DESCRIPTION

Title of Invention

TEMPERATURE CONTROL SYSTEM

Technical Field

[0001] The present invention relates to a temperature control system for controlling a temperature of a heat medium used for a semiconductor manufacturing apparatus, such as an etching apparatus, a CVD apparatus, or a PVD apparatus.

Background Art

[0002] A semiconductor manufacturing apparatus (e.g., an etching apparatus, a CVD apparatus, or a PVD apparatus) for manufacturing semiconductor devices is configured to perform a manufacturing process while controlling a processing temperature. For example, in the etching apparatus, a processing temperature for a wafer is regulated by liquid as a temperature-regulated heat medium flowing through a flow passage formed in a susceptor that supports the wafer.

[0003] The heat medium to be supplied to the semiconductor manufacturing apparatus is cooled and heated in advance by a cooling device and a heating device. The cooled heat medium and the heated heat medium are mixed, so that a temperature-regulated heat medium is produced. The temperature-regulated heat medium passes through the semiconductor manufacturing apparatus to thereby regulate the processing temperature of the wafer in the semiconductor manufacturing apparatus.

[0004] However, since the cooled heat medium and the heated heat medium are mixed to produce the heat medium having a required temperature, there are following problems.

1. Because it is necessary to use the same heat medium for a heat medium cooled by the cooling device, a heat medium heated by the heating device, and a heat medium to be supplied to the semiconductor manufacturing apparatus, a large amount of a heat medium that can be stably used from a low temperature range to a high temperature range is required. Such a heat medium having a wide usable temperature range is very

expensive.

2. Because a balance between an amount of the heat medium on a cooling side and an amount of the heat medium on a heating side may be lost, an adjustment of the amount of the heat medium between a cooling system and a heating system is required.

[0005] Therefore, in order to solve such problems, as shown in FIG. 11, a temperature control system has been proposed, which includes a first circulation circuit 301 in which a first heat medium for cooling circulates, a second circulation circuit 302 in which a second heat medium for heating circulates, a third circulation circuit 303 in which a third heat medium supplied to a semiconductor manufacturing apparatus 200 circulates, a first heat exchanger 305 configured to exchange heat between the first heat medium and the third heat medium, and a second heat exchanger 306 configured to exchange heat between the second heat medium and the third heat medium.

[0006] The temperature control system includes a cooling device 307 configured to cool the first heat medium flowing through the first circulation circuit 301, a heating device 308 configured to heat the second heat medium flowing through the second circulation circuit 302, a first buffer tank 311 configured to retain the first heat medium, and a second buffer tank 312 configured to retain the second heat medium. The third circulation circuit 303 is coupled to the semiconductor manufacturing apparatus 200. The third heat medium circulates through the third circulation circuit 303 and the semiconductor manufacturing apparatus 200. A processing temperature in the semiconductor manufacturing apparatus 200 is regulated by the third heat medium. A temperature of the third heat medium is regulated by the first heat medium and the second heat medium in the first heat exchanger 305 and the second heat exchanger 306.

[0007] According to this temperature control system, the first circulation circuit 301, the second circulation circuit 302, and the third circulation circuit 303 can be independent closed circuits by providing the first heat exchanger 305 and the second heat exchanger 306. Therefore, a heat medium different from the first heat medium and the second heat medium can be used as the third heat medium having a wide usable temperature range,

and as a result, an amount of use of the third heat medium can be reduced.

Citation List

Patent Literature

[0008] Patent document 1: Japanese laid-open patent publication No. 2021-77086

Summary of Invention

Technical Problem

[0009] However, in the temperature control system shown in FIG. 11, the first heat exchanger 305 configured to exchange heat between the first heat medium and the third heat medium, and the second heat exchanger 306 configured to exchange heat between the second heat medium and the third heat medium are arranged in parallel. Therefore, the third circulation circuit 303 needs to be lengthened to couple these two heat exchangers 305 and 306, and as a result, there is a limit to reducing the amount of use of the third heat medium circulating in the third circulation circuit 303. In addition, since the third circulation circuit 303 is subjected to heat insulation processing, an installation space is required to be larger compared to a diameter of a pipe of the third circulation circuit 303. Furthermore, in the parallel arrangement, check valves 314 and 315 for preventing a backflow of the third heat medium that has passed through the first heat exchanger 305 and the second heat exchanger 306 are required. As a result, there is a problem that a cost of the temperature control system may increase.

[0010] Therefore, the present invention provides a temperature control system capable of reducing an amount of use of a third heat medium that exchanges heat with a first heat medium for cooling and a second heat medium for heating compared to a conventional amount of use of the third heat medium.

Solution to Problem

[0011] In an embodiment, there is provided a temperature control system for regulating a temperature of a semiconductor manufacturing apparatus, comprising: a first circulation circuit in which a first heat medium circulates; a second circulation circuit in which a second heat medium circulates, the second circulation circuit being independent of the

first circulation circuit; a third circulation circuit in which a third heat medium circulates, the third circulation circuit being independent of the first circulation circuit and the second circulation circuit; a cooling device configured to cool the first heat medium flowing through the first circulation circuit; a heating device configured to heat the second heat medium flowing through the second circulation circuit; a first heat exchanger configured to exchange heat between the first heat medium cooled by the cooling device and the third heat medium; a second heat exchanger configured to exchange heat between the second heat medium heated by the heating device and the third heat medium; a first bypass line coupled to the third circulation circuit and configured to bypass the first heat exchanger; and a second bypass line coupled to the third circulation circuit and configured to bypass the second heat exchanger, wherein the first heat exchanger and the second heat exchanger are coupled in series by the third circulation circuit.

[0012] Since the first heat exchanger and the second heat exchanger are coupled in series by the third circulation circuit, a length of the third circulation circuit can be shortened. The third heat medium has a wide usable temperature range and is chemically inactive. The third heat medium having such properties is generally more expensive than the first heat medium and the second heat medium. According to the present invention, since the third circulation circuit can be shortened, an amount of use of the third heat medium can be reduced.

Since these heat-medium circuits are subjected to heat insulation processing, installation spaces are required to be larger compared to diameters of pipes of the heat-medium circuits. However, according to the present invention, since the third circulation circuit can be shortened, a space occupied by the third circulation circuit can be reduced. Therefore, an installation space required for the temperature control system can be reduced.

[0013] In an embodiment, the temperature control system further comprises: a first heat storage section having a first heat storage material configured to store thermal energy of the first heat medium, wherein the first heat storage section is coupled to the first

circulation circuit, and is disposed downstream of the first heat exchanger in a flow direction of the first heat medium.

[0014] Since the first heat storage section can cool the first heat medium using the stored thermal energy, a thermal load on the cooling device can be leveled. When a sudden temperature change (i.e., a temporary temperature rise associated with an increase in a temperature of the third heat medium to be supplied to the first heat exchanger) occurs in the first heat medium, the temperature change can be mitigated. A temporary increase in the thermal load on the cooling device occurs when a process in the semiconductor manufacturing apparatus is switched. Since the first heat medium exchanges heat with the first heat storage section, a rapid temperature rise of the first heat medium entering the cooling device can be suppressed, and as a result, the temporary increase in the thermal load on the cooling device can be mitigated.

[0015] In an embodiment, the first heat storage section is coupled to the first circulation circuit and the third circulation circuit, the first heat storage section is disposed downstream of the first heat exchanger in the flow direction of the first heat medium, and is disposed upstream of the first heat exchanger in a flow direction of the third heat medium, and the first heat storage section is configured to exchange heat between the third heat medium before being delivered to the first heat exchanger and the first heat storage material.

[0016] The first heat storage section can cool the third heat medium before being delivered to the first heat exchanger using the stored thermal energy. Since the third heat medium is cooled by the first heat storage section and the first heat exchanger, a responsiveness of temperature regulation of the semiconductor manufacturing apparatus can be improved.

[0017] In an embodiment, the temperature control system further comprises: a second heat storage section having a second heat storage material configured to store thermal energy of the second heat medium, wherein the second heat storage section is coupled to the second circulation circuit, and is disposed downstream of the second heat exchanger

in a flow direction of the second heat medium.

[0018] Since the second heat storage section can heat the second heat medium using the stored thermal energy, a thermal load on the heating device can be leveled. When a sudden temperature change (i.e., a temporary temperature drop associated with a decrease in the temperature of the third heat medium to be supplied to the second heat exchanger) occurs in the second heat medium, the temperature change can be mitigated. A temporary increase in the thermal load on the heating device occurs when the process in the semiconductor manufacturing apparatus is switched. Since the second heat medium exchanges heat with the second heat storage section, a rapid temperature drop of the second heat medium entering the heating device can be suppressed, and as a result, the temporary increase in the thermal load on the heating device can be mitigated.

[0019] In an embodiment, the second heat storage section is coupled to the second circulation circuit and the third circulation circuit, the second heat storage section is disposed downstream of the second heat exchanger in the flow direction of the second heat medium, and is disposed upstream of the second heat exchanger in the flow direction of the third heat medium, and the second heat storage section is configured to exchange heat between the third heat medium before being delivered to the second heat exchanger and the second heat storage material.

[0020] The second heat storage section can heat the third heat medium before being delivered to the second heat exchanger using the stored thermal energy. Since the third heat medium is heated by the second heat storage section and the second heat exchanger, the responsiveness of temperature regulation of the semiconductor manufacturing apparatus can be improved.

[0021] In an embodiment, the first heat exchanger and the second heat exchanger comprise a plurality of first heat exchangers and a plurality of second heat exchangers, the plurality of first heat exchangers are coupled in parallel by the first circulation circuit, the plurality of second heat exchangers are coupled in parallel by the second circulation circuit, the third circulation circuit comprises a plurality of third circulation circuits, the

plurality of first heat exchangers and the plurality of second heat exchangers constitute a plurality of sets of first heat exchangers and second heat exchangers, the plurality of sets of first heat exchangers and second heat exchangers are coupled to the plurality of third circulation circuits, respectively, the first bypass line comprises a plurality of first bypass lines configured to bypass the plurality of first heat exchangers, and the second bypass line comprises a plurality of second bypass lines configured to bypass the plurality of second heat exchangers.

[0022] The first heat medium and the second heat medium are supplied to the plurality of first heat exchangers and the plurality of second heat exchangers, so that the number of components, such as the cooling device, the heating device, and pumps can be reduced.

Advantageous Effects of Invention

[0023] Since the first heat exchanger and the second heat exchanger are coupled in series by the third circulation circuit, the length of the third circulation circuit can be shortened. The third heat medium has the wide usable temperature range and is chemically inactive. The third heat medium having such properties is generally more expensive than the first heat medium and the second heat medium. According to the present invention, since the third circulation circuit can be shortened, the amount of use of the third heat medium can be reduced.

Brief Description of Drawings

[0024]

[FIG. 1] FIG. 1 is a schematic diagram showing an embodiment of a semiconductor manufacturing system including a temperature control system and a semiconductor manufacturing apparatus;

[FIG. 2] FIG. 2 is a schematic diagram showing another embodiment of the semiconductor manufacturing system including the temperature control system and the semiconductor manufacturing apparatus;

[FIG. 3] FIG. 3 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system and the

semiconductor manufacturing apparatus;

[FIG. 4] FIG. 4 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system and the semiconductor manufacturing apparatus;

[FIG. 5] FIG. 5 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system and the semiconductor manufacturing apparatus;

[FIG. 6] FIG. 6 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system and the semiconductor manufacturing apparatus;

[FIG. 7] FIG. 7 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system and the semiconductor manufacturing apparatus;

[FIG. 8] FIG. 8 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system and the semiconductor manufacturing apparatus;

[FIG. 9] FIG. 9 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system and the semiconductor manufacturing apparatus;

[FIG. 10] FIG. 10 is a schematic diagram showing an embodiment of the semiconductor manufacturing system including the temperature control system and a plurality of semiconductor manufacturing apparatuses; and

[FIG. 11] FIG. 11 is a schematic diagram showing a conventional temperature control system.

Description of Embodiments

[0025] Hereinafter, embodiments of the present invention will be described with reference to the drawings. FIG. 1 is a schematic diagram showing an embodiment of a semiconductor manufacturing system including a temperature control system 1 and a

semiconductor manufacturing apparatus 2. The temperature control system 1 is configured to supply a heat medium for regulating a temperature of the semiconductor manufacturing apparatus 2 (e.g., an etching apparatus, a CVD apparatus, or a PVD apparatus) to the semiconductor manufacturing apparatus 2.

[0026] The temperature control system 1 is configured to control the temperature of the heat medium used for the semiconductor manufacturing apparatus 2 by using a first heat medium, a second heat medium, and a third heat medium. The temperature control system 1 includes a first circulation circuit 11 in which the first heat medium circulates, a second circulation circuit 12 in which the second heat medium circulates, a third circulation circuit 13 in which the third heat medium circulates, a cooling device 7 configured to cool the first heat medium flowing through the first circulation circuit 11, and a heating device 8 configured to heat the second heat medium flowing through the second circulation circuit 12.

[0027] The cooling device 7 is coupled to the first circulation circuit 11. The heating device 8 is coupled to the second circulation circuit 12. The temperature control system 1 includes a first pump 14 coupled to the first circulation circuit 11. The first pump 14 circulates the first heat medium in the first circulation circuit 11. The temperature control system 1 includes a second pump 15 coupled to the second circulation circuit 12. The second pump 15 circulates the second heat medium in the second circulation circuit 12.

[0028] The third circulation circuit 13 is coupled to the semiconductor manufacturing apparatus 2, and the third heat medium circulates through the third circulation circuit 13 and the semiconductor manufacturing apparatus 2. A processing temperature in the semiconductor manufacturing apparatus 2 is regulated by the third heat medium. The temperature of the third heat medium is regulated by the first heat medium and the second heat medium, which will be described later.

[0029] The second circulation circuit 12 is independent of the first circulation circuit 11, and the third circulation circuit 13 is independent of the first circulation circuit 11 and the

second circulation circuit 12. Specifically, the first circulation circuit 11, the second circulation circuit 12, and the third circulation circuit 13 form closed circuits independent of each other, and the first heat medium, the second heat medium, and the third heat medium are not mixed.

[0030] Different heat media can be used as the first heat medium, the second heat medium, and the third heat medium. For example, a common brine is used as the first heat medium for cooling. Examples of the brine include ethylene glycol, propylene glycol, and calcium chloride. An example of the second heat medium for heating is silicone oil. An example of the third heat medium is a fluorine-based inert liquid. The third heat medium is an insulator that is chemically stable from a low temperature to a high temperature in order to directly regulate the processing temperature in the semiconductor manufacturing apparatus 2.

[0031] A usable lower limit temperature of the third heat medium is lower than usable lower limit temperatures of the first heat medium and the second heat medium. A usable upper limit temperature of the third heat medium is higher than usable upper limit temperatures of the first heat medium and the second heat medium. Specifically, a usable temperature range of the third heat medium is wider than usable temperature ranges of the first heat medium and the second heat medium. The usable temperature is a temperature at which a viscosity (fluidity) of the heat medium can be maintained and a phase of the heat medium does not change (does not boil and does not solidify).

[0032] The temperature control system 1 includes a first buffer tank 16 configured to retain the first heat medium, and a second buffer tank 17 configured to retain the second heat medium. The first buffer tank 16 is coupled to the first circulation circuit 11, and the second buffer tank 17 is coupled to the second circulation circuit 12. In one embodiment, the first buffer tank 16 and the second buffer tank 17 may not be provided.

[0033] The temperature control system 1 further includes a first heat exchanger 21 configured to exchange heat between the first heat medium cooled by the cooling device 7 and the third heat medium, and a second heat exchanger 22 configured to exchange heat

between the second heat medium heated by the heating device 8 and the third heat medium. The first heat exchanger 21 is coupled to the first circulation circuit 11 and the third circulation circuit 13. The first heat medium flowing through the first circulation circuit 11 and the third heat medium flowing through the third circulation circuit 13 exchange heat in the first heat exchanger 21. The second heat exchanger 22 is coupled to the second circulation circuit 12 and the third circulation circuit 13. The second heat medium flowing through the second circulation circuit 12 and the third heat medium flowing through the third circulation circuit 13 exchange heat in the second heat exchanger 22.

[0034] The first heat exchanger 21 and the second heat exchanger 22 are coupled in series by the third circulation circuit 13. In this embodiment, the first heat exchanger 21 is disposed downstream of the second heat exchanger 22 in a flow direction of the third heat medium. In one embodiment, the first heat exchanger 21 may be disposed upstream of the second heat exchanger 22 in the flow direction of the third heat medium. Since the first heat exchanger 21 and the second heat exchanger 22 are coupled in series, a length of the third circulation circuit 13 can be shortened. The third heat medium has a wide usable temperature range and is chemically inactive. The third heat medium having such properties is generally more expensive than the first heat medium and the second heat medium. According to this embodiment, since the third circulation circuit 13 can be shortened, an amount of use of the third heat medium can be reduced.

[0035] According to this embodiment, since the third circulation circuit 13 can be shortened, a space occupied by the third circulation circuit 13 can be reduced. Therefore, an installation space required for the temperature control system 1 can be reduced. Furthermore, check valves required in a parallel arrangement can be eliminated.

[0036] The first heat medium circulating in the first circulation circuit 11 is cooled to a predetermined target cooling temperature by the cooling device 7. Examples of the cooling device 7 include a vapor compression refrigeration machine, an absorption refrigeration machine, or the like. Types of the vapor compression refrigeration

machine include a turbo refrigeration machine, a screw refrigeration machine, a rotary refrigeration machine, a scroll refrigeration machine, etc., and these can be used. A configuration of the cooling device 7 is not particularly limited as long as the first heat medium can be cooled.

[0037] The second heat medium circulating in the second circulation circuit 12 is heated to a predetermined target heating temperature by the heating device 8. An example of the heating device 8 is an electric heater. A configuration of the heating device 8 is not particularly limited as long as the second heat medium can be heated.

[0038] The first heat exchanger 21 is configured to exchange heat between the first heat medium cooled by the cooling device 7 and the third heat medium before being delivered to the semiconductor manufacturing apparatus 2. The second heat exchanger 22 is configured to exchange heat between the second heat medium heated by the heating device 8 and the third heat medium before being delivered to the semiconductor manufacturing apparatus 2. The third heat medium is cooled by the first heat medium and is heated by the second heat medium. In the embodiment shown in FIG. 1, since the second heat exchanger 22 is disposed upstream of the first heat exchanger 21, the third heat medium is first heated by the second heat medium in the second heat exchanger 22, and is subsequently cooled by the first heat medium in the first heat exchanger 21.

[0039] The temperature of the third heat medium passing through the semiconductor manufacturing apparatus 2 and returning to the temperature control system 1 varies depending on a processing step in the semiconductor manufacturing apparatus 2. Thus, in order to bring the third heat medium to an appropriate temperature according to the processing step in the semiconductor manufacturing apparatus 2, a flow rate of the third heat medium passing through the first heat exchanger 21 and a flow rate of the third heat medium passing through the second heat exchanger 22 are changed as follows.

[0040] The temperature control system 1 includes a first bypass line 31 coupled to the third circulation circuit 13 and configured to bypass the first heat exchanger 21, a first control valve 34 coupled to the first bypass line 31 and the third circulation circuit 13, a

second bypass line 32 coupled to the third circulation circuit 13 and configured to bypass the second heat exchanger 22, a second control valve 35 coupled to the second bypass line 32 and the third circulation circuit 13, and an operation controller 38 configured to control operations of the first control valve 34 and the second control valve 35.

[0041] The first control valve 34 is configured to control a flow rate of the third heat medium flowing through the first heat exchanger 21 and a flow rate of the third heat medium flowing through the first bypass line 31. The flow rates of the third heat medium are controlled by the first control valve 34 within a range of 0 to 100%. For example, when the first control valve 34 controls the flow rate of the third heat medium flowing through the first heat exchanger 21 to 0% and controls the flow rate of the third heat medium flowing through the first bypass line 31 to 100%, the third heat medium flows through the first bypass line 31 but does not flow through the first heat exchanger 21. In this case, the third heat medium is not cooled by the first heat medium. In another example, when the first control valve 34 controls the flow rate of the third heat medium flowing through the first heat exchanger 21 to 50% and controls the flow rate of the third heat medium flowing through the first bypass line 31 to 50%, the third heat medium flows through both the first bypass line 31 and the first heat exchanger 21. In still another example, when the first control valve 34 controls the flow rate of the third heat medium flowing through the first heat exchanger 21 to 100% and controls the flow rate of the third heat medium flowing through the first bypass line 31 to 0%, the third heat medium flows through the first heat exchanger 21 but does not flow through the first bypass line 31.

[0042] In this manner, the first bypass line 31 and the first control valve 34 control the flow rate of the third heat medium flowing through the first heat exchanger 21, so that the temperature of the third heat medium delivered to the semiconductor manufacturing apparatus 2 can be regulated. In one example, when a target value of the processing temperature in the semiconductor manufacturing apparatus 2 is higher than the temperature of the third heat medium returned from the semiconductor manufacturing

apparatus 2, the first control valve 34 controls the flow rate of the third heat medium flowing through the first heat exchanger 21 to 0% and the flow rate of the third heat medium flowing through the first bypass line 31 to 100%.

[0043] In this embodiment, the first control valve 34 is a three-way valve. However, a configuration of the first control valve 34 is not limited to the three-way valve as long as the first control valve 34 can control the flow rates of the third heat medium flowing through the first heat exchanger 21 and the first bypass line 31. For example, the first control valve 34 may be a combination of two-way valves.

[0044] The second control valve 35 is configured to control a flow rate of the third heat medium flowing through the second heat exchanger 22 and a flow rate of the third heat medium flowing through the second bypass line 32. The flow rates of the third heat medium are controlled by the second control valve 35 within a range of 0 to 100%. For example, when the second control valve 35 controls the flow rate of the third heat medium flowing through the second heat exchanger 22 to 0% and controls the flow rate of the third heat medium flowing through the second bypass line 32 to 100%, the third heat medium flows through the second bypass line 32 but does not flow through the second heat exchanger 22. In this case, the third heat medium is not heated by the second heat medium. In another example, when the second control valve 35 controls the flow rate of the third heat medium flowing through the second heat exchanger 22 to 50% and controls the flow rate of the third heat medium flowing through the second bypass line 32 to 50%, the third heat medium flows through both the second bypass line 32 and the second heat exchanger 22. In still another example, when the second control valve 35 controls the flow rate of the third heat medium flowing through the second heat exchanger 22 to 100% and controls the flow rate of the third heat medium flowing through the second bypass line 32 to 0%, the third heat medium flows through the second heat exchanger 22 but does not flow through the second bypass line 32.

[0045] In this manner, the second bypass line 32 and the second control valve 35 control the flow rate of the third heat medium flowing through the second heat exchanger 22, so

that the temperature of the third heat medium delivered to the semiconductor manufacturing apparatus 2 can be regulated. In one example, when a target value of the processing temperature in the semiconductor manufacturing apparatus 2 is lower than the temperature of the third heat medium returned from the semiconductor manufacturing apparatus 2, the second control valve 35 controls the flow rate of the third heat medium flowing through the second heat exchanger 22 to 0% and the flow rate of the third heat medium flowing through the second bypass line 32 to 100%.

[0046] In this embodiment, the second control valve 35 is a three-way valve. However, a configuration of the second control valve 35 is not limited to the three-way valve as long as the second control valve 35 can control the flow rates of the third heat medium flowing through the second heat exchanger 22 and the second bypass line 32. For example, the second control valve 35 may be a combination of two-way valves.

[0047] The operation controller 38 includes at least one computer. The operation controller 38 includes a memory 38a storing programs therein, and an arithmetic device 38b configured to perform arithmetic operations according to instructions contained in the programs. The memory 38a includes a main memory, such as a random access memory (RAM), and an auxiliary memory, such as a hard disk drive (HDD) or a solid state drive (SSD). Examples of the arithmetic device 38b include a CPU (Central Processing Unit) and a GPU (Graphic Processing Unit). However, the specific configurations of the operation controller 38 are not limited to these examples.

[0048] FIG. 2 is a schematic diagram showing another embodiment of the semiconductor manufacturing system including the temperature control system 1 and the semiconductor manufacturing apparatus 2. Configurations and operations of this embodiment, which will not be particularly described, are the same as those of the above-described embodiment described with reference to FIG. 1, and duplicated descriptions will be omitted. As shown in FIG. 2, the temperature control system 1 of this embodiment further includes a first heat storage section 41 having a first heat storage material 44 configured to store thermal energy of the first heat medium. The first heat

storage section 41 is coupled to the first circulation circuit 11, and is disposed downstream of the first heat exchanger 21 in a flow direction of the first heat medium.

[0049] When a thermal load on the cooling device 7 is low, i.e., when the target value of the processing temperature in the semiconductor manufacturing apparatus 2 is high, the first heat storage section 41 stores the thermal energy possessed by the first heat medium. When the thermal load on the cooling device 7 is high, i.e., when the target value of the processing temperature in the semiconductor manufacturing apparatus 2 is low, the first heat storage section 41 transfers the stored thermal energy to the first heat medium. In this manner, the first heat storage section 41 can cool the first heat medium using the stored thermal energy, so that the thermal load on the cooling device 7 can be leveled. In addition, the first heat storage section 41 is provided, so that a capacity of the first buffer tank 16 for the first heat medium can be reduced.

[0050] In one embodiment, the first heat storage material 44 of the first heat storage section 41 is made of a medium that changes from a liquid phase to a solid phase at or near the target cooling temperature in the cooling device 7. The first heat storage material 44 having such properties can store latent heat associated with a phase change as thermal energy. In another embodiment, the first heat storage material 44 may be made of a solid or a liquid that does not change phase.

[0051] FIG. 3 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system 1 and the semiconductor manufacturing apparatus 2. Configurations and operations of this embodiment, which will not be particularly described, are the same as those of the above-described embodiment described with reference to FIG. 2, and duplicated descriptions will be omitted.

[0052] As shown in FIG. 3, the first heat storage section 41 is coupled to the first circulation circuit 11 and the third circulation circuit 13. The first heat storage section 41 is disposed downstream of the first heat exchanger 21 in the flow direction of the first heat medium, and is disposed upstream of the first heat exchanger 21 in the flow direction

of the third heat medium. The first heat storage section 41 is configured to exchange heat between the third heat medium before being delivered to the first heat exchanger 21 and the first heat storage material 44.

[0053] The first heat storage section 41 can cool the third heat medium before being delivered to the first heat exchanger 21 using the stored thermal energy. Since the third heat medium is cooled by the first heat storage section 41 and the first heat exchanger 21, a responsiveness of temperature regulation of the semiconductor manufacturing apparatus 2 can be improved.

[0054] FIG. 4 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system 1 and the semiconductor manufacturing apparatus 2. Configurations and operations of this embodiment, which will not be particularly described, are the same as those of the above-described embodiment described with reference to FIG. 2, and duplicated descriptions will be omitted. As shown in FIG. 4, the temperature control system 1 of this embodiment further includes a second heat storage section 42 having a second heat storage material 45 configured to store thermal energy of the second heat medium. The second heat storage section 42 is coupled to the second circulation circuit 12, and is disposed downstream of the second heat exchanger 22 in a flow direction of the second heat medium.

[0055] When the thermal load on the heating device 8 is low, i.e., when the target value of the processing temperature in the semiconductor manufacturing apparatus 2 is low, the second heat storage section 42 stores the thermal energy possessed by the second heat medium. When the thermal load on the heating device 8 is high, i.e., when the target value of the processing temperature in the semiconductor manufacturing apparatus 2 is high, the second heat storage section 42 transfers the stored thermal energy to the second heat medium. In this manner, the second heat storage section 42 can heat the second heat medium using the stored thermal energy, so that the thermal load on the heating device 8 can be leveled. In addition, the second heat storage section 42 is provided, so

that a capacity of the second buffer tank 17 for the second heat medium can be reduced.

[0056] In one embodiment, the second heat storage material 45 of the second heat storage section 42 is made of a medium that changes from a solid phase to a liquid phase at the target heating temperature in the heating device 8. The second heat storage material 45 having such properties can store latent heat associated with a phase change to a liquid phase as thermal energy. In another embodiment, the second heat storage material 45 may be made of a solid or a liquid that does not change phase.

[0057] In one embodiment, as shown in FIG. 5, both the first heat storage section 41 and the second heat storage section 42 may be provided.

[0058] FIG. 6 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system 1 and the semiconductor manufacturing apparatus 2. Configurations and operations of this embodiment, which will not be particularly described, are the same as those of the above-described embodiment described with reference to FIG. 3, and duplicated descriptions will be omitted.

[0059] As shown in FIG. 6, the second heat storage section 42 is coupled to the second circulation circuit 12 and the third circulation circuit 13. The second heat storage section 42 is disposed downstream of the second heat exchanger 22 in the flow direction of the second heat medium, and is disposed upstream of the second heat exchanger 22 in the flow direction of the third heat medium. The second heat storage section 42 is configured to exchange heat between the third heat medium before being delivered to the second heat exchanger 22 and the second heat storage material 45.

[0060] The second heat storage section 42 can heat the third heat medium before being delivered to the second heat exchanger 22 using the stored thermal energy. Since the third heat medium is heated by the second heat storage section 42 and the second heat exchanger 22, the responsiveness of temperature regulation of the semiconductor manufacturing apparatus 2 can be improved.

[0061] In one embodiment, as shown in FIG. 7, both the first heat storage section 41 and

the second heat storage section 42 may be provided.

[0062] FIG. 8 is a schematic diagram showing still another embodiment of the semiconductor manufacturing system including the temperature control system 1 and the semiconductor manufacturing apparatus 2. Configurations and operations of this embodiment, which will not be particularly described, are the same as those of the above-described embodiment described with reference to FIG. 1, and duplicated descriptions will be omitted. In this embodiment, the cooling device that cools the first heat medium is integrally formed with the first heat exchanger that exchanges heat between the first heat medium and the third heat medium. More specifically, the cooling device and the first heat exchanger constitute one refrigeration cycle.

[0063] As shown in FIG. 8, a compressor 51, a condenser 52 as the cooling device, and an evaporator 53 as the first heat exchanger are coupled to the first circulation circuit 11. The first heat medium circulates through the compressor 51, the condenser 52, and the evaporator 53. Refrigerant vapor of the first heat medium is compressed by the compressor 51. The compressed refrigerant vapor is delivered to the condenser 52 as the cooling device through the first circulation circuit 11, and is condensed by the condenser 52 to turn to refrigerant liquid. The refrigerant liquid is delivered to the evaporator 53 as the first heat exchanger through the first circulation circuit 11, and evaporates to turn to refrigerant vapor by removing heat from the third heat medium. The refrigerant vapor is delivered to the compressor 51 through the first circulation circuit 11, and is compressed by the compressor 51.

[0064] In this manner, the first heat medium can cool the third heat medium while circulating through the compressor 51, the condenser 52, and the evaporator 53 constituting the refrigeration cycle. In this embodiment, the first buffer tank 16 and the first pump 14 are not provided. According to this embodiment, the configurations of the cooling side can be simplified.

[0065] In the embodiments shown in FIGS. 1 to 8, the first heat exchanger 21 and the second heat exchanger 22 are coupled in series by the third circulation circuit 13, and the

first heat exchanger 21 is disposed downstream of the second heat exchanger 22 in the flow direction of the third heat medium. In one embodiment, as shown in FIG. 9, the first heat exchanger 21 may be disposed upstream of the second heat exchanger 22 in the flow direction of the third heat medium. The configuration shown in FIG. 9 is applicable to the embodiments described with reference to FIGS. 1 to 8.

[0066] FIG. 10 is a schematic diagram showing another embodiment of the semiconductor manufacturing system including the temperature control system 1 and a plurality of semiconductor manufacturing apparatuses 2. The temperature control system 1 is the temperature control system 1 of the embodiment described with reference to FIG. 1, and duplicated descriptions will be omitted. In one embodiment, the temperature control system 1 may be the temperature control system 1 of any of the embodiments described with reference to FIGS. 2 to 9.

[0067] As shown in FIG. 10, the temperature control system 1 includes a plurality of first heat exchangers 21, a plurality of second heat exchangers 22, and a plurality of third circulation circuits 13. The plurality of first heat exchangers 21 are coupled in parallel by the first circulation circuit 11, and the plurality of second heat exchangers 22 are coupled in parallel by the second circulation circuit 12. The plurality of first heat exchangers 21 and the plurality of second heat exchangers 22 constitute a plurality of sets G1, G2, and G3 of first heat exchangers 21 and second heat exchangers 22. The plurality of sets G1, G2, and G3 of first heat exchangers 21 and second heat exchangers 22 are coupled to the plurality of third circulation circuits 13, respectively.

[0068] The plurality of sets G1, G2, and G3 of first heat exchangers 21 and second heat exchangers 22 are coupled to the plurality of semiconductor manufacturing apparatuses 2 by the plurality of third circulation circuits 13. Each set of the first heat exchanger 21 and the second heat exchanger 22 is arranged in series by each third circulation circuit 13. In this embodiment, each of the first heat exchangers 21 is disposed downstream of each of the second heat exchangers 22 in the flow direction of the third heat medium. In one embodiment, each of the first heat exchangers 21 may be disposed upstream of each of

the second heat exchangers 22 in the flow direction of the third heat medium.

[0069] The temperature control system 1 includes a plurality of first bypass lines 31 configured to bypass the plurality of first heat exchangers 21, a plurality of second bypass lines 32 configured to bypass the plurality of second heat exchangers 22, a plurality of first control valves 34 coupled to the plurality of first bypass lines 31 and the plurality of third circulation circuits 13, a plurality of second control valves 35 coupled to the plurality of second bypass lines 32, and an operation controller 38 configured to control operations of the plurality of first control valves 34 and the plurality of second control valves 35.

[0070] Processing temperatures in the plurality of semiconductor manufacturing apparatuses 2 are independently controlled by the third heat medium temperature-regulated by the plurality of sets G1, G2, and G3 of first heat exchangers 21 and second heat exchangers 22.

[0071] The previous description of embodiments is provided to enable a person skilled in the art to make and use the present invention. Moreover, various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles and specific examples defined herein may be applied to other embodiments. Therefore, the present invention is not intended to be limited to the embodiments described herein but is to be accorded the widest scope as defined by limitation of the claims.

Industrial Applicability

[0072] The present invention is applicable to a temperature control system for controlling a temperature of a heat medium used for a semiconductor manufacturing apparatus, such as an etching apparatus, a CVD apparatus, or a PVD apparatus.

Reference Signs List

[0073] 1 temperature control system

2 semiconductor manufacturing apparatus

7 cooling device

8 heating device

11 first circulation circuit

12 second circulation circuit

13 third circulation circuit

14 first pump

15 second pump

16 first buffer tank

17 second buffer tank

21 first heat exchanger

22 second heat exchanger

31 first bypass line

32 second bypass line

34 first control valve

35 second control valve

38 operation controller

41 first heat storage section

42 second heat storage section

44 first heat storage material

45 second heat storage material

51 compressor

52 condenser

53 evaporator

CLAIMS

[Claim 1] A temperature control system for regulating a temperature of a semiconductor manufacturing apparatus, comprising:

a first circulation circuit in which a first heat medium circulates;

a second circulation circuit in which a second heat medium circulates, the second circulation circuit being independent of the first circulation circuit;

a third circulation circuit in which a third heat medium circulates, the third circulation circuit being independent of the first circulation circuit and the second circulation circuit;

a cooling device configured to cool the first heat medium flowing through the first circulation circuit;

a heating device configured to heat the second heat medium flowing through the second circulation circuit;

a first heat exchanger configured to exchange heat between the first heat medium cooled by the cooling device and the third heat medium;

a second heat exchanger configured to exchange heat between the second heat medium heated by the heating device and the third heat medium;

a first bypass line coupled to the third circulation circuit and configured to bypass the first heat exchanger; and

a second bypass line coupled to the third circulation circuit and configured to bypass the second heat exchanger,

wherein the first heat exchanger and the second heat exchanger are coupled in series by the third circulation circuit.

[Claim 2] The temperature control system according to claim 1, further comprising:

a first heat storage section having a first heat storage material configured to store thermal energy of the first heat medium,

wherein the first heat storage section is coupled to the first circulation circuit, and is disposed downstream of the first heat exchanger in a flow direction of the first heat medium.

[Claim 3] The temperature control system according to claim 2, wherein

the first heat storage section is coupled to the first circulation circuit and the third circulation circuit,

the first heat storage section is disposed downstream of the first heat exchanger in the flow direction of the first heat medium, and is disposed upstream of the first heat exchanger in a flow direction of the third heat medium, and

the first heat storage section is configured to exchange heat between the third heat medium before being delivered to the first heat exchanger and the first heat storage material.

[Claim 4] The temperature control system according to claim 1, further comprising:

a second heat storage section having a second heat storage material configured to store thermal energy of the second heat medium,

wherein the second heat storage section is coupled to the second circulation circuit, and is disposed downstream of the second heat exchanger in a flow direction of the second heat medium.

[Claim 5] The temperature control system according to claim 4, wherein

the second heat storage section is coupled to the second circulation circuit and the third circulation circuit,

the second heat storage section is disposed downstream of the second heat exchanger in the flow direction of the second heat medium, and is disposed upstream of the second heat exchanger in a flow direction of the third heat medium, and

the second heat storage section is configured to exchange heat between the third heat medium before being delivered to the second heat exchanger and the second heat storage material.

[Claim 6] The temperature control system according to claim 1, wherein

the first heat exchanger and the second heat exchanger comprise a plurality of first heat exchangers and a plurality of second heat exchangers,

the plurality of first heat exchangers are coupled in parallel by the first circulation circuit,

the plurality of second heat exchangers are coupled in parallel by the second circulation circuit,

the third circulation circuit comprises a plurality of third circulation circuits,

the plurality of first heat exchangers and the plurality of second heat exchangers constitute a plurality of sets of first heat exchangers and second heat exchangers,

the plurality of sets of first heat exchangers and second heat exchangers are coupled to the plurality of third circulation circuits, respectively,

the first bypass line comprises a plurality of first bypass lines configured to bypass the plurality of first heat exchangers, and

the second bypass line comprises a plurality of second bypass lines configured to bypass the plurality of second heat exchangers.