back a second metal film by supplying the oxygen-containing gas
and the fluorine-containing etching gas to the process chamber that accommodates
the substrate having a surface at which a first metal film is formed at an opening part
in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially and repeatedly performs, a
plurality of times:

supplying the oxygen-containing gas to the substrate;
removing the oxygen-containing gas;
supplying the fluorine-containing etching gas to the substrate; and
removing the fluorine-containing etching gas.

14. A substrate processing apparatus, comprising:
a process chamber configured to accommodate a substrate;
a gas supply system configured to supply an oxygen-containing gas and a fluorine-
containing etching gas to the process chamber;
an exhaust system configured to exhaust the process chamber; and
a controller configured to control the gas supply system and the exhaust system so as
to perform:

etching back a second metal film by supplying the oxygen-containing gas
and the fluorine-containing etching gas to the process chamber that accommodates
the substrate having a surface at which a first metal film is formed at an opening part
in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially and repeatedly performs, a
plurality of times:

supplying the oxygen-containing gas to the substrate;
simultaneously supplying the oxygen-containing gas and the
fluorine-containing etching gas to the substrate; and
removing the oxygen-containing gas and the fluorine-containing
etching gas.

15. A program that causes, by a computer, a substrate processing apparatus to perform a process comprising:

etching back a second metal film by supplying an oxygen-containing gas and a
fluorine-containing etching gas to a substrate accommodated in a process chamber of the
substrate processing apparatus, the substrate having a surface at which a first metal film is
formed at an opening part in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially performs:

supplying the oxygen-containing gas to the substrate;
simultaneously supplying the oxygen-containing gas and the fluorine-
containing etching gas to the substrate; and
supplying the oxygen-containing gas to the substrate.

16. A program that causes, by a computer, a substrate processing apparatus to perform a process comprising:

etching back a second metal film by supplying an oxygen-containing gas and a
fluorine-containing etching gas to a substrate accommodated in a process chamber of the
substrate processing apparatus, the substrate having a surface at which a first metal film is
formed at an opening part in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially and repeatedly performs, a plurality of
times:

supplying the oxygen-containing gas to the substrate;

removing the oxygen-containing gas;
supplying the fluorine-containing etching gas to the substrate; and
removing the fluorine-containing etching gas.

17. A program that causes, by a computer, a substrate processing apparatus to perform a process comprising:

etching back a second metal film by supplying an oxygen-containing gas and a fluorine-containing etching gas to a substrate accommodated in a process chamber of the substrate processing apparatus, the substrate having a surface at which a first metal film is formed at an opening part in which the second metal film is embedded; and

removing the oxygen-containing gas and the fluorine-containing etching gas,
wherein the act of etching back sequentially and repeatedly performs, a plurality of times:

supplying the oxygen-containing gas to the substrate;
simultaneously supplying the oxygen-containing gas and the fluorine-containing etching gas to the substrate; and
removing the oxygen-containing gas and the fluorine-containing etching gas.