

possibility that a vaporization failure is likely to occur in the vaporizer 100.

[0095] In addition, when the acquired temperature of the processing gas is higher than a predetermined pressure range, in order to prevent reliquefaction of the processing gas, the controller 121 may control the temperature of at least one of the pipe heater 289c, the filter heater 630, and the gas port heater 285 so as to raise it by a predetermined width.

(C) Control based on Concentration Value Data of the Densitometer 500

[0096] When the concentration value of the reaction gas (i.e., the concentration value of the H_2O_2 gas) in the processing gas delivered from the vaporizer 100 is not stable during the process of supplying the processing gas, it is estimated that a vaporization failure of the liquid precursor occurs in the vaporizer 100. Therefore, when it is determined that a state, in which a ratio of the gas concentration of the reaction gas to a predetermined reference concentration value (reference concentration value) in the processing gas in the processing gas supply pipe 289a acquired from the densitometer 500 is equal to or less than a predetermined ratio, continues for a predetermined period of time, the controller 121 notifies the user of a vaporization failure in the vaporizer 100 or that there is a high possibility that a vaporization failure is likely to occur in the vaporizer 100, for example, through the input/output device 122, or records it as a log in the memory device 121c. Furthermore, the concentration value of the reaction gas in the processing gas also varies depending on the conditions such as the flow rate of the carrier gas. Therefore, in some embodiments, for example, the reference concentration value corresponding to the carrier gas supply amount may be stored as a table in advance, and the reference concentration value corresponding to the carrier gas supply amount at each time point controlled by the MFC 601b as the carrier gas flow rate control part may be determined sequentially by referring to the table. In addition, when it is determined that the acquired concentration decrease amount of the reaction gas in the processing gas per predetermined time continues to have a predetermined value or more, or when it is determined that the acquired concentration value of the reaction gas in the processing gas is lower than a predetermined concentration value or a value within

a range of predetermined concentration value, the controller 121 may perform the same processing on the assumption of a vaporization failure in the vaporizer 100 or that there is a high possibility that a vaporization failure is likely to occur in the vaporizer 100.

[0097] Furthermore, as illustrated in FIG. 11C, when it is determined that a state, in which the ratio of the acquired concentration value of the reaction gas to the reference concentration value in the processing gas is equal to or less than the predetermined ratio (first concentration ratio), continues for a predetermined period of time (S121), the controller 121 controls the vaporization heater 103 of the vaporizer 100 through the temperature controller 106 to raise the temperature of the vaporization heater 103 by a predetermined width (S122). For example, when it is detected that a state continues for 30 to 60 seconds in which the acquired concentration value of the reaction gas in the processing gas is a value lower than the reference concentration value by 5 to 15% or more (i.e., a value of 85 to 95% or less of the reference concentration value), the control of S122 is performed. In this embodiment, when it is detected that a state continues for 30 seconds or more in which the acquired concentration value of the reaction gas in the processing gas is a value lower than the reference concentration value by 10% or more (i.e., a value of 90% or less of the reference concentration value), the controller 121 performs the control of S122. Thus, the vaporization failure of the liquid precursor in the vaporizer 100 can be improved or eliminated. In addition, 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.

[0098] Furthermore, 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, in which the ratio of the acquired concentration value of the reaction gas to the reference concentration value in the processing gas is equal to or less than the predetermined ratio (first concentration ratio), continues for a predetermined period of time (S121), 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

(S122). 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 concentration value of the reaction gas in the processing gas varies irrespective of the presence or absence of vaporization failure, control based on the gas concentration value 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 some embodiments. In addition, the MFC 601b is controlled so that the flow rate of the carrier gas falls within a range of predetermined flow rate or less.

[0099] Furthermore, when a vaporization failure of the liquid precursor occurs in the vaporizer 100, the vaporization failure may be improved or eliminated by reducing the flow rate of the liquid precursor supplied to the vaporizer 100. Therefore, when it is determined that a state, in which the ratio of the acquired concentration value of the reaction gas to the reference concentration value in the processing gas is equal to or less than the predetermined ratio (first concentration ratio), continues for a predetermined period of time (S121), the controller 121 may control the LMFC 303 that controls the flow rate of the liquid precursor supplied to the vaporizer 100 to reduce the supply amount of the liquid precursor by a predetermined width (S122). However, when the flow rate of the liquid precursor is changed, the concentration of the H_2O_2 gas in the generated processing gas and the supply amount of the H_2O_2 gas itself may change. Therefore, the control to change the flow rate of the carrier gas or 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 liquid precursor in some embodiments.

[0100] On the other hand, when the concentration value of the reaction gas in the processing gas increases, re-liquefaction (dew condensation) of the processing gas is relatively likely to occur. In addition, the concentration value of the reaction gas in the processing gas may fall within a range of predetermined concentration value for stable substrate processing in some embodiments. Therefore, when it is determined that a state in which the acquired concentration value of the reaction gas in the processing gas is a value of a predetermined ratio (second concentration

ratio) or more of the reference concentration value continues for a predetermined period of time (S121), in order to suppress the occurrence of re-liquefaction, the controller 121 controls 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 (S123). Furthermore, it may control the LMFC 303 that controls the flow rate of the liquid precursor supplied to the vaporizer 100 to decrease the supply amount of the liquid precursor by a predetermined width (S123). For example, when it is detected that a state in which the acquired concentration value of the reaction gas in the processing gas is a value higher than the reference concentration value by 5 to 15% or more (i.e., a value of 105 to 115% or more of the reference concentration value) continues for 30 to 60 seconds or more, the control of S123 is performed. In this embodiment, when it is detected that a state in which the acquired concentration value of the reaction gas in the processing gas is a value higher than the reference concentration value by 10% or more (i.e., a value of 110% or more of the reference concentration value) continues for 30 seconds or more, the controller 121 performs control of S123.

[0101] In this embodiment, when the ratio of the concentration value of the reaction gas to the reference concentration value in the processing gas acquired at S121 is equal to or less than the first concentration ratio, at least one of the temperature control of the vaporization heater 103, the supply amount control of the carrier gas, and the supply amount control of the liquid precursor at S122 described above is performed, but the predetermined ratio may be individually set according to each control. In addition, the temperature control of the vaporization heater 103, the supply amount control of the carrier gas, and the supply amount control of the liquid precursor at S122 described above may be performed independently, and two or more of these controls may be performed simultaneously or at different timings. Likewise, the supply amount control of the carrier gas and the supply amount control of the liquid precursor at S123 described above may be performed independently, or these controls may be performed simultaneously or at different timings.

[0102] Furthermore, when the acquired concentration value of the reaction gas in the processing

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;
 - a liquid precursor introduction part configured to introduce the liquid precursor into the vaporization vessel;
 - a carrier gas introduction part configured to introduce the carrier gas into the vaporization vessel; and
 - a heater configured to heat the liquid precursor introduced into the vaporization vessel,
 - a carrier gas supply controller configured to control a supply amount of the carrier gas supplied to the vaporizer;
 - a liquid precursor supply controller configured to control a supply amount 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;
 - a processing gas temperature sensor configured to detect a temperature of the processing gas delivered from the vaporizer into the processing gas supply pipe;
 - 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; and
 - a controller configured to:
 - control the heater to adjust a temperature of the heater, based on the temperature of the processing gas detected by the processing gas temperature sensor;
 - acquire the gas concentration of the reaction gas detected by the gas

concentration sensor; and

control the liquid precursor supply controller to reduce the supply amount of the liquid precursor when it is determined that a state, in which a ratio of the gas concentration of the reaction gas to a predetermined reference concentration value is equal to or less than a predetermined ratio, continues for a predetermined period of time.

2. The apparatus of Claim 1, comprising a processing gas pressure sensor configured to detect a pressure of the processing gas in the processing gas supply pipe,

wherein the controller is configured to control the heater to adjust the temperature of the heater based on the pressure of the processing gas detected by the processing gas pressure sensor and the temperature of the processing gas detected by the processing gas temperature sensor.

3. The apparatus of Claim 1,

wherein the controller is configured to control the heater to adjust the temperature of the heater based on the gas concentration of the reaction gas detected by the gas concentration sensor and the temperature of the processing gas detected by the processing gas temperature sensor.

4. The apparatus of Claim 1, wherein the controller is configured to control the heater to adjust the temperature of the heater based on the temperature of the processing gas detected by the processing gas temperature sensor and control the carrier gas supply controller to adjust the supply amount of the carrier gas.

5. The apparatus of Claim 1, wherein, when the temperature of the processing gas detected by the processing gas temperature sensor is lower than a predetermined temperature, the controller is configured to control the heater to increase the temperature of the heater.

6. The apparatus of Claim 4, wherein, when the temperature of the processing gas detected by the processing gas temperature sensor is lower than a predetermined temperature, the

controller is configured to control the carrier gas supply controller to increase the supply amount of the carrier gas.

7. The apparatus of Claim 1, wherein, when the temperature of the processing gas detected by the processing gas temperature sensor is lower than a predetermined temperature, the controller is configured to control the liquid precursor supply controller to decrease the supply amount of the liquid precursor.

8. The apparatus of Claim 1, comprising a processing gas pressure sensor configured to detect a pressure of the processing gas in the processing gas supply pipe,
wherein the controller is configured to control the carrier gas supply controller to adjust the supply amount of the carrier gas, based on the pressure of the processing gas detected by the processing gas pressure sensor.

9. The apparatus of Claim 1, comprising a processing gas pressure sensor configured to detect a pressure of the processing gas in the processing gas supply pipe,
wherein the controller is configured to control the liquid precursor supply controller to adjust the supply amount of the liquid precursor, based on the pressure of the processing gas detected by the processing gas pressure sensor.

10. The apparatus of Claim 1,
wherein the controller is configured to control the carrier gas supply controller to adjust the supply amount of the carrier gas, based on the gas concentration of the reaction gas detected by the gas concentration sensor.

11. The apparatus of Claim 1, wherein the processing gas includes a hydrogen peroxide gas as the reaction gas.

12. 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 deliver a processing gas containing a reaction gas and a carrier gas, the reaction gas being generated by vaporizing a liquid precursor;
 - a processing gas supply pipe configured to introduce the processing gas delivered from the vaporizer into the process chamber;
 - a processing gas temperature sensor that detects a temperature of the processing gas delivered from the vaporizer into the processing gas supply pipe; 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 includes:
- loading the substrate into the process chamber;
 - generating the processing gas by supplying the liquid precursor and the carrier gas into the vaporizer and heating the liquid precursor by a heater to vaporize the liquid precursor;
 - introducing the processing gas generated in the vaporizer into the process chamber through the processing gas supply pipe;
 - adjusting a temperature of the heater based on the temperature of the processing gas detected by the processing gas temperature sensor;
 - acquiring the gas concentration of the reaction gas detected by the gas concentration sensor; and
 - reducing a supply amount of the liquid precursor supplied into the vaporizer when it is determined that a state, in which a ratio of the gas concentration of the reaction gas to a predetermined reference concentration value is equal to or less than a predetermined ratio, continues for a

predetermined period of time.

13. The method of Claim 12, wherein the substrate processing apparatus includes a processing gas pressure sensor configured to detect a pressure of the processing gas in the processing gas supply pipe,

wherein the temperature of the heater is adjusted based on the pressure of the processing gas detected by the processing gas pressure sensor and the temperature of the processing gas detected by the processing gas temperature sensor in the act of adjusting the temperature of the heater.

14. The method of Claim 12,

wherein the temperature of the heater is adjusted based on the gas concentration of the reaction gas detected by the gas concentration sensor and the temperature of the processing gas detected by the processing gas temperature sensor in the act of adjusting the temperature of the heater.

15. The method of Claim 12, wherein the temperature of the heater is adjusted and a supply amount of the carrier gas supplied into the vaporizer is adjusted based on the temperature of the processing gas detected by the processing gas temperature sensor in the act of adjusting the temperature of the heater.

16. The method of Claim 12, wherein the temperature of the heater is adjusted and the supply amount of the liquid precursor supplied into the vaporizer is adjusted based on the temperature of the processing gas detected by the processing gas temperature sensor in the act of adjusting the temperature of the heater.

17. A computer-readable recording medium storing a program that causes a computer to perform a predetermined process of processing a substrate by controlling a substrate processing

apparatus, the substrate processing apparatus including: a process chamber configured to accommodate the substrate; a vaporizer configured to deliver a processing gas containing a reaction gas and a carrier gas, the reaction gas being generated by vaporizing a liquid precursor; a processing gas supply pipe configured to introduce the processing gas delivered from the vaporizer into the process chamber; a processing gas temperature sensor that detects a temperature of the processing gas delivered from the vaporizer into the processing gas supply pipe; 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, and the predetermined process comprising:

loading the substrate into the process chamber;

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

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

adjusting a temperature of the heater based on the temperature of the processing gas detected by the processing gas temperature sensor;

acquiring the gas concentration of the reaction gas detected by the gas concentration sensor; and

reducing a supply amount of the liquid precursor supplied into the vaporizer when it is determined that a state in which a ratio of the gas concentration of the reaction gas to a predetermined reference concentration value is equal to or less than a predetermined ratio, continues for a predetermined period of time.