

SUBSTRATE PROCESSING APPARATUS, METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE, AND RECORDING MEDIUM

TECHNICAL FIELD

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

BACKGROUND

[0002] A processing technology for controlling leakage current interference between transistor elements becomes increasingly technically difficult according to the miniaturization of large scale integrated circuits (LSIs). For isolation between LSI elements, a method is used in which voids such as grooves or holes are formed between elements to be isolated in silicon as a substrate and an insulator is deposited in the voids. An oxide film, such as a silicon oxide film (SiO film), is often used as the insulator. The SiO film is formed by oxidation of an Si substrate itself, a chemical vapor deposition (CVD) method, and an insulator coating (spin on dielectric: SOD) method.

[0003] Due to the recent miniaturization, an embedding method by the CVD method is reaching the technical limit for embedding microstructures, particularly embedding of oxide into a void structure which is deep in a vertical direction or narrow in a horizontal direction. With this background, as an embedding method using flowable oxides, for example, adoption of SOD is also on the rise. For the SOD, a coating insulating material containing inorganic or organic components called spin on glass (SOG) is used. This material was adopted in the manufacturing process of LSIs before the appearance of a CVD oxide film, but since the processing technology was not fine enough to produce processing dimension of about 0.35 to 1 μm , a heat treatment in the modification method after coating was performed at about 400 degrees C under a nitrogen atmosphere. However, in recent LSIs, the minimum processing dimension is smaller than the width of 50 nm and thus the use of polysilazane (SiH_2NH) (or

[0009] In the processing for obtaining a dense oxide film from a coating film of polysilazane or the like by SOD or an insulating material embedded by the flowable CVD method, in order to reduce the heat load onto the transistors or the like, it is also desirable to lower the temperature of a processing gas used in this processing. For example, a vaporized gas obtained by vaporizing a liquid precursor may be used as a processing gas for processing a coating film of polysilazane. Under a low temperature condition, however, there is a case where a vaporized gas precursor in a droplet or mist state may be supplied to the coating film due to incomplete vaporization of the liquid precursor of the vaporized gas, occurrence of reliquefaction in a processing apparatus, or the like. In this case, it may cause foreign substances (particles or the like) and thus the characteristics of the oxide film may remarkably deteriorate.

SUMMARY

[0010] Some embodiments of the present disclosure provide a technique capable of suppressing occurrence of droplets, mists or the like in a processing gas in a processing apparatus even under a low temperature condition, and improving the characteristics of a film formed on a substrate to be processed with the processing gas.

[0011] According to one embodiment of the present disclosure, a substrate processing apparatus includes: a process chamber configured to accommodate a substrate; a vaporizer configured to vaporize a liquid precursor to generate a reaction gas and deliver a processing gas containing the reaction gas and a carrier gas, wherein the vaporizer includes a vaporization vessel in which the liquid precursor is vaporized, and a heater configured to heat the liquid precursor introduced into the vaporizing vessel; a carrier gas flow rate controller configured to control a flow rate of the carrier gas supplied to the vaporizer; a liquid precursor flow rate controller configured to control a flow rate of the liquid precursor supplied to the vaporizer; a processing gas supply pipe configured to introduce the processing gas delivered from the vaporizer into the process chamber; and a gas concentration sensor configured to detect a gas concentration of the reaction gas

contained in the processing gas delivered from the vaporizer into the processing gas supply pipe.

[0012] According to the present disclosure in some embodiments, it is possible to suppress occurrence of droplets, mists or the like of a processing gas in a processing apparatus even under a low temperature condition, and to improve characteristics of a film formed on a substrate to be processed by the processing gas.

BRIEF DESCRIPTION OF DRAWINGS

[0013] FIG. 1 is a schematic configuration diagram illustrating a configuration of a substrate processing apparatus according to one embodiment of the present disclosure.

FIG. 2 is a schematic vertical cross sectional view illustrating a configuration of a processing furnace included in the substrate processing apparatus according to one embodiment of the present disclosure.

FIG. 3 is an external view illustrating a configuration of a processing gas heating part included in the substrate processing apparatus according to one embodiment of the present disclosure.

FIG. 4 is a schematic vertical cross sectional view illustrating a configuration of a vaporizer included in the substrate processing apparatus according to one embodiment of the present disclosure.

FIG. 5 is a schematic vertical cross sectional view illustrating a configuration of a gas filter included in the substrate processing apparatus according to one embodiment of the present disclosure.

FIG. 6 is a schematic configuration diagram illustrating a configuration of a gas densitometer included in the substrate processing apparatus according to one embodiment of the

heating part 207 along a side portion of an outer wall of the process vessel 203. The processing gas supply nozzle 501a and the oxygen-containing gas supply nozzle 502a are made of, for example, quartz or the like having a low thermal conductivity. The processing gas supply nozzle 501a and the oxygen-containing gas supply nozzle 502a may have a double pipe structure. Leading ends (downstream ends) of the processing gas supply nozzle 501a and the oxygen-containing gas supply nozzle 502a are airtightly inserted into the process vessel 203 from the top of the process vessel 203. A supply hole 501b and a supply hole 502b are formed at the leading ends of the processing gas supply nozzle 501a and the oxygen-containing gas supply nozzle 502a located inside the process vessel 203, respectively. The supply hole 501b and the supply hole 502b are configured to supply a processing gas and an oxygen-containing gas supplied into the process vessel 203 toward the ceiling plate 217c installed in an upper portion of the boat 217 accommodated in the process vessel 203.

[0027] A gas supply pipe 602c is connected to an upstream end of the oxygen-containing gas supply nozzle 502a. In addition, a valve 602a, a mass flow controller (MFC) 602b which forms a gas flow rate control part, a valve 602d, and an oxygen-containing gas heating part 602e are installed in the gas supply pipe 602c sequentially from the corresponding upstream side. As the oxygen-containing gas, for example, a gas containing at least one of an oxygen (O_2) gas, an ozone (O_3) gas, and a nitrous oxide (N_2O) gas is used. In this embodiment, the O_2 gas is used as the oxygen-containing gas. The oxygen-containing gas heating part 602e is installed so as to heat the oxygen-containing gas, and may be configured to heat it to, for example, about 80 to 200 degrees C. In some embodiments, the oxygen-containing gas may be heated to about 100 to 170 degrees C. By heating the oxygen-containing gas, it is possible to assist heating of the processing gas supplied into the process chamber 201. Furthermore, it is possible to suppress liquefaction of the processing gas in the process vessel 203. It may also be configured such that the heating of the oxygen-containing gas is performed by the first heating part 207.

[0028] As the gas supplied from the oxygen-containing gas supply nozzle 502a, it may be possible to use a gas having low reactivity to the wafers 200 or a film formed on the wafers 200,

302, and a liquid flow rate controller (LMFC) 303 for controlling the flow rate of the liquid precursor supplied to the vaporizer 100, from the corresponding upstream side. The carrier gas supply part is configured by a carrier gas supply pipe 601c, a carrier gas valve 601a, an MFC 601b as a carrier gas flow rate control part, a carrier gas valve 601d, and the like. In this embodiment, an O₂ gas, which is an oxygen-containing gas, is used as the carrier gas. However, as the carrier gas, it may be possible to use a gas containing at least one or more oxygen-containing gas (for example, an O₃ gas, an NO gas or the like, in addition to an O₂ gas). As the carrier gas, it may also be possible to use a gas having low reactivity to the wafers 200 or a film formed on the wafers 200. For example, it may be possible to use an N₂ gas, or a rare gas such as an Ar gas, an He gas, an Ne gas, or the like.

[0033] Here, a processing gas supply part is configured at least by the processing gas supply nozzle 501a and the supply hole 501b. The processing gas supply part may further include the processing gas supply pipe 289a, the valve 289b, the gas filter 600, the gas densitometer 500, the processing gas temperature sensor 286, the processing gas pressure sensor 287, the vaporizer 100, and the like. Furthermore, an oxygen-containing gas supply part is configured at least by the oxygen-containing gas supply nozzle 502a and the supply hole 502b. The oxygen-containing gas supply part may further include the gas supply pipe 602c, the oxygen-containing gas heating part 602e, the valve 602d, the MFC 602b, the valve 602a, and the like. In addition, a gas supply part (gas supply system) is configured by the processing gas supply part and the oxygen-containing gas supply part.

(Vaporizer)

[0034] FIG. 4 illustrates a configuration of the vaporizer 100. The vaporizer 100 uses a dropping method in which a liquid precursor is vaporized by dropping a liquid precursor onto a heated member. The vaporizer 100 includes a vaporization vessel 101 as a heated member, a vaporization space 102 formed by the vaporization vessel 101, a vaporization heater 103 as a heating part for heating the vaporization vessel 101, an exhaust port 104 for exhausting

(delivering) a vaporized gas generated by vaporizing the liquid precursor as the processing gas to the processing gas supply pipe 289a together with a carrier gas, a thermocouple (temperature sensor) 105 for measuring a temperature of the vaporization vessel 101, a temperature controller 106 for controlling the temperature of the vaporization heater 103 based on the temperature measured by the thermocouple 105, a dropping nozzle 107 as a liquid supply part for supplying a hydrogen peroxide solution supplied from the LMFC 303 into the vaporization vessel 101, and a carrier gas introduction port 108 for supplying the carrier gas supplied from the carrier gas supply pipe 601c into the vaporization vessel 101.

[0035] The vaporization vessel 101 is heated by the vaporization heater 103 so as to vaporize the dropped liquid precursor simultaneously when it reaches the inner surface of the vaporization vessel 101. In addition, a heat insulating material 109, which can improve the heating efficiency of the vaporization vessel 101 by the vaporization heater 103 and which can thermally insulate between the vaporizer 100 and other units, is installed. The vaporization vessel 101 is made of quartz, SiC or the like in order to prevent reaction with the liquid precursor. In the vaporization vessel 101, the temperature is lowered due to the temperature of the dropped liquid precursor or vaporization heat. Therefore, in order to prevent the temperature from being lowered, it is desirable that it be made of a material having high thermal conductivity, for example, SiC.

[0036] When a liquid precursor formed by mixing two or more precursors having different boiling points, such as a hydrogen peroxide solution, is heated and vaporized, even when it is heated at a temperature higher than the boiling point of the liquid precursor, since the entire liquid precursor is not uniformly heated, there is a case where only vaporization of one specified precursor having a low boiling point contained in the liquid precursor first proceeds, and vaporization of other precursors does not proceed. As a result, concentration of other precursors occurs in the heated liquid precursor and thus there is a possibility that nonuniformity may occur in the concentration ratio of a finally vaporized gas.

[0037] More specifically, since the hydrogen peroxide solution used in this embodiment contains

231 is connected to a vacuum pump 246 (exhaust device) through an auto pressure controller (APC) valve 255 as a pressure regulator. The interior of the process chamber 201 is exhausted by a negative pressure generated by the vacuum pump 246. The APC valve 255 is an opening/closing valve that can perform the exhaust and end the exhaust of the process chamber 201 by opening and closing the APC valve 255. It is also a pressure regulating valve that can adjust the pressure by adjusting an opening degree of the APC valve 255. In addition, a pressure sensor 223 as a pressure detector is installed on the upstream side of the APC valve 255. In this manner, the interior of the process chamber 201 is vacuum-exhausted so as to reach a predetermined pressure (degree of vacuum). A pressure controller 224 (*see* FIG. 8) is electrically connected to the pressure sensor 223 and the APC valve 255, and the pressure controller 224 is configured to control the APC valve 255 at a desired timing based on the pressure detected by the pressure sensor 223 so that the interior of the process chamber 201 reaches a desired pressure.

[0048] The exhaust part is configured by the gas exhaust pipe 231, the APC valve 255, and the like. The pressure sensor 223, and the like may also be included in the exhaust part. The vacuum pump 246 may also be included in the exhaust part.

(Second Heating Part)

[0049] As described above, since the first heating part 207 is installed so as to heat the wafers 200 in the process vessel 203, the region in which the wafers 200 are accommodated in the process vessel 203 is heated by the first heating part 207. However, it is difficult to heat a region other than the accommodating region of the wafers 200 in the process vessel 203 with the first heating part 207. As a result, there is a case where a low temperature region is generated in a region other than the region heated by the first heating part 207 in the process vessel 203, and thus, the gas containing H₂O₂ may be cooled and reliquefied when it passes through the low temperature region.

[0050] When a liquid generated by reliquefaction of the gas containing H₂O₂ is collected on the

process vessel 203. With this heating, it is possible to prevent liquefaction of the processing gas at the furnace opening or adhesion of particles, impurities or the like generated up to the drying process to the furnace opening.

[0054] In addition, as described above, the gas port heater 285 is installed at the connection portion between the processing gas supply nozzle 501a and the processing gas supply pipe 289a, and is configured to heat the processing gas passing through the connection portion. The gas port heater 285 is controlled to have a desired temperature so that dew condensation does not occur inside the processing gas supply pipe 289a. For example, it is controlled from 50 to 300 degrees C. In addition, an exhaust tube heater 284 is installed at a connection portion between the gas exhaust pipe 231 and the process vessel 203. The exhaust tube heater 284 is controlled to have a desired temperature so that dew condensation does not occur inside the gas exhaust pipe 231. For example, it is controlled from 50 to 300 degrees C.

(Control Part)

[0055] As illustrated in FIG. 8, the controller 121, which is a control part (control means), may be configured as a computer including a central processing unit (CPU) 121a, a random access memory (RAM) 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 121e. An input/output device 122 formed of, e.g., a touch panel, a display or the like, is connected to the controller 121.

[0056] The memory device 121c 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 for specifying sequences and conditions of substrate processing as described hereinbelow, or the like is readably stored in the memory device 121c. The program recipe functions as a program for causing the controller 121 to execute each sequence in a substrate processing process, as described hereinbelow, to obtain a predetermined result. Hereinafter, the program recipe and the control program will be generally and simply referred to

as a "program." Furthermore, the program recipe will be simply referred to as a "recipe."

When the term "program" is used herein, it may indicate a case of including only the recipe, a case of including only the control program, or a case of including both the recipe and the control program. The RAM 121b is configured as a memory area (work area) in which a program or data read by the CPU 121a is temporarily stored.

[0057] The I/O port 121d is connected to the LMFC 303, the MFCs 601b and 602b, the valves 601a, 601d, 602a, 602d and 302, the APC valve 255, the first heating part 207 (207a, 207b, 207c, and 207d), the second heating part 280, the first to fourth temperature sensors 263a to 263d, the boat rotation mechanism 267, the pressure sensor 223, the pressure controller 224, the temperature controller 106, processing gas temperature sensor 286, the processing gas pressure sensor 287, the gas densitometer 500, the vaporization heater 103, the pipe heater 289c, the filter heater 630, the exhaust tube heater 284, the gas port heater 285, and the like, as described above.

[0058] The CPU 121a is configured to read the control program from the memory device 121c and execute the same. The CPU 121a also reads the recipe from the memory device 121c according to an input of an operation command from the input/output device 122. In addition, the CPU 121a is configured to control, according to the contents of the recipe thus read, the flow rate adjusting operation of a liquid precursor by the LMFC 303, the flow rate adjusting operation of a gas by the MFCs 601b and 602b, the opening/closing operation of the valves 601a, 601d, 602a, 602d, 302 and 289b, the opening/closing adjusting operation of the APC valve 255, the temperature adjusting operation performed by the first heating part 207 based on the first to fourth temperature sensors 263a to 263d, the temperature adjusting operation by the second heating part 280, the driving and stopping of the vacuum pump 246, the operation of adjusting the rotation speed of the boat rotation mechanism 267, the temperature adjusting operation of the vaporization heater 103, the pipe heater 289c, the filter heater 630, the exhaust tube heater 284 and the gas port heater 285 through the temperature controller 106, and the like. In addition, a control operation as described hereinbelow is executed based on the data of the processing gas acquired by the processing gas temperature sensor 286, the processing gas pressure sensor 287,

vessel 101. The vaporization vessel 101 is heated by the vaporization heater 103 to a desired temperature (e.g., 180 to 220 degrees C). Thus, the droplets of the dropped liquid precursor (hydrogen peroxide solution) make contact with the inner surface of the vaporization vessel 101 so that it is instantaneously heated and evaporated to become a gas.

[0070] Then, the valve 289b is opened and the gasified liquid precursor (vaporized gas) is supplied as the processing gas into the process chamber 201 through the exhaust port 104, the processing gas supply pipe 289a, the gas densitometer 500, the gas filter 600, the valve 289b, the processing gas supply nozzle 501a, and the supply hole 501b. The processing gas passing through the gas filter 600 is heated when passing through the heated filter part 620, so that the liquid precursor in a droplet state or a mist state contained in the processing gas is vaporized. The processing gas introduced into the process chamber 201 from the supply hole 501b is further heated by the processing gas heating part 217d and is then supplied to the wafers 200. The H₂O₂ gas contained in the processing gas oxidizes with the silicon-containing film on the surface of the wafers 200 as a reaction gas to modify the silicon-containing film into an SiO film. During the supply of the processing gas to the wafers 200 at this step, as will be described hereinbelow, the respective components of the processing gas supply part are controlled based on the data acquired from the processing gas temperature sensor 286, the processing gas pressure sensor 287, and the gas densitometer 500.

[0071] Furthermore, the interior of the process vessel 203 is exhausted by the vacuum pump 246 while supplying the processing gas into the process vessel 203. That is, the APC valve 255 is opened, and the exhaust gas exhausted from the interior of the process vessel 203 via the gas exhaust pipe 231 is exhausted by the vacuum pump 246. After the lapse of a predetermined period of time, the valve 289 b is closed to stop the supply of the processing gas into the process vessel 203. Then, after the lapse of a predetermined period of time, the APC valve 255 is closed to stop the exhaust from the interior of the process vessel 203.

[0072] In this embodiment, there has been described a case where the hydrogen peroxide solution is supplied as the liquid precursor to the vaporizer 100 and the processing gas containing

103 of the vaporizer 100 through the temperature controller 106 to raise the temperature of the vaporization heater 103 by a predetermined width (S112) when it is determined that a state in which the acquired pressure value of the processing gas is a value equal to or less than a predetermined ratio (first pressure ratio) with respect to the reference pressure value continues for a predetermined period of time (S111),. For example, when it is detected that a state in which the acquired pressure value of the processing gas is a value lower than the reference pressure value by 0.5 to 2% or more (i.e., a value of 98 to 99.5% or less of the reference pressure value) and continues for 30 to 60 seconds or more, the control of S112 is performed. In this embodiment, when it is detected that a state continues for 30 seconds or more in which the acquired pressure value of the processing gas is lower than the reference pressure value by 1% or more (i.e., a value of 99% or less of the reference pressure value), the controller 121 performs the control of S112. Thus, the vaporization failure of the liquid precursor in the vaporizer 100 can be improved or eliminated. The vaporization heater 103 is controlled so that the temperature of the vaporization heater 103 falls within a range of, for example, 180 to 220 degrees C.

[0090] In addition, when a vaporization failure of the liquid precursor occurs in the vaporizer 100, the vaporization failure may be improved or eliminated by increasing the flow rate of the carrier gas supplied to the vaporizer 100. Therefore, when it is determined that a state continues for a predetermined period of time (S111) in which the acquired pressure value of the processing gas is a value equal to or less than a predetermined ratio (first pressure ratio) with respect to the reference pressure value, the controller 121 may control the MFC 601b that controls the flow rate of the carrier gas supplied to the vaporizer 100 to increase the supply amount of the carrier gas by a predetermined width (S112). However, when the flow rate of the carrier gas is changed, the concentration of the H_2O_2 gas in the generated processing gas may change. In addition, since the acquired pressure of the processing gas varies irrespective of the presence or absence of vaporization failure, control based on the pressure of the processing gas is difficult. Therefore, the control to change the temperature of the vaporization heater 103 may be performed with higher priority than the control to change the flow rate of the carrier gas in

WHAT IS CLAIMED IS:

1. A substrate processing apparatus, comprising:
 - a process chamber configured to accommodate a substrate;
 - a vaporizer configured to vaporize a liquid precursor to generate a reaction gas and deliver a processing gas containing the reaction gas and a carrier gas, the vaporizer including:
 - a vaporization vessel in which the liquid precursor is vaporized; and
 - a heater configured to heat the liquid precursor introduced into the vaporizing vessel;
 - a carrier gas flow rate controller configured to control a flow rate of the carrier gas supplied to the vaporizer;
 - a liquid precursor flow rate controller configured to control a flow rate of the liquid precursor supplied to the vaporizer;
 - a processing gas supply pipe configured to introduce the processing gas delivered from the vaporizer into the process chamber; and
 - a gas concentration sensor configured to detect a gas concentration of the reaction gas contained in the processing gas delivered from the vaporizer into the processing gas supply pipe.
2. The apparatus of Claim 1, further comprising a controller configured to acquire the gas concentration of the reaction gas detected by the gas concentration sensor and determine a vaporization state of the liquid precursor supplied into the vaporization vessel based on the acquired gas concentration of the reaction gas.
3. The apparatus of Claim 2, wherein when a state in which the acquired gas concentration of the reaction gas is a value equal to or less than a predetermined ratio of a predetermined concentration value as a reference continues for a predetermined period of time, the controller is configured to determine that a vaporization failure of the liquid precursor supplied into the

vaporization vessel has occurred.

4. The apparatus of Claim 2, wherein when it is determined that a vaporization failure of the liquid precursor supplied into the vaporization vessel has occurred, the controller is configured to control a display device to notify a user that the vaporization failure has occurred.

5. The apparatus of Claim 2, wherein when it is determined that a vaporization failure of the liquid precursor supplied into the vaporization vessel has occurred, the controller is configured to control a memory device to record occurrence of the vaporization failure.

6. The apparatus of Claim 1, further comprising a controller configured to acquire the gas concentration of the reaction gas detected by the gas concentration sensor and perform at least one of the operations to (a) control the heater to adjust a temperature of the heater based on the acquired gas concentration of the reaction gas, (b) control the carrier gas flow rate controller to adjust a supply amount of the carrier gas, and (c) control the liquid precursor flow rate controller to adjust a supply amount of the liquid precursor.

7. The apparatus of Claim 1, wherein a gas concentration of the reaction gas detected by the gas concentration sensor is acquired, and when a state in which the acquired gas concentration of the reaction gas is a value equal to or less than a predetermined ratio of a predetermined concentration value as a reference continues for a predetermined period of time, it is configured to perform at least one of the operations to (a) control the carrier gas flow rate controller to increase a supply amount of the carrier gas, and (b) control the liquid precursor flow rate controller to decrease a supply amount of the liquid precursor.

8. The apparatus of Claim 1, further comprising a controller configured to acquire the gas concentration of the reaction gas detected by the gas concentration sensor, and when a state in

which the acquired gas concentration of the reaction gas is a value equal to or larger than a predetermined ratio of a predetermined concentration value as a reference continues for a predetermined period of time, to control the liquid precursor flow rate controller to reduce the supply amount of the liquid precursor.

9. The apparatus of Claim 1, wherein the processing gas contains a hydrogen peroxide gas as the reaction gas.
10. The apparatus of Claim 1, wherein the liquid precursor is a hydrogen peroxide solution.
11. The apparatus of Claim 10, wherein the processing gas contains a hydrogen peroxide gas as the reaction gas.
12. The apparatus of Claim 1, further comprising a controller configured to control the heater such that the temperature of the heater is 220 degrees C or lower.
13. A method of manufacturing a semiconductor device, comprising:
 - processing a substrate using a substrate processing apparatus, the substrate processing apparatus including:
 - a process chamber configured to accommodate the substrate;
 - a vaporizer configured to vaporize a liquid precursor to generate a reaction gas and deliver a processing gas containing the reaction gas and a carrier gas, wherein the vaporizer includes a vaporization vessel in which the liquid precursor is vaporized, and a heater configured to heat the liquid precursor introduced into the vaporizing vessel;
 - a processing gas supply pipe configured to introduce the processing gas delivered from the vaporizer into the process chamber; and
 - a gas concentration sensor configured to detect a gas concentration of the

reaction gas contained in the processing gas delivered from the vaporizer into the processing gas supply pipe,

wherein the act of processing the substrate comprises:

- loading the substrate into the process chamber;

- generating the processing gas by supplying the liquid precursor and the carrier gas from the liquid precursor introduction part into the vaporizer and heating the liquid precursor supplied into the vaporizer by the heater to vaporize the liquid precursor;

- introducing the processing gas generated in the vaporizer into the processing chamber through the processing gas supply pipe; and

- acquiring the gas concentration of the reaction gas detected by the gas concentration sensor and determine a vaporization state of the liquid precursor supplied into the vaporization vessel based on the acquired gas concentration of the reaction gas.

14. A computer-readable recording medium storing a program that causes a computer to perform a predetermined process in a substrate processing apparatus, the substrate processing apparatus comprising:

- a process chamber configured to accommodate the substrate;

- a vaporizer configured to vaporize a liquid precursor to generate a reaction gas and deliver a processing gas containing the reaction gas and a carrier gas, wherein the vaporizer includes a vaporization vessel in which the liquid precursor is vaporized, and a heater configured to heat the liquid precursor introduced into the vaporizing vessel;

- a processing gas supply pipe configured to introduce the processing gas delivered from the vaporizer into the process chamber; and

- a gas concentration sensor configured to detect a gas concentration of the reaction gas contained in the processing gas delivered from the vaporizer into the processing gas supply pipe,

wherein the predetermined process comprises:

loading the substrate into the process chamber;

generating the processing gas by supplying the liquid precursor and the carrier gas from the liquid precursor introduction part into the vaporizer and heating the liquid precursor supplied into the vaporizer by the heater to vaporize the liquid precursor;

introducing the processing gas generated in the vaporizer into the processing chamber through the processing gas supply pipe; and

acquiring the gas concentration of the reaction gas detected by the gas concentration sensor and determine a vaporization state of the liquid precursor supplied into the vaporization vessel based on the acquired gas concentration of the reaction gas

.