

[DESCRIPTION]

[Title]

VAPORIZER, SUBSTRATE PROCESSING APPARATUS AND METHOD
5 OF MANUFACTURING SEMICONDUCTOR DEVICE

[Technical Field]

[0001]

The present disclosure relates to a vaporizer, a substrate processing apparatus and a method of manufacturing a semiconductor device.

[Related Art]

[0002]

As a method of obtaining a denser film from a film formed by a process such as a SOD (spin on dielectric) method and a CVD (chemical vapor deposition) method, the film is modified into the denser film by supplying a modifying gas to the film. For
15 example, as in a technique disclosed in Patent Document 1, as a method of obtaining a denser oxide film such as a silicon oxide (SiO) film from an insulating material film, a gas containing hydrogen peroxide (H₂O₂) is supplied to the insulating material film to modify the insulating material film.

[Related Art Document]

[Patent Document]

[0003]

Patent Document 1: International Publication No. WO2013/077321

[Disclosure]

[Technical Problem]

25 [0004]

As one of the methods of generating a desired process gas such as the gas containing H_2O_2 , it is conceivable to vaporize a liquid source by a vaporizer to obtain the desired process gas. However, according to the conventional vaporizer, it is difficult to precisely control or to manage a temperature of the liquid source introduced into the vaporizer.

Described herein is a technique capable of precisely controlling or managing the temperature of the liquid source introduced into the vaporizer.

[Technical Solution]

[0005]

According to one aspect of the technique of the present disclosure, there is provided a vaporizer including: a liquid source supplier configured to supply a liquid source; a vaporization vessel constituting a vaporization chamber in which the liquid source supplied through the liquid source supplier is vaporized; a first heater configured to heat the vaporization vessel; and a heat insulating material provided to prevent heat emitted from the first heater from transferring to the liquid source supplier.

[Advantageous Effects]

[0006]

According to some embodiments in the present disclosure, it is possible to precisely control or to manage a temperature of a liquid source introduced into a vaporizer.

[Brief Description of Drawings]

[0007]

FIG. 1 schematically illustrates a configuration of a substrate processing apparatus according to an embodiment described herein.

FIG. 2 schematically illustrates a vertical cross-section of a process furnace of

the substrate processing apparatus according to the embodiment described herein.

FIG. 3 schematically illustrates a vertical cross-sectional structure of a vaporizer of the substrate processing apparatus according to the embodiment described herein.

5 FIG. 4(A) schematically illustrates the vertical cross-sectional structure of the vaporizer of the substrate processing apparatus according to the embodiment described herein, and FIG. 4(B) schematically illustrates a gap of the vaporizer shown in FIG. 4A.

FIG. 5(A) illustrates a calculation result of a temperature of a gas flowing between parallel flat plates of 1.0 mm, and FIG. 5(B) illustrates a calculation of the
10 temperature of the gas flowing between parallel flat plates of 0.8 mm.

FIG. 6 illustrates a calculation result of a pressure increase amount when water vapor flows through the gap at 25 slm.

FIG. 7 illustrates a schematic configuration of a controller of the substrate processing apparatus according to the embodiment described herein.

15 FIG. 8 is a flowchart schematically illustrating a pre-processing step of a substrate processing according to the embodiment described herein.

FIG. 9 is a flowchart schematically illustrating the substrate processing according to the embodiment described herein.

FIG. 10 schematically illustrates a vertical cross-sectional structure of a
20 vaporizer of the substrate processing apparatus according to a second embodiment described herein.

FIG. 11(A) schematically illustrates the vertical cross-sectional structure of the vaporizer of the substrate processing apparatus according to the second embodiment described herein, and FIG. 11(B) schematically illustrates a vertical cross-sectional
25 structure of a vaporizer of the substrate processing apparatus according to a comparative

example.

[Detailed Description]

[0008]

<Embodiment of Technique of Present Disclosure>

5 Hereinafter, a preferred embodiment of the technique of the present disclosure will be described with reference to the drawings.

[0009]

(1) Configuration of Substrate Processing Apparatus

First, an exemplary configuration of a substrate processing apparatus 10 in
10 which a method of manufacturing a semiconductor device according to the present embodiment is performed will be described with reference to FIGS. 1 and 2. The substrate processing apparatus 10 is an apparatus of processing a substrate using a process gas generated by vaporizing a liquid source containing hydrogen peroxide (H_2O_2), that is, a hydrogen peroxide solution. For example, the substrate processing
15 apparatus 10 is an apparatus of processing a wafer 200 serving as the substrate made of a material such as silicon. Preferably, the substrate processing apparatus 10 is used when processing the wafer 200 of a concave-convex structure (grooves) which is a microstructure. According to the present embodiment, an oxide film is formed by filling the grooves with a polysilazane film, which is a silicon-containing film, and processing
20 the polysilazane film with the process gas.

[0010]

According to the present embodiment, the H_2O_2 vaporized or converted to be in a mist state (that is, the H_2O_2 in a gaseous phase) is referred to as a “ H_2O_2 gas”, a gas containing at least the H_2O_2 gas is referred to as “process gas”, and an aqueous solution
25 of the H_2O_2 is referred to as

the “hydrogen peroxide solution” or the “liquid source”.

[0011]

<Process vessel>

As shown in FIG. 1, a process furnace 202 constituting the substrate processing apparatus 10 includes a process vessel (reaction tube) 203. The process vessel 203 is of a cylindrical shape with an open lower end. A process chamber 201 is provided in a hollow cylindrical portion of the process vessel 203. The process chamber 201 is configured to accommodate a plurality of wafers including the wafer 200 serving as a substrate vertically in a horizontal orientation in a multistage manner by a boat 217 described later.

[0012]

A seal cap 219 serving as a furnace opening lid configured to airtightly seal a lower end opening (furnace opening) of the process vessel 203 is provided under the process vessel 203. The seal cap 219 is provided under the process vessel 203 and is in contact with the lower end of the process vessel 203. The process chamber 201, which is a process space where the substrate is processed, is defined by the process vessel 203 and the seal cap 219.

[0013]

<Substrate Retainer>

The boat 217 serving as a substrate retainer is configured to hold (support) the plurality of the wafers including the wafer 200 in a multistage manner. The boat 217 includes a plurality of support columns 217a provided between a bottom plate 217b and a top plate 217c. The plurality of the wafers including the wafer 200 are arranged at the plurality of the support columns 217a in a horizontal orientation in a multistage manner along a tube axis direction.

[0014]

A heat insulator 218 is provided under the boat 217. The heat insulator 218 is configured

to suppress the heat from a first heating apparatus 207 from being transferred to the seal cap 219.

[0015]

<Elevator>

5 A boat elevator serving as an elevator configured to elevate and lower the boat 217 is provided under the process vessel 203. When the boat 217 is elevated by the boat elevator, the seal cap 219 then airtightly closes the furnace opening. A boat rotator 267 configured to rotate the boat 217 is provided at the seal cap 219 opposite to the process chamber 201.

10 [0016]

<First Heating Apparatus>

 The first heater 207 is provided outside the process vessel 203. The first heater 207 is of a concentric ring shape surrounding a side wall surface of the process vessel 203. The first heater 207 is configured to heat the plurality of the wafers including the wafer 200 accommodated in the process vessel 203. The first heater 207 is supported by
15 a heater base 206. As shown in FIG. 2, the first heater 207 includes a first sub-heater 207a, a second sub-heater 207b, a third sub-heater 207c and a fourth sub-heater 207d. A first temperature sensor 263a, a second temperature sensor 263b, a third temperature sensor 263c and a fourth temperature sensor 263d are provided in the process vessel 203.
20 The first temperature sensor 263a through the fourth temperature sensor 263d serve as temperature detectors configured to detect temperatures of the plurality of the wafers including the wafer 200, respectively, or to detect an ambient temperature, and are provided for the first sub-heater 207a through the fourth sub-heater 207d serving as sub-heaters, respectively. For example, the first temperature sensor 263a through the fourth
25 temperature sensor 263d such as thermocouples may be provided between the process vessel 203 and the boat 217, respectively.

[0017]

The first heating apparatus 207 and the first temperature sensor 263a through the fourth temperature sensor 263d are electrically connected to a controller 121 which will be described later. A first external temperature sensor 264a, a second external temperature sensor 264b, a third external temperature sensor 264c and a fourth external temperature sensor 264d may be further provided at the first sub-heater 207a through the fourth sub-heater 207d, respectively. The first external temperature sensor 264a through the fourth external temperature sensor 264d constituted by thermocouples and serving as temperature detectors are configured to detect temperatures of the first sub-heater 207a through the fourth sub-heater 207d, respectively. The first external temperature sensor 264a through the fourth external temperature sensor 264d are electrically connected to the controller 121.

[0018]

<Gas Supplier (Gas Supply System)>

As shown in FIGS. 1 and 2, a process gas supply nozzle 501a and an oxygen-containing gas supply nozzle 502a are provided between the process vessel 203 and the first heating apparatus 207 along an outer sidewall of the process vessel 203. Tips (downstream ends) of the process gas supply nozzle 501a and the oxygen-containing gas supply nozzle 502a are inserted into the process vessel 203 through a ceiling of the process vessel 203 in an airtight manner. A supply hole 501b and a supply hole 502b are provided at the tips of the process gas supply nozzle 501a and the oxygen-containing gas supply nozzle 502a located in the process vessel 203, respectively.

[0019]

A gas supply pipe 602c is connected to an upstream end of the oxygen-containing gas

supply nozzle 502a. A valve 602a, a mass flow controller (MFC) 602b constituting a gas flow rate controller, a valve 602d and an oxygen-containing gas heater 602e are sequentially provided at the gas supply pipe 602c in order from an upstream side to a downstream side of the gas supply pipe 602c. For example, a gas including at least one among oxygen (O_2) gas, ozone (O_3) gas and nitrous oxide (NO_2) may be used as the oxygen-containing gas. According to the present embodiment, the O_2 gas is used as the oxygen-containing gas. The oxygen-containing gas heater 602e is provided to heat the oxygen-containing gas.

[0020]

A downstream end of a process gas supply pipe 289a configured to supply the process gas is connected to an upstream end of the process gas supply nozzle 501a. A vaporizer 100 serving as a process gas generator configured to generate the process gas by vaporizing the liquid source and a valve 289b are sequentially provided at the process gas supply pipe 289a in order from an upstream side to a downstream side of the process gas supply pipe 289a. According to the present embodiment, a gas containing at least the H_2O_2 is used as the process gas. A pipe heater 289c such as a jacket heater is provided around the process gas supply pipe 289a. A vaporized gas pipe configured to supply a vaporized gas generated by the vaporizer 100 into the process chamber 201 is constituted by the process gas supply pipe 289a and the process gas supply nozzle 501a.

[0021]

A liquid source supply system 300 configured to supply the liquid source of the process gas to the vaporizer 100 and a carrier gas supply supplier (carrier gas supply system) configured to supply a carrier gas to the vaporizer 100 are connected to the vaporizer 100. The vaporized gas of the liquid source generated in the vaporizer 100 is delivered (ejected) to the process gas

supply pipe 289a as the process gas together with the carrier gas.

[0022]

The liquid source supply system 300 includes a liquid source supply 301, a valve 302 and a liquid mass flow controller (LMFC) 303 configured to control a flow rate of the liquid source supplied to the vaporizer 100, which are sequentially provided in order on the upstream side to a downstream side of the liquid source supply system 300. The carrier gas supply supplier is constituted at least by a carrier gas supply pipe 601c, a carrier gas valve 601a, an MFC 601b serving as a carrier gas flow rate controller and a carrier gas valve 601d. According to the present embodiment, the oxygen-containing gas such as the O₂ gas may be used as the carrier gas. However, a gas including at least one of oxygen-containing gases (for example, the O₃ gas and the NO gas as well as the O₂ gas) may be used as the carrier gas. In addition, a gas whose reactivity with the wafer 200 or films formed on the wafer 200 is low may be used as the carrier gas. For example, N₂ gas or a rare gas may be used as the carrier gas.

[0023]

According to the present embodiment, a process gas supplier (process gas supply system) is constituted at least by the process gas supply nozzle 501a and the supply hole 501b. The process gas supplier may further include the process gas supply pipe 289a, the valve 289b and the vaporizer 100. An oxygen-containing gas supplier (oxygen-containing gas supply system) is constituted at least by the oxygen-containing gas supply nozzle 502a and the supply hole 502b. The oxygen-containing gas supplier may further include the gas supply pipe 602c, the oxygen-containing gas heater 602e, the valve 602d, the MFC 602b and the valve 602a. A gas supply supplier (gas supply system) is constituted by the process gas supplier and the oxygen-containing gas supplier.

[0024]

<Vaporizer>

Subsequently, a schematic structure of the vaporizer 100 will be described with reference to FIG. 3. The vaporizer 100 is constituted by: a liquid source supplier (atomization device or atomizer) 150 configured to supply the liquid source into a vaporization vessel 111; and a vaporization portion 108 configured to heat and vaporize the liquid source supplied into the vaporization vessel 111 by a vaporizer heater 113. The vaporizer 100 vaporizes the liquid source by supplying fine droplets of the liquid source atomized by the liquid source supplier 150 into the vaporization vessel 111 heated by the vaporizer heater 113. In addition, the vaporization vessel 111 and the liquid source supplier 150, which constitute the vaporizer 100, are formed as a single body. In addition, both the vaporization vessel 111 and the liquid source supplier 150 are made of a quartz material (quartz glass).

[0025]

<Vaporization Portion>

A detailed structure of the vaporization portion 108 will be described. The vaporization portion 108 is constituted mainly by: the vaporization vessel 111; a vaporization chamber 112 provided in the vaporization vessel 111; the vaporizer heater 113 serving as a first heater and configured to heat the vaporization vessel 111; a metal block 116 configured to transfer the heat emitted from the vaporizer heater 113 to the vaporization vessel 111; an exhaust port 114 and a temperature sensor 115 constituted by thermocouples and configured to measure a temperature of the vaporization vessel 111.

[0026]

In addition, the vaporization portion 108 may be divided into two blocks, that is, an outer block 110a and an inner block 110b. The outer block 110a is of a cylindrical shape, and the

inner block 110b of a cylindrical column shape is inserted into an inner side of the outer block 110a of a cylindrical shape. An upper portion (tip portion) of the inner block 110b is of a dome shape (spherical shape). A gap 112b is provided between a wall surface of an inner circumference of the outer block 110a of a cylindrical shape and a wall surface of an outer circumference of the outer block 110a. The outer block 110a includes: an outer heater 113a described later; a part of the metal block 116; a part of the vaporization vessel 111 (a quartz material 111a described later); and a part of a heat insulating material 160. The inner block 110b includes: an inner heater 113b described later; a part of the metal block 116; a part of the vaporization vessel 111 (a quartz material 111b described later); a part of the heat insulating material 160; and the temperature sensor 115.

[0027]

The vaporizer heater 113 is constituted by the outer heater 113a embedded in the outer block 110a and the inner heater 113b embedded in the inner block 110b. Each of the outer heater 113a and the inner heater 113b is controlled based on temperature data measured by the temperature sensor 115.

[0028]

The vaporization chamber 112 is defined by an upper space 112a and the gap 112b. The upper space 112a is provided between a lower surface of a ceiling wall 161 of the vaporization vessel 111 to which the liquid source supplier 150 is connected and an upper portion of the inner block 110b. In addition, the vaporization vessel 111 is constituted by: the quartz material 111a serving as an outer vessel provided on a surface of the outer block 110a exposed to the vaporization chamber 112; the quartz material 111b serving as an inner vessel provided on a

surface of the inner block 110b exposed to the vaporization chamber 112; and the ceiling wall 161. That is, the vaporization vessel 111 is configured as a double tube structure by the quartz material 111a and the quartz material 111b.

[0029]

That is, the vaporization vessel 111 defines the vaporization chamber 112 configured to vaporize the liquid source supplied by the liquid source supplier 150, and the vaporized gas generated in the vaporization chamber 112 is exhausted (delivered) to the process gas supply pipe 289a as the process gas together with the carrier gas through the exhaust port 114.

[0030]

A surface of the vaporization vessel 111 exposed to the vaporization chamber 112, that is, the surface of the vaporization vessel 111 in contact with the liquid source or the vaporized gas is entirely made of quartz which is a material free of metal. Thus, it is possible to prevent the metal contamination generated by the reaction between the material of the vaporization vessel 111 and the H_2O_2 whose reactivity with the metal is high.

[0031]

<Liquid Source Supplier (Atomization device or Atomizer)>

The liquid source supplier 150 is provided above the vaporization vessel 111. In addition, the liquid source supplier 150 is provided above an upper end of the metal block 116 and above the vaporization chamber 112. In addition, according to the present embodiment, the vaporization vessel 111 and the liquid source supplier 150 are integrally formed, and are partitioned by the ceiling wall 161. However, the vaporization vessel 111 and the liquid source supplier 150 may be configured as separable components.

[0032]

The liquid source supplier 150 is constituted by: a liquid source inlet port 151 configured to introduce the liquid source supplied via the LMFC 303; an outlet port 152 configured to eject the liquid source introduced via the liquid source inlet port 151 into the vaporization vessel 111; a liquid source introducing pipe 158 configured to introduce the liquid source from the liquid source inlet port 151 to the outlet port 152; a carrier gas inlet port 153 configured to introduce the carrier gas supplied via the carrier gas supply pipe 601c; and a carrier gas outlet port 155 configured to eject the carrier gas introduced via the carrier gas inlet port 153 into the vaporization vessel 111.

[0033]

In addition, a buffer space 154 is provided between the carrier gas inlet port 153 and the carrier gas outlet port 155. The carrier gas outlet port 155 is constituted by a narrow gap provided between an edge of an opening provided at the ceiling wall 161 and the liquid source introducing pipe 158 inserted in the opening provided at the ceiling wall 161. The carrier gas outlet port 155 is provided in the vicinity of the outlet port 152 at a tip of the liquid source introducing pipe 158.

[0034]

That is, the carrier gas introduced into the carrier gas inlet port 153 is ejected into the upper space 112a from the carrier gas outlet port 155 provided in the vicinity of the outlet port 152 of the liquid source introducing pipe 158 via the buffer space 154. A flow path of the carrier gas in the carrier gas outlet port 155 is constrained to be narrow. Since a flow of the carrier gas passing through the carrier gas outlet port 155 is very fast, the droplets of the liquid source

ejected via a tip of the outlet port 152 are atomized by the carrier gas. As described above, the liquid source ejected via the outlet port 152 is ejected into the upper space 112a of the vaporization vessel 111 as fine liquid droplets together with the carrier gas.

[0035]

<Configuration of Heater and Peripherals thereof>

A thermal conductivity of the quartz material constituting the vaporization vessel 111 is low. Therefore, in comparison with a vaporization vessel made of a metal, it is difficult to uniformly transfer the heat from the heater to the liquid source and to vaporize the liquid source. According to the present embodiment, the metal block 116 serving as a first metal block and heated by the outer heater 113a is inserted between the outer heater 113a and the vaporization vessel 111 in order to indirectly transfer the heat generated from the outer heater 113a to the quartz material of the vaporization vessel 111. The metal block 116 is provided so as to cover an outer surface of the quartz material 111a from below the quartz material 111a to the same height position as the ceiling wall 161, or from below the quartz material 111a to a height position lower than the ceiling wall 161. In order to uniformly heat the quartz material 111a, it is preferable that the metal block 116 is provided so as to cover an entire surface of the quartz material 111a (that is, the metal block 116 extends to the same height as the ceiling wall 161). However, according to the present embodiment, since the heat insulating material 160 described later is provided between the metal block 116 and the liquid source supplier 150, a height of the upper end of the metal block 116 is set lower than the ceiling wall 161 by a thickness of the heat insulating material 160 in order to obtain a sufficient heat insulating effect.

[0036]

According to the embodiment, the metal block 116 is made of aluminum (Al). A thermal conductivity of the quartz material is lower than that of the metal. However, by inserting the metal block 116 whose thermal conductivity is high, it is possible to uniformly transfer the heat from the outer heater 113a to the vaporization vessel 111.

[0037]

A heat transfer paste 117 is applied between the vaporizer heater 113 and the metal block 116 and between the metal block 116 and the vaporization vessel 111. Since the heat transfer paste 117 is filled in gaps between the vaporizer heater 113 and the metal block 116 and between the metal block 116 and the vaporization vessel 111, it is possible to remove the gaps described above and to transfer the heat more uniformly. In particular, if there is a gap between the metal block 116 and the vaporization vessel 111, a temperature difference may easily occur in the vaporization vessel 111. Thus, it is effective to apply the heat transfer paste 117 to the gap.

[0038]

<Heat Insulating Structure>

The periphery of the vaporization portion 108 is covered with the heat insulating material 160 constituted by a heat insulating cloth. Specifically, the heat insulating material 160 is provided so as to cover at least a part of a surface of the metal block 116, more specifically, an upper surface, a lower surface and an outer peripheral surface of the metal block 116. In particular, a portion of the heat insulating material 160 provided so as to cover the upper surface of the metal block 116 is disposed between the outer heater 113a and the liquid source supplier 150 (more specifically, between the metal block 116 in the outer block 110a and the liquid source supplier 150), and is configured to block (shield) the heat emitted from the outer heater

113a to the liquid source supplier 150. That is, the heat insulating material 160 is provided so that the liquid source supplier 150 is thermally sufficiently isolated from the vaporizer heater 113 (particularly, the outer heater 113a provided close to the liquid source supplier 150).

[0039]

In the present specification, “the emission of the heat” means at least one among the radiation of the heat and the conduction of the heat. More specifically, (a) the heat indirectly radiated from the metal block 116 heated by the outer heater 113a, (b) the heat indirectly conducted through the metal block 116, (c) the heat directly radiated from the outer heater 113a (when the outer heater 113a is exposed from the metal block 116) and the like may be considered as the heat emitted from the outer heater 113a blocked by the heat insulating material 160. According to the present embodiment, by providing the heat insulating material 160, it is possible to block at least the heat of (a) and the heat of (b) from the liquid source supplier 150.

[0040]

According to the vaporizer in which the heat insulating material 160 is not provided, the temperature of the vaporization vessel 111 (that is, a temperature of the vaporization chamber 112) is controlled to a desired temperature, while a temperature of the liquid source in the liquid source supplier 150 is thermally interfered by the heat from the vaporizer heater 113 configured to heat the vaporization chamber 112. Therefore, it is difficult to control or to manage the temperature of the liquid source in the liquid source supplier 150 to the desired temperature independent of the temperature of the vaporization vessel 111. In particular, when the liquid source containing a compound such as the H_2O_2 which rapidly decomposes with its temperature increase is used, if the temperature of the liquid source is not controlled or managed, a

concentration of the compound in the liquid source before vaporized in the vaporization chamber 112 may fluctuate without being controlled or managed, and as a result, the concentration of the compound in the vaporized gas generated in the vaporization chamber 112 may vary unintentionally.

5 [0041]

Therefore, according to the present embodiment, by providing the heat insulating material 160, it is possible to suppress the interference of the heat from the vaporizer heater 113 to the liquid source supplier 150, and as a result, it is possible to easily control or manage the temperature of the liquid source in the liquid source
10 supplier 150. According to the present embodiment, the vaporizer heater 113 is controlled so that the vaporization vessel 111 is heated to a temperature ranging from 180 °C to 210 °C. On the other hand, by providing the heat insulating material 160, it is possible to suppress the interference of the heat from the vaporizer heater 113, and as a result, it is possible to manage the temperature of the liquid source in the liquid source
15 supplier 150 to 100 °C or lower. In addition, according to the present embodiment, it is possible to suppress the temperature of the liquid source in the liquid source supplier 150 to a predetermined temperature (for example, 100 °C) or less without providing a cooler. According to the verification by the disclosers, when the temperature of the liquid source containing the H₂O₂ is 100 °C or lower, the concentration of the H₂O₂ in
20 the liquid source is stable, and the concentration of the obtained vaporized gas is also stable. In the present specification, a notation of a numerical range such as “from 180 °C to 210 °C” means that a lower limit and an upper limit are included in the numerical range. Therefore, for example, a numerical range “from 180 °C to 210 °C” means a range equal to or higher than 180 °C and equal to or lower than

210 °C. The same also applies to other numerical ranges described herein.

[0042]

Parameters of the heat insulating material 160 such as a material, a thickness and a structure of the heat insulating material 160 are selected so that the temperature of the liquid source in the liquid source supplier 150 is 100 °C or lower with respect to the heating by the vaporizer heater 113. According to the present embodiment, the heat insulating cloth whose thermal conductivity ranges from 0.1 W/mk to 0.3 W/mk may be used as the heat insulating material 160. More specifically, in order to maintain the temperature of the liquid source in the liquid source supplier 150 at 100 °C or lower, it is preferable to configure the heat insulating material 160 such that a temperature of the liquid source supplier 150 measured by a temperature sensor 119 described later is 100 °C or lower.

[0043]

According to the present embodiment, a part of the heat insulating material 160 provided on the upper surface of the metal block 116 may be replaced with another heat insulating material. For example, the part of the heat insulating material 160 may be replaced with a resin plate material such as polytetrafluoroethylene (PTFE), perfluoroalkoxyalkane (PFA), polybenzimidazole (PBI), and polyetheretherketone (PEEK), whose thermal conductivity are equivalent to that of the heat insulating cloth described above. In addition, the part of the heat insulating material 160 may be converted into the heat insulating material 160 by forming the part of the metal block 116 into a porous structure to provide a heat insulating function.

[0044]

The temperature sensor 119 constituted by thermocouples is mounted on an outer

surface of the liquid source introducing pipe 158 in the buffer space 154. The temperature sensor 119 measures the temperature of the liquid source supplier 150, more specifically, the temperature of the liquid source introducing pipe 158. By providing the temperature sensor 119 so as to measure the temperature of the outer surface of the liquid source introducing pipe 158, it is possible to indirectly measure the temperature of the liquid source passing through the liquid source introducing pipe 158. According to the present embodiment, the temperature sensor 119 is connected to the controller 121, and the controller 121 is configured to monitor the temperature of the liquid source.

[0045]

The vaporizer 100 according to the present embodiment is provided with the temperature sensor 119 on the outer surface of the liquid source introducing pipe 158. However, the temperature sensor 119 may be provided at another location, or a plurality of temperature sensors including the temperature sensor 119 may be provided. For example, the temperature sensor 119 or the plurality of the temperature sensors including the temperature sensor 119 may be provided at locations such as an inner surface of the liquid source introducing pipe 158 and a side surface of the buffer space 154. When the temperature sensor 119 is provided on the outer surface of the liquid source introducing pipe 158, another temperature sensor 119 may be provided in the buffer space 154 according to the present embodiment. When it is difficult to provide another temperature sensor 119 in the buffer space 154, another temperature sensor 119 may be provided outside the buffer space 154 (in particular, at an upstream side of the liquid source introducing pipe 158).

[0046]

In addition, when the temperature measured by the temperature sensor 119 exceeds a desired temperature due to the interference of the heat emitted from the vaporizer heater 113, the temperature of the vaporizer heater 113 may be controlled based on the temperature data measured by the temperature sensor 115 and the temperature sensor 119. In such a case, the temperature data measured by the temperature sensor 115 and the temperature sensor 119 are output to a temperature controller 106, and the temperature controller 106 is configured to control the temperature of the vaporizer heater 113 based on the temperature data. However, when the heat insulating material 160 sufficiently suppresses the interference of the heat supplied from the vaporizer heater 113 to the liquid source supplier 150 (that is, when the liquid source supplier 150 is thermally substantially isolated from the vaporizer heater 113), the control of the vaporizer heater 113 based on the temperature data measured by the temperature sensor 119 may not be performed.

[0047]

In addition, as in a second embodiment of the technique of the present disclosure described later, by providing a heater configured to heat the liquid source supplier 150 separately from the vaporizer heater 113, it is also possible to control the temperature of the liquid source to maintain the desired temperature of 100 °C or lower.

[0048]

<Double Tube Structure of Vaporization Vessel>

In addition, according to the present embodiment, as described above, the vaporization vessel 111 is configured as the double tube structure in order to more efficiently transfer the heat from the heater to the liquid source. The droplets of the liquid source supplied from the liquid source supplier 150 are heated and vaporized by passing through the upper space 112a and the gap 112b of a cylindrical shape constituting a gas flow path of a cylindrical shape. In addition, according to the present embodiment, the vaporization vessel 111 is configured as the double tube structure as

described above in order to more efficiently transfer the heat from the heater such as the vaporizer heater 113 to the liquid source.

[0049]

5 In order to prevent the vaporization vessel 111 from being damaged by directly contacting with the metal block 116, an O-ring 118 made of a heat resistant material is provided between the metal block 116 of the outer block 110a and the vaporization vessel 111.

[0050]

10 Similar to the vaporization vessel 111, the exhaust port 114 is made of the quartz material. A connection interface of the exhaust port 114 whereat the process gas supply pipe 289a is connected thereto is configured as a flange structure. The exhaust port 114 seals the connection interface to the process gas supply pipe 289a by an O-ring interposed therebetween.

[0051]

15 According to the present embodiment, a width of the gap 112b (that is, a width of the gas flow path of a cylindrical shape) is set to 0.6 mm or more and 0.8 mm or less. Hereinafter, the basis of setting the width of the gap 112b will be described with reference to FIGS. 4 through 6.

[0052]

20 In order to analyze a temperature of the gas flowing through the gap 112b shown in FIG. 4(A), let us assume that it is the convection heat transfer problem of the gas flowing between heated parallel flat plates as shown in FIG 4(B). Then, the temperature of the gas flowing between the parallel flat plates is calculated by the following difference equation.

25 [Equation 1]

$$u \frac{\partial T}{\partial x} = \alpha \frac{\partial^2 T}{\partial y^2}$$

(Convection term) (Heat conduction term)

[0053]

In [Equation 1], x indicates a coordinate position in a length direction of the flow path, and y indicates a coordinate position in a width direction of the flow path. Further, T indicates the temperature of the gas, u indicates a velocity component, and α indicates the thermal conductivity.

[0054]

FIG. 5(A) illustrates a calculation result of the temperature of the gas when the distance between the parallel flat plates is 1.0 mm, and FIG. 5(B) illustrates a calculation of the temperature of the gas when the distance between the parallel flat plates is 0.8 mm. When calculating the calculation results shown in FIGS. 5(A) and 5(B), a length L of the flow path is set to 0.15 m, and the calculation is performed by heating each of the parallel flat plates to 200 °C. The other processing conditions are the same except the distance between the parallel flat plates. Vertical axes shown in FIG. 5 represent the temperature of the gas, and horizontal axes shown in FIG. 5 represent the coordinate position y in the width direction of the flow path.

[0055]

As shown in FIGS. 5(A) and 5(B), in the vicinity of an inlet of the flow path ($x = 0.05$ m), as compared with a case where the distance between the parallel flat plates is 1.0 mm, it is confirmed that the temperature of the gas at a center of the flow path ($y = 0.4$ mm) can be increased when the distance between the parallel flat plates is 0.8 mm. In addition, in the vicinity

of an outlet of the flow path ($x = 0.10$ m), as compared with the case where the distance between the parallel flat plates is 1.0 mm, it is confirmed that the temperature of the gas at the center of the flow path ($y = 0.4$ mm) can be increased when the distance between the parallel flat plates is 0.8 mm. That is, it is considered that the heat transfer efficiency is improved and the vaporization efficiency is improved as the distance between the parallel flat plates is reduced. In particular, it is confirmed that the temperature of the gas can be sufficiently increased even at the center of the flow path by setting the distance between the parallel flat plates to 0.8 mm or less.

[0056]

FIG. 6 illustrates a calculation result of a pressure increase amount of the vaporization chamber 112 when water vapor flows through the gap 112b at 25 slm. A vertical axis shown in FIG. 6 represents the pressure increase amount, and a horizontal axis shown in FIG. 6 represents a width of the flow path.

[0057]

As shown in FIG. 5, when the width of the flow path of the vaporization chamber 112 (the width of the gap 112b) is narrow, the heat transfer efficiency is improved, and the vaporization of the introduced droplets (mist) tends to be stabilized. On the other hand, as shown in FIG. 6, when the width of the flow path is too narrow, an inner pressure of the vaporization chamber 112 increases sharply. Thus, the droplets are difficult to be vaporized, and the vaporization failure may occur. Specifically, when the width of the flow path is 0.5 mm or less, it is expected that the inner pressure of the vaporization chamber 112 may rapidly increase and the vaporization failure may occur. It is thought that the vaporization of the H_2O_2 -containing gas follows the same tendency. From the results described above, it is confirmed that the width of

the flow path is set to 0.6 mm or more in order to prevent the vaporization failure.

[0058]

That is, considering the calculation results shown in FIGS. 5 and 6, when the width of the gap 112b serving as the width of the flow path is 0.8 mm or less, it is possible to sufficiently increase the temperature of the gas at the center of the flow path. In addition, when the width of the gap 112b is 0.6 mm or more, serving as a width capable of preventing the vaporization failure due to the pressure increase described above, it is thought that it is possible to suppress the vaporization failure by reducing the pressure increase amount while improving the heat transfer efficiency and the vaporization efficiency.

[0059]

<Exhaust System>

One end of a gas exhaust pipe 231 configured to exhausting the gas in the process chamber 201 is connected to a lower sidewall of the process vessel 203. A vacuum pump 246 is connected to the other end of the gas exhaust pipe 231 via an APC (Automatic Pressure Controller) valve 255 serving as a pressure regulator. A pressure sensor 223 serving as a pressure detector is provided at an upstream side of the APC valve 255. A pressure controller 224 is electrically connected to the pressure sensor 223 and the APC valve 255. The pressure controller 224 is configured to control the APC valve 255 such that an inner pressure of the process chamber 201 is adjusted to a desired pressure at a desired timing based on a pressure detected by the pressure sensor 223.

[0060]

<Controller>

As shown in FIG. 7, the controller 121 serving as a control device (control apparatus), is

embodied by a computer having a CPU (Central Processing Unit) 121a, a RAM (Random Access Memory) 121b, a memory 121c and an I/O port 121d. The RAM 121b, the memory 121c and the I/O port 121d may exchange data with the CPU 121a via an internal bus 121e. An input/output device 122 constituted by components such as a touch panel and a display may be connected to the controller 121.

[0061]

The memory 121c is configured by components such as a flash memory and a hard disk drive (HDD). For example, a control program configured to control the operation of the substrate processing apparatus 10 or a process recipe containing information on the sequences and conditions of a substrate processing described later is readably stored in the memory 121c. The process recipe is obtained by combining steps of the substrate processing described later such that the controller 121 can execute the steps to acquire a predetermine result, and functions as a program. Hereafter, the process recipe and the control program may be collectively or individually referred to as a “program”. In addition, the process recipe may also be simply referred to as a “recipe”. In the present specification, the term “program” may indicate only the process recipe, may indicate only the control program, or may indicate both of the process recipe and the control program. The RAM 121b functions as a memory area (work area) where a program or data read by the CPU 121a is temporarily stored.

[0062]

The I/O port 121d is electrically connected to the components such as the LMFC 303, the MFCs 601b and 602b, the valves 601a, 601d, 602a, 602d, 302 and 289b, the APC valve 255, the first heating apparatus 207, the first temperature sensor 263a through the fourth temperature

sensor 263d, the boat rotator 267, the pressure sensor 223, the pressure controller 224, the temperature controller 106, the vaporizer heater 113, the temperature sensors 115 and 119 and the pipe heater 289c.

[0063]

The CPU 121a is configured to read a control program from the memory 121c and execute the read control program. In addition, the CPU 121a is configured to read a recipe from the memory 121c in accordance with an operation command inputted from the input/output device 122. According to the contents of the read recipe, the CPU 121a may be configured to control various operations such as a flow rate adjusting operation of the LMFC 303 for the liquid source, flow rate adjusting operations of the MFCs 601b and 602b for various gases, opening/closing operations of the valves 601a, 601d, 602a, 602d, 302 and 289b, an opening/closing operation of the APC valve 255, a temperature adjusting operation of the first heating apparatus 207 based on the first temperature sensor 263a through the fourth temperature sensor 263d, a start and stop of the vacuum pump 246, a rotation speed adjusting operation of the boat rotator 267, a temperature adjusting operation of the vaporizer heater 113 via the temperature controller 106, and a temperature adjusting operation of the pipe heater 289c via the temperature controller 106.

[0064]

The controller 121 may be embodied by installing the above-described program stored in an external memory 123 into a computer. For example, the external memory 123 may include a magnetic tape, a magnetic disk such as a flexible disk and a hard disk, an optical disk such as a CD and a DVD, a magneto-optical disk such as MO and a semiconductor memory such as a USB memory and a memory card. The memory 121c or the external memory 123 may be embodied by a non-transitory computer readable recording medium. Hereafter, the memory 121c

and the external memory 123 are collectively referred to as recording media. In the present specification, the term “recording media” may indicate only the memory 121c, may indicate only the external memory 123, and may indicate both of the memory 121c and the external memory 123. Instead of the external memory 123, a communication means such as the Internet and a dedicated line may be used for providing the program to the computer.

[0065]

(2) Pre-processing

Hereinafter, a pre-processing performed before a modifying step of the wafer 200 serving as the substrate will be described with reference to FIG. 8. As shown in FIG. 8, according to the pre-processing, the wafer 200 is loaded into a coating apparatus (not shown) (substrate loading step T10), and a polysilazane coating step T20 and a pre-baking step T30 are performed to the wafer 200 in the coating apparatus. According to the polysilazane coating step T20, the polysilazane is coated on the wafer 200 by the coating apparatus. According to the pre-baking step T30, the solvent is removed from the polysilazane coated on the wafer 200 by heating the polysilazane coated on the wafer 200. Thereby, a polysilazane coating film, which is a silicon-containing film, is formed on the wafer 200. After the polysilazane coating film is formed on the wafer 200, the wafer 200 is unloaded from the coating apparatus (substrate unloading step, T40).

[0066]

(3) Substrate Processing

Hereinafter, an exemplary sequence of the substrate processing, which is a part of manufacturing processes of a semiconductor device, will be described with reference to FIG. 9. The substrate processing is performed by using the substrate processing apparatus 10 described above. According to the present embodiment, as an example of the substrate processing, the

modifying step (oxidation step) wherein the silicon-containing film formed on the wafer 200 serving as a substrate is modified (oxidized) into a silicon oxide film (SiO film) using the gas containing the H₂O₂ as the process gas will be described. Herein, the components of the substrate processing apparatus 10 are controlled by the controller 121.

[0067]

<Substrate Loading Step S10>

First, the wafer 200 is charged into the boat 217. The boat 217 accommodating the wafer 200 is elevated by the boat elevator and loaded into the process vessel 203. With the boat 217 loaded, the seal cap 219 seals the lower end opening (furnace opening) of the process furnace 202.

[0068]

<Pressure and Temperature Adjusting Step S20>

The vacuum pump 246 vacuum-exhausts an inner atmosphere of the process vessel 203 such that an inner pressure of the process vessel 203 is adjusted to a desired pressure. The oxygen-containing gas is supplied into the process vessel 203 via the supply hole 502b. In the pressure and temperature adjusting step S20, the inner pressure of the process vessel 203 is measured by the pressure sensor 223, and the opening degree of the APC valve 255 is controlled based on the measured pressure. Preferably, the inner pressure of the process vessel 203 is adjusted to a slightly depressurized state, for example, to a pressure ranging from about 700 hPa to about 1,000 hPa. The first heating apparatus 207 heats the process vessel 203 such that the temperature of the wafer 200 in the process vessel 203 is adjusted to a desired first temperature ranging from 40 °C to 100 °C, for example.

[0069]

The boat rotator 267 starts to rotate the boat 217 while the wafer 200 is heated. The boat

rotator 267 continuously rotates the boat 217 until at least a modifying step S30 described later is completed.

[0070]

<Modifying Step S30>

When the wafer 200 is heated to the first temperature and the boat 217 is rotated at a predetermined desired speed, the liquid source is supplied to the vaporizer 100 by the liquid source supply system 300. That is, the valve 302 is opened to supply the liquid source to the liquid source supplier 150 via the liquid source inlet port 151. The flow rate of the liquid source is adjusted by the LMFC 303 when the liquid source is supplied to the liquid source supplier 150. The liquid source supplied to the liquid source supplier 150 is monitored by the temperature sensor 119 whether the temperature thereof is 100 °C or lower (for example, from 80 °C to 100 °C). The liquid source supplied to the liquid source supplier 150 is atomized by the carrier gas when the liquid source is ejected through the outlet port 152, and is sprayed into the upper space 112a in the vaporization vessel 111 as fine liquid droplets (for example, in the mist state). The vaporization vessel 111 is heated to a desired temperature (for example, from 180 °C to 210 °C) by the vaporizer heater 113 via the metal block 116, and the droplets of the sprayed liquid source are heated and vaporized in the surface of the vaporization vessel 111 or in the vaporization chamber 112. Thereby, the droplets are transformed into a gas state. The vaporized liquid source is delivered as the process gas (vaporized gas) together with the carrier gas via the exhaust port 114 to the process gas supply pipe 289a.

[0071]

The temperature of the vaporizer heater 113 is adjusted based on the temperature data

measured by the temperature sensor 115 in order to avoid the vaporization failure. When the liquid source in the droplet state is contained in the process gas supplied into the process chamber 201 due to the vaporization failure, for example, particles may be generated during the modifying step. Thus, the quality of the SiO film may deteriorate. When a temperature of a partial or the entire portion of the vaporization vessel 111 is decreased, the droplet may not be completely vaporized or may be re-liquefied. Thus, the temperature of the vaporizer heater 113 is adjusted to be equal to or higher than the predetermined temperature such that the droplets are completely vaporized and not re-liquefied.

[0072]

The process gas, which is the gas delivered from the vaporizer 100, is supplied into the process chamber 201 by opening the valve 289b via the process gas supply pipe 289a, the valve 289b, the process gas supply nozzle 501a and the supply hole 501b. The process gas introduced into the process chamber 201 via the supply hole 501b is supplied to the wafer 200. The H₂O₂ gas contained in the process gas acts as a reactive gas. The H₂O₂ gas contained in the process gas reacts with the silicon-containing film on the wafer 200 to modify the silicon-containing film into the SiO film.

[0073]

While the process gas is supplied into the process vessel 203, the inner atmosphere of the process vessel 203 is exhausted by the vacuum pump 246. That is, the APC valve 255 is opened, and the vacuum pump 246 exhausts the gas exhausted from the process vessel 203 through the gas exhaust pipe 231. After a predetermined time has elapsed, the valve 289b is closed and the supply of the process gas into the process vessel 203 is stopped. After another predetermined time has elapsed, the APC valve 255 is closed and the exhaust of the inner

atmosphere of the process vessel 203 is stopped.

[0074]

While the present embodiment is described by way of an example wherein the hydrogen peroxide solution is used as the liquid source, the present embodiment is not limited thereto. For example, a liquid containing ozone (O_3) and a liquid such as water (H_2O) may be used as the liquid source in the present embodiment. However, when the liquid source containing the compound such as the H_2O_2 which rapidly decomposes with its temperature increase used in the present embodiment is vaporized, it is particularly preferable to use the vaporizer 100 according to the present embodiment.

[0075]

<Drying Step S40>

After the modifying step S30 is completed, the temperature of the wafer 200 is elevated to a predetermined second temperature equal to or less than the temperature of the pre-baking step T30. The second temperature is higher than the first temperature described above, and is set to a temperature equal to or less than the temperature of the pre-baking step T30. After the temperature of the wafer 200 is elevated to the second temperature, the wafer 200 and the inside of the process vessel 203 are gradually dried while maintaining the second temperature.

[0076]

<Temperature Lowering and Returning to Atmospheric Pressure Step S50>

After the drying step S40 is completed, the particles or impurities remaining in the process vessel 203 are removed by opening the APC valve 255 and vacuum-exhausting the inner atmosphere of the process vessel 203. After the vacuum-exhaust, the APC valve 255 is closed and the inner pressure of the process vessel 203 is returned to an atmospheric pressure. After the

inner pressure of the process vessel 203 is returned to the atmospheric pressure and a predetermined time has elapsed, the temperature of wafer 200 is lowered until a predetermined temperature (for example, a temperature at which the wafer 200 can be unloaded) is reached.

5 [0077]

<Substrate Unloading Step S60>

Thereafter, the boat 217 charged with the processed wafers including the wafer 200 is unloaded out of the process vessel 203 through the lower end of the process vessel 203. The processed wafers including the wafer 200 are then discharged from the
10 boat 217. Thereby, the substrate processing according to the present embodiment is completed.

[0078]

<Second Embodiment of Technique of Present Disclosure>

Subsequently, a second embodiment of the technique of the present disclosure
15 will be described with reference to FIG. 10. In the second embodiment, the detailed description of the same configurations and steps as those of the embodiment described above will be omitted.

[0079]

In a substrate processing apparatus according to the present embodiment, a
20 vaporizer 400 is used instead of the vaporizer 100. The vaporizer 400 according to the present embodiment is provided with an atomizing heater 162 serving as a second heater configured to heat the liquid source supplier 150 around the liquid source supplier 150.

[0080]

25 According to the vaporizer 400, a metal block 163 serving as a second metal block is inserted between the atomizing heater 162 and the liquid source supplier 150 in order to conduct the heat emitted from the atomizing heater 162 to the quartz material of the liquid source

supplier 150. That is, the metal block 163 is provided along a side surface of the liquid source supplier 150 so as to cover the periphery of the liquid source supplier 150. The metal block 163 is heated by the atomizing heater 162 and is configured to conduct the heat to the buffer space 154.

[0081]

In addition, the temperature sensor 119 constituted by thermocouples is mounted on the outer surface of the liquid source introducing pipe 158 in the buffer space 154, and the metal block 163 is heated by the atomizing heater 162 based on the temperature data measured by the temperature sensor 119.

[0082]

The temperature controller 106 individually controls the vaporizer heater 113 serving as the first heater and the atomizing heater 162 serving as the second heater. Specifically, the temperature controller 106 is configured to maintain the temperature of the liquid source supplier 150 to a predetermined temperature of 80 °C or higher and 100 °C or lower (for example, 90 °C) based on the temperature data measured by the temperature sensor 119. In addition, the temperature controller 106 is configured to control a temperature of the atomizing heater 162 based on the temperature data measured by the temperature sensor 115 such that the temperature of the vaporization vessel 111 is 180 °C or higher and 210 °C or lower.

[0083]

According to the present embodiment, by providing a heat insulating material 165 described later, it is possible to suppress the interference of the heat emitted from the outer heater 113a to the liquid source supplier 150, the metal block 163 and the atomizing heater 162.

Therefore, the vaporizer heater 113 and the atomizing heater 162 do not thermally interfere with each other, and it is possible to easily control the temperature of the liquid source supplier 150 and the temperature of the vaporization vessel 111. That is, it is possible to control the vaporizer heater 113 based on the temperature data measured by the temperature sensor 115, and it is possible to control the atomizing heater 162 based on the temperature data measured by the temperature sensor 119.

[0084]

In addition, according to the present embodiment, by controlling the atomizing heater 162 to maintain the temperature of the liquid source supplier 150 to a predetermined temperature, it is possible to maintain a decomposition rate of the H_2O_2 in the liquid source in the liquid source supplier 150 constant. That is, since the concentration of the H_2O_2 in the liquid source supplied to the vaporization chamber 112 can be controlled to be constant, it is possible to easily manage the concentration of the H_2O_2 in the gas generated in the vaporizer 400 based on a theoretical value thereof.

[0085]

In addition, when the temperature of the liquid source supplied to the vaporization chamber 112 is too low, a time until the liquid source is vaporize may become long and the vaporization failure may occur. According to the present embodiment, by preheating the liquid source supplier 150 to 80 °C or higher and 100 °C or lower, it is possible to promote the vaporization of the liquid source in the vaporization chamber 112 while suppressing a rapid decomposition of the H_2O_2 in the liquid source supplier 150.

[0086]

The vaporizer 400 is covered with the heat insulating material 160 formed as a single body therewith, and the heat insulating material 165 is provided between the metal block 116 and the metal block 163 in addition to the heat insulating material 160. That is, the heat insulating material 165 is provided between the outer heater 113a serving as the first heater and the atomizing heater 162 serving as the second heater. In addition, the heat insulating material 165 is provided between the ceiling wall 161 of the vaporization vessel 111 connected to the liquid source supplier 150 and the upper surface of the metal block 116.

[0087]

As described above, the heat insulating material 165 is provided below the liquid source supplier 150, and is configured to prevent the heat emitted from the vaporizer heater 113 from transferring to the metal block 163 and the liquid source supplier 150 via the metal block 116. In other words, by configuring the liquid source supplier 150 and the vaporization chamber 112 as separated and independent structures, it is possible to reduce the temperature interference between the liquid source supplier 150 and the vaporization chamber 112.

[0088]

<Other Embodiments of Technique of Present Disclosure>

While the technique of the present disclosure is described in detail by way of the embodiments, the technique of the present disclosure is not limited thereto. The technique of the present disclosure may be modified in various ways without departing from the gist thereof.

[0089]

While the embodiments are described by way of an example in which the wafer 200 with the polysilazane film formed thereon is processed, the technique of the present disclosure is not limited thereto. The technique of the present disclosure may also be

applied when the wafer 200 with a film containing a silazane bond (-Si-N-) formed thereon is processed. The vaporizer described above may also be used when a coating film containing materials such as hexamethyldisilazane (HMDS), hexamethylcyclotrisilazane (HMCTS), polycarbosilazane and polyorganosilazane is
5 processed.

[0090]

In addition, the vaporizer described above may also be used when a film such as a plasma polymerized film of tetrasilylamine and ammonia is processed. In addition, the vaporizer described above may also be used when a silicon-containing film formed by a
10 CVD method, for example, a silicon-containing film formed by the CVD method using a silicon source such as monosilane (SiH_4) gas and trisilylamine (TSA) gas is processed. In particular, the silicon-containing film may be formed by a flowable CVD method.

[0091]

In addition, the embodiments are described by way of an example in which a
15 substrate processing apparatus including a vertical type process furnace is used. However, for example, the vaporizer described above may also be applied when a single type substrate processing apparatus, a substrate processing apparatus including a hot wall type process furnace, a substrate processing apparatus including a cold wall type process furnace or a substrate processing apparatus capable of processing the wafer 200
20 by activating the process gas is used.

[0092]

<Example>

Hereinafter, examples of the technique of the present disclosure will be described.

25 [0093]

As the example of the technique of the present disclosure, the vaporizer 400

shown in FIGS. 10 and 11(A) is used, and as a comparative example, a vaporizer 500 shown in FIG. 11(B) is used to supply water H₂O) serving as the liquid source. Experiments in which the liquid source is supplied to the liquid source supplier 150 and vaporized are performed. The vaporizer 500 is configured without the heat insulating material 165 of the vaporizer 400, and the liquid source supplier 150 and the vaporization vessel 111 of the vaporizer 500 are not thermally separated and independent. The processing conditions of the example and the comparative example are the same.

[0094]

According to the vaporizer 500 shown in FIG. 11(B), it is confirmed that it is possible to vaporize a maximum of 20 g/min of the liquid source when a liquid supplier temperature (the temperature of the liquid source supplier 150) is 143 °C. On the other hand, according to the vaporizer 400 shown in FIG. 11(A), it is confirmed that it is possible to vaporize a maximum of 20 g/min of the liquid source when the liquid supplier temperature is 89 °C.

[0095]

That is, according to the present embodiments, it was confirmed that, by providing the heat insulating material 165 between the atomizing heater 162 configured to heat the liquid source supplier and the vaporizer heater 113 configured to heat the vaporization chamber 112, it is possible to maintain the liquid supplier temperature to 100 °C or lower, and even when the liquid supplier temperature is 100 °C or lower, it is possible to vaporize the same amount of the liquid source as when the liquid supplier temperature is higher than 100 °C.

[Description of Reference Numerals]

[0096]

substrate processing apparatus

100,400	vaporizer
150	liquid source supplier
108	vaporization portion
111	vaporization vessel
112	vaporization chamber
160, 165	heat insulating material
200	wafer (substrate)

[CLAIMS]**[Claim 1]**

- A vaporizer comprising:
- 5 a liquid source supplier configured to supply a liquid source;
 a vaporization vessel constituting a vaporization chamber in which the liquid source supplied through the liquid source supplier is vaporized;
 a first heater configured to heat the vaporization vessel;
 a heat insulating material provided to prevent heat emitted from the first heater
10 from transferring to the liquid source supplier;
 a second heater configured to heat the liquid source supplier; and
 a controller configured to individually control a temperature of the first heater and a temperature of the second heater.

15 **[Claim 2]**

The vaporizer of claim 1, wherein the heat insulating material is provided between the first heater and the second heater.

[Claim 3]

- 20 The vaporizer of claim 1 or 2, wherein the vaporization vessel comprises:
 an outer vessel of a cylindrical shape; and
 an inner vessel provided at an inner side of the outer vessel and being of a column shape,
 wherein a gap is provided between an outer wall of the inner vessel and an
25 inner wall of the outer vessel to define a flow path of a cylindrical shape in which the liquid source is vaporized, and a width of the flow path is 0.6 mm or more and 0.8 mm or less.

[Claim 4]

- 30 The vaporizer of any one of claims 1 through 3, wherein the heat insulating material is configured such that a temperature of the liquid source supplier is 100 °C or

lower.

[Claim 5]

The vaporizer of claim 2, wherein the controller is further configured to control
5 the temperature of the second heater such that a temperature of the liquid source
supplier is 80 °C or higher and 100 °C or lower.

[Claim 6]

The vaporizer of any one of claims 1 through 5, wherein the liquid source
10 supplier comprises:

an outlet port configured to eject the liquid source into the vaporization
chamber; and

a liquid source introducing pipe configured to introduce the liquid source to the
outlet port.

15

[Claim 7]

The vaporizer of claim 6, wherein the liquid source supplier further comprises:

a carrier gas outlet port provided adjacent to the outlet port and configured to
eject a carrier gas into the vaporization vessel; and

20 a carrier gas introducing pipe configured to introduce the carrier gas to the
carrier gas outlet port.

[Claim 8]

The vaporizer of any one of claims 1 through 7, wherein the vaporization vessel
25 and the liquid source supplier are formed as a single body made of quartz.

[Claim 9]

A vaporizer comprising:

a liquid source supplier configured to supply a liquid source;

30 a vaporization vessel constituting a vaporization chamber in which the liquid
source supplied through the liquid source supplier is vaporized;

a first heater configured to heat the vaporization vessel;
a heat insulating material provided to prevent heat emitted from the first heater from transferring to the liquid source supplier;
a second heater configured to heat the liquid source supplier;
5 a controller configured to individually control a temperature of the first heater and a temperature of the second heater; and
a first metal block inserted between the first heater and the vaporization vessel, and configured to be heated by the first heater and transfer the heat to the vaporization vessel,
10 wherein the heat insulating material is configured to cover at least a part of a surface of the first metal block so as to prevent the heat emitted from the first metal block from transferring to the liquid source supplier.

[Claim 10]

15 The vaporizer of claim 9, wherein the vaporization vessel comprises an outer vessel of a cylindrical shape, and
the first metal block is provided so as to cover an outer surface of the outer vessel from below the outer vessel to a height position same as a ceiling wall of the vaporization vessel connected to the liquid source supplier, or from below the outer
20 vessel to a height position lower than the ceiling wall.

[Claim 11]

The vaporizer of claim 9 or 10, further comprising:
a second metal block inserted between the second heater and the liquid source
25 supplier, and configured to be heated by the second heater and transfer the heat to the liquid source supplier,
wherein the heat insulating material is provided between the first metal block and the second metal block.

30 [Claim 12]

The vaporizer of any one of claims 1 through 11, wherein the liquid source

contains hydrogen peroxide.

[Claim 13]

- A substrate processing apparatus comprising:
- 5 a process chamber in which a substrate is processed;
 - a vaporizer comprising:
 - a liquid source supplier configured to supply a liquid source;
 - a vaporization vessel constituting a vaporization chamber in which the liquid source supplied through the liquid source supplier is vaporized;
 - 10 a first heater configured to heat the vaporization vessel;
 - a heat insulating material provided to prevent heat emitted from the first heater from transferring to the liquid source supplier;
 - a second heater configured to heat the liquid source supplier; and
 - a controller configured to individually control a temperature of the first
 - 15 heater and a temperature of the second heater; and
 - a vaporized gas pipe configured to supply a vaporized gas generated by the vaporizer into the process chamber.

[Claim 14]

- A method of manufacturing a semiconductor device comprising:
- 20 (a) loading a substrate into a process chamber;
 - (b) supplying a liquid source into a vaporization vessel constituting a vaporization chamber in which the liquid source supplied by a liquid source supplier configured to supply the liquid source is vaporized;
 - 25 (c) heating the vaporization vessel by a first heater configured to heat the vaporization vessel while preventing heat emitted from the first heater from transferring to the liquid source supplier by a heat insulating material and heating the liquid source supplier by a second heater configured to heat the liquid source supplier; and
 - (d) generating a vaporized gas by vaporizing the liquid source supplied into the
 - 30 heated vaporization vessel and supplying the vaporized gas into the process chamber,
 - wherein a temperature of the first heater and a temperature of the second heater

are respectively controlled.