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 for use in a semiconductor manufacturing apparatus, such as an etching apparatus, a CVD apparatus, and a PVD apparatus.

Background Art

[0002] A semiconductor manufacturing apparatus (for example, an etching apparatus, a CVD apparatus, and a PVD apparatus) for manufacturing a semiconductor device is configured to perform a manufacturing process while controlling a processing temperature. For example, in the etching apparatus, a processing temperature of a wafer is regulated by causing a liquid as a temperature-regulated heat medium to flow through a flow path formed in a susceptor supporting the wafer.

[0003] A temperature of the heat medium supplied to the semiconductor manufacturing apparatus is regulated directly or indirectly by a cooling device and a heating device. For example, a temperature-regulated heat medium is generated by mixing a heat medium cooled by the cooling device and a heat medium heated by the heating device. Then, a processing temperature in the semiconductor manufacturing apparatus is regulated by the heat medium supplied to the semiconductor manufacturing apparatus. In another example, as shown in Patent document 1, a first heat medium and a second heat medium are respectively cooled and heated by the cooling device and the heating device, a temperature of a third heat medium is regulated by heat exchange between the cooled first heat medium and heated second heat medium and the third heat medium, so that a processing temperature in the semiconductor manufacturing apparatus is regulated by the third heat medium supplied to the semiconductor manufacturing apparatus.

Citation List

Patent Literature

[0004] Patent document 1: Japanese laid-open patent publication No. 2021-77086

Patent document 2: Japanese laid-open patent publication No. 2016-162794

Summary of Invention

Technical Problem

[0005] During processing of a wafer in the semiconductor manufacturing apparatus, a target processing temperature for the wafer changes depending on a processing step. For example, when the target processing temperature in the semiconductor manufacturing apparatus decreases during the processing of the wafer, it is necessary to rapidly decrease the temperature of the heat medium to be supplied to the semiconductor manufacturing apparatus, and as a result, a thermal load on the cooling device temporarily increases. Similarly, when the target processing temperature in the semiconductor manufacturing apparatus increases during the processing of the wafer, it is necessary to rapidly increase the temperature of the heat medium to be supplied to the semiconductor manufacturing apparatus, and as a result, a thermal load on the heating device temporarily increases.

[0006] However, if a cooling capacity of the cooling device and a heating capacity of the heating device are increased in preparation for a temporary load fluctuation, disadvantages, such as an increase in size and an increase in cost of the cooling device and the heating device, arise.

[0007] Therefore, the present invention provides a temperature control system capable of rapidly responding to a change in a target processing temperature in a semiconductor manufacturing apparatus without changing a rated capacity of a cooling device or a heating device.

Solution to Problem

[0008] In an embodiment, there is provided a temperature control system configured to regulate a temperature of a semiconductor manufacturing apparatus, comprising: a first circulation circuit configured to circulate a first heat medium; a second circulation circuit which is independent of the first circulation circuit and configured to circulate a second

heat medium; a plurality of third circulation circuits which are independent of the first circulation circuit and the second circulation circuit and configured to circulate a third heat medium; 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 plurality of first heat exchangers configured to perform heat exchange between the first heat medium cooled by the cooling device and the third heat medium circulating through the plurality of third circulation circuits; a plurality of second heat exchangers configured to perform heat exchange between the second heat medium heated by the heating device and the third heat medium circulating through the plurality of third circulation circuits; a plurality of first variable flow-rate devices coupled to the plurality of first heat exchangers in series, respectively, by the first circulation circuit; and an operation controller configured to control operations of the plurality of first variable flow-rate devices, wherein 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 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, and the operation controller is configured to, when a cooling thermal load on the third heat medium flowing through one of the plurality of third circulation circuits exceeds a cooling load threshold, instruct the first variable flow-rate device corresponding to the first heat exchanger coupled to that third circulation circuit to increase a flow rate of the first heat medium from a rated flow rate to an excess flow rate.

[0009] According to the present invention, increasing the flow rate of the first heat medium sent to the first heat exchanger coupled to the third circulation circuit through which the third heat medium having an increased cooling thermal load flows can temporarily increase a cooling capacity of the corresponding first heat exchanger. An increase in the cooling thermal load usually occurs temporarily, and thus, the cooling

thermal load does not increase simultaneously in all of the plurality of third circulation circuits. Therefore, even if a temporary increase in the cooling thermal load occurs, the cooling device can process a total cooling thermal load within its rated cooling capacity.

[0010] In an embodiment, the temperature control system further comprises a plurality of first heat-medium outlet temperature measuring devices configured to measure cooling thermal loads on the third heat medium flowing through the plurality of third circulation circuits, wherein the plurality of first heat-medium outlet temperature measuring devices are coupled to the first circulation circuit and are located downstream of the plurality of first heat exchangers, the plurality of first heat-medium outlet temperature measuring devices are each configured to measure temperature of the first heat medium that has passed through the plurality of first heat exchangers, and the operation controller is configured to, when the temperature of the first heat medium that has passed through the first heat exchanger coupled to one of the plurality of third circulation circuits exceeds a cooling temperature threshold, instruct the first variable flow-rate device corresponding to the first heat exchanger coupled to that third circulation circuit to increase the flow rate of the first heat medium from the rated flow rate to the excess flow rate.

[0011] The temperature of the first heat medium, measured by the first heat-medium outlet temperature measuring device, reflects the cooling thermal load on the third heat medium flowing through the corresponding third circulation circuit. Therefore, the operation controller can temporarily increase the flow rate of the first heat medium based on the measured value of the temperature of the first heat medium. The determination of the increase in the cooling thermal load may be based on an external signal, a signal from the third circulation circuit side (a temperature or a signal from a control device on the third circulation circuit side), or the like, other than the temperature of the first heat medium.

[0012] In an embodiment, the operation controller is configured to, when a predetermined first flow-rate increase time has elapsed since the flow rate of the first heat medium is increased to the excess flow rate, instruct the corresponding first variable flow-rate device to decrease the flow rate of the first heat medium to the rated flow rate.

[0013] The increase in the cooling thermal load on the third heat medium flowing through the third circulation circuit is temporary. Therefore, decreasing the flow rate of the first heat medium to the rated flow rate after the predetermined first flow-rate increase time has elapsed can suppress an increase in power of the entire temperature control system. A condition for terminating the excess flow rate state may be the temperature of the first heat medium, an external signal, or a signal from the third circulation circuit side (a temperature or a signal from the control device on the third circulation circuit side) other than the time.

[0014] In an embodiment, the plurality of first variable flow-rate devices comprise a plurality of first variable speed pumps coupled to the plurality of first heat exchangers in series, respectively, by the first circulation circuit, and the operation controller is configured to individually control rotational speeds of the plurality of first variable speed pumps.

[0015] According to the present invention, the operation controller increases the rotational speed of the first variable speed pump to thereby increase the flow rate of the first heat medium sent to the first heat exchanger coupled to the third circulation circuit through which the third heat medium having the increased cooling thermal load flows, and can therefore temporarily increase the cooling capacity of the corresponding first heat exchanger.

[0016] In an embodiment, the temperature control system further comprises a plurality of second variable flow-rate devices coupled to the plurality of second heat exchangers in series, respectively, by the second circulation circuit, wherein the operation controller is configured to, when a heating thermal load on the third heat medium flowing through one of the plurality of third circulation circuits exceeds a heating load threshold, instruct the second variable flow-rate device corresponding to the second heat exchanger coupled to that third circulation circuit to increase a flow rate of the second heat medium from a rated flow rate to an excess flow rate.

[0017] According to the present invention, increasing the flow rate of the second heat medium sent to the second heat exchanger coupled to the third circulation circuit through which the third heat medium having an increased heating thermal load flows can

temporarily increase a heating capacity of the corresponding second heat exchanger. An increase in the heating thermal load usually occurs temporarily, and thus, the heating thermal load does not increase simultaneously in all of the plurality of third circulation circuits. Therefore, even if a temporary increase in the heating thermal load occurs, the heating device can process a total heating thermal load within its rated heating capacity.

[0018] In an embodiment, the plurality of second variable flow-rate devices comprise a plurality of second variable speed pumps coupled to the plurality of second heat exchangers in series, respectively, by the second circulation circuit, and the operation controller is configured to individually control rotational speeds of the plurality of second variable speed pumps.

[0019] According to the present invention, the operation controller increases the rotational speed of the second variable speed pump to thereby increase the flow rate of the second heat medium sent to the second heat exchanger coupled to the third circulation circuit through which the third heat medium having the increased heating thermal load flows, and can therefore temporarily increase the heating capacity of the corresponding second heat exchanger.

[0020] In an embodiment, there is provided a temperature control system configured to regulate a temperature of a semiconductor manufacturing apparatus, comprising: a first circulation circuit configured to circulate a first heat medium; a second circulation circuit which is independent of the first circulation circuit and configured to circulate a second heat medium; a plurality of third circulation circuits which are independent of the first circulation circuit and the second circulation circuit and configured to circulate a third heat medium; 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 plurality of first heat exchangers configured to perform heat exchange between the first heat medium cooled by the cooling device and the third heat medium circulating through the plurality of third circulation circuits; a plurality of second heat exchangers configured to perform heat exchange between the second heat

medium heated by the heating device and the third heat medium circulating through the plurality of third circulation circuits; a plurality of second variable flow-rate devices coupled to the plurality of second heat exchangers in series, respectively, by the second circulation circuit; and an operation controller configured to control operations of the plurality of second variable flow-rate devices, wherein 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 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, and the operation controller is configured to, when a heating thermal load on the third heat medium flowing through one of the plurality of third circulation circuits exceeds a heating load threshold, instruct the second variable flow-rate device corresponding to the second heat exchanger coupled to that third circulation circuit to increase a flow rate of the second heat medium from a rated flow rate to an excess flow rate.

[0021] According to the present invention, increasing the flow rate of the second heat medium sent to the second heat exchanger coupled to the third circulation circuit through which the third heat medium having an increased heating thermal load flows can temporarily increase a heating capacity of the corresponding second heat exchanger. An increase in the heating thermal load usually occurs temporarily, and thus, the heating thermal load does not increase simultaneously in all of the plurality of third circulation circuits. Therefore, even if a temporary increase in the heating thermal load occurs, the heating device can process a total heating thermal load within its rated heating capacity.

[0022] In an embodiment, the temperature control system further comprises a plurality of second heat-medium outlet temperature measuring devices configured to measure heating thermal loads on the third heat medium flowing through the plurality of third circulation circuits, wherein the plurality of second heat-medium outlet temperature measuring devices are coupled to the second circulation circuit and are located downstream of the plurality of

second heat exchangers, the plurality of second heat-medium outlet temperature measuring devices are each configured to measure temperature of the second heat medium that has passed through the plurality of second heat exchangers, and the operation controller is configured to, when the temperature of the second heat medium that has passed through the second heat exchanger coupled to one of the plurality of third circulation circuits falls below a heating temperature threshold, instruct the second variable flow-rate device corresponding to the second heat exchanger coupled to that third circulation circuit to increase the flow rate of the second heat medium from the rated flow rate to the excess flow rate.

[0023] The temperature of the second heat medium, measured by the second heat-medium outlet temperature measuring device, reflects the heating thermal load on the third heat medium flowing through the corresponding third circulation circuit. Therefore, the operation controller can temporarily increase the flow rate of the second heat medium based on the measured value of the temperature of the second heat medium. The determination of the increase in the heating thermal load may be based on an external signal, a signal from the third circulation circuit side (a temperature or a signal from a control device on the third circulation circuit side), or the like, other than the temperature of the second heat medium.

[0024] In an embodiment, the operation controller is configured to, when a predetermined second flow-rate increase time has elapsed since the flow rate of the second heat medium is increased to the excess flow rate, instruct the corresponding second variable flow-rate device to decrease the flow rate of the second heat medium to the rated flow rate.

[0025] The increase in the heating thermal load on the third heat medium flowing through the third circulation circuit is temporary. Therefore, decreasing the flow rate of the second heat medium to the rated flow rate after the predetermined second flow-rate increase time has elapsed can suppress an increase in power of the entire temperature control system. A condition for terminating the excess flow rate state may be the temperature of the second heat medium, an external signal, or a signal from the third circulation circuit side (a temperature or a signal from the control device on the third circulation circuit side) other

than the time.

[0026] In an embodiment, the plurality of second variable flow-rate devices comprise a plurality of second variable speed pumps coupled to the plurality of second heat exchangers in series, respectively, by the second circulation circuit, and the operation controller is configured to individually control rotational speeds of the plurality of second variable speed pumps.

[0027] According to the present invention, the operation controller increases the rotational speed of the second variable speed pump to thereby increase the flow rate of the second heat medium sent to the second heat exchanger coupled to the third circulation circuit through which the third heat medium having the increased heating thermal load flows, and can therefore temporarily increase the heating capacity of the corresponding second heat exchanger.

[0028] In an embodiment, the temperature control system further comprises a plurality of first variable flow-rate devices coupled to the plurality of first heat exchangers in series, respectively, by the first circulation circuit, wherein the operation controller is configured to, when a cooling thermal load on the third heat medium flowing through one of the plurality of third circulation circuits exceeds a cooling load threshold, instruct the first variable flow-rate device corresponding to the first heat exchanger coupled to that third circulation circuit to increase a flow rate of the first heat medium from a rated flow rate to an excess flow rate.

[0029] According to the present invention, increasing the flow rate of the first heat medium sent to the first heat exchanger coupled to the third circulation circuit through which the third heat medium having an increased cooling thermal load flows can temporarily increase a cooling capacity of the corresponding first heat exchanger. An increase in the cooling thermal load usually occurs temporarily, and thus, the cooling thermal load does not increase simultaneously in all of the plurality of third circulation circuits. Therefore, even if a temporary increase in the cooling thermal load occurs, the cooling device can process a total cooling thermal load within its rated cooling capacity.

[0030] In an embodiment, the plurality of first variable flow-rate devices comprise a plurality of first variable speed pumps coupled to the plurality of first heat exchangers in series, respectively, by the first circulation circuit, and the operation controller is configured to individually control rotational speeds of the plurality of first variable speed pumps.

[0031] According to the present invention, the operation controller increases the rotational speed of the first variable speed pump to thereby increase the flow rate of the first heat medium sent to the first heat exchanger coupled to the third circulation circuit through which the third heat medium having the increased cooling thermal load flows, and can therefore temporarily increase the cooling capacity of the corresponding first heat exchanger.

Advantageous Effects of Invention

[0032] According to the present invention, even if a temporary increase in thermal load occurs, the cooling device or the heating device can process a total thermal load within its rated capacity.

Brief Description of Drawings

[0033]

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

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

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

[FIG. 4] FIG. 4 is a schematic diagram showing yet another embodiment of a semiconductor manufacturing system including a temperature control system and a plurality of semiconductor manufacturing apparatuses.

[FIG. 5] FIG. 5 is a schematic diagram showing yet another embodiment of a semiconductor manufacturing system including a temperature control system and a plurality of semiconductor manufacturing apparatuses.

[FIG. 6] FIG. 6 is a schematic diagram showing yet another embodiment of a semiconductor manufacturing system including a temperature control system and a plurality of semiconductor manufacturing apparatuses.

[FIG. 7] FIG. 7 is a schematic diagram showing yet another embodiment of a semiconductor manufacturing system including a temperature control system and a plurality of semiconductor manufacturing apparatuses.

[FIG. 8] FIG. 8 is a schematic diagram showing yet another embodiment of a semiconductor manufacturing system including a temperature control system and a plurality of semiconductor manufacturing apparatuses.

Description of Embodiments

[0034] 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 plurality of semiconductor manufacturing apparatuses 2. The temperature control system 1 is configured to supply, to the plurality of semiconductor manufacturing apparatuses 2, a heat medium for regulating the temperature of the plurality of semiconductor manufacturing apparatuses 2 (for example, an etching apparatus, a CVD apparatus, a PVD apparatus, etc.).

[0035] The temperature control system 1 is configured to control a temperature of the heat medium used for the plurality of semiconductor manufacturing apparatuses 2 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 plurality of third circulation circuits 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.

[0036] 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, so that the first heat medium circulates in the first circulation circuit 11 by the first pump 14. The temperature control system 1 includes a second pump 15 coupled to the second circulation circuit 12, so that the second heat medium circulates in the second circulation circuit 12 by the second pump 15.

[0037] The plurality of semiconductor manufacturing apparatuses 2 are coupled to the plurality of third circulation circuits 13, respectively. The third heat medium circulates through each third circulation circuit 13 and each semiconductor manufacturing apparatus 2. A processing temperature in each semiconductor manufacturing apparatus 2 is regulated by the third heat medium flowing through the corresponding third circulation circuit 13. A temperature of the third heat medium is regulated by the first heat medium and the second heat medium as will be described later. A flow rate of the third heat medium circulating through the third circulation circuit 13 and flowing to a first heat exchanger 21 and a second heat exchanger 22 is regulated by a pump, a valve, etc. (not shown).

[0038] The second circulation circuit 12 is independent of the first circulation circuit 11, and the plurality of third circulation circuits 13 are 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 plurality of third circulation circuits 13 form closed circuits that are independent of each other. The plurality of third circulation circuits 13 also form closed circuits that are independent of each other. Therefore, the first heat medium, the second heat medium, and the third heat medium are not mixed.

[0039] Different heat media can be used for the first heat medium, the second heat

medium, and the third heat medium. For example, a typical 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 includes a silicone oil. An example of the third heat medium includes a fluorine-based inert liquid. The third heat medium is an insulator that is chemically stable in a range from a low temperature to a high temperature in order to directly regulate the processing temperature in each semiconductor manufacturing apparatus 2.

[0040] 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 viscosity (fluidity) of the heat medium can be maintained and a phase of the heat medium does not change (i.e., does not boil and does not solidify).

[0041] The temperature control system 1 includes a first buffer tank 16 configured to hold the first heat medium therein, and a second buffer tank 17 configured to hold the second heat medium therein. 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 an embodiment, the first buffer tank 16 and the second buffer tank 17 may not be provided.

[0042] The temperature control system 1 further includes a plurality of first heat exchangers 21 and a plurality of second heat exchangers 22. The plurality of first heat exchangers 21 are coupled to the first circulation circuit 11 and the plurality of third circulation circuits 13. The plurality of second heat exchangers 22 are coupled to the second circulation circuit 12 and the plurality of third circulation circuits 13. The plurality of first heat exchangers 21 are configured to perform heat exchange between the first heat medium cooled by the cooling device 7 and the third heat medium circulating through the plurality of third circulation circuits 13. The plurality of second heat exchangers 22 are

configured to perform heat exchange between the second heat medium heated by the heating device 8 and the third heat medium circulating through the plurality of third circulation circuits 13.

[0043] The plurality of first heat exchangers 21 are coupled in parallel by the first circulation circuit 11. More specifically, the first circulation circuit 11 has a first heat-medium supply line 31 for delivering the first heat medium, cooled by the cooling device 7, to the plurality of first heat exchangers 21, a first heat-medium return line 32 for returning the first heat medium, which has exchanged heat with the third heat medium in the plurality of first heat exchangers 21, to the cooling device 7, and a plurality of first branch lines 33 coupled to the first heat-medium supply line 31 and the first heat-medium return line 32. One end of each first branch line 33 is coupled to the first heat-medium supply line 31, and the other end of each first branch line 33 is coupled to the first heat-medium return line 32.

[0044] The plurality of first heat exchangers 21 are coupled to the plurality of first branch lines 33, respectively. The first heat medium cooled by the cooling device 7 is delivered to the plurality of first heat exchangers 21 through the first heat-medium supply line 31 and the plurality of first branch lines 33. The first heat medium that has exchanged heat with the third heat medium in the plurality of first heat exchangers 21 flows through the plurality of first branch lines 33 and the first heat-medium return line 32, and is returned to the cooling device 7 via the first buffer tank 16.

[0045] The plurality of second heat exchangers 22 are coupled in parallel by the second circulation circuit 12. More specifically, the second circulation circuit 12 has a second heat-medium supply line 41 for delivering the second heat medium, heated by the heating device 8, to the plurality of second heat exchangers 22, a second heat-medium return line 42 for returning the second heat medium, which has exchanged heat with the third heat medium in the plurality of second heat exchangers 22, to the heating device 8, and a plurality of second branch lines 43 coupled to the second heat-medium supply line 41 and the second heat-medium return line 42. One end of each second branch line 43 is coupled to the second heat-medium supply line 41, and the other end of each second branch line 43

is coupled to the second heat-medium return line 42.

[0046] The plurality of second heat exchangers 22 are coupled to the plurality of second branch lines 43, respectively. The second heat medium heated by the heating device 8 is delivered to the plurality of second heat exchangers 22 through the second heat-medium supply line 41 and the plurality of second branch lines 43. The second heat medium that has exchanged heat with the third heat medium in the plurality of second heat exchangers 22 is returned to the heating device 8 through the plurality of second branch lines 43 and the second heat-medium return line 42.

[0047] 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. 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. The processing temperatures in the plurality of semiconductor manufacturing apparatuses 2 are independently controlled by the third heat medium whose temperature is regulated by the plurality of sets G1, G2, and G3 of first heat exchangers 21 and second heat exchangers 22.

[0048] The temperature control system 1 further includes a plurality of first flow control valves 51 as a plurality of first variable flow-rate devices that are coupled to the plurality of first heat exchangers 21 in series, respectively, by the first circulation circuit 11, and an operation controller 100 configured to control operations of the plurality of first flow control valves 51. The plurality of first flow control valves 51 are coupled to the plurality of first branch lines 33. The plurality of first flow control valves 51 are located upstream of the plurality of first heat exchangers 21 and downstream of the cooling device 7 in a flow direction of the first heat medium.

[0049] The plurality of first flow control valves 51 are electrically coupled to the operation controller 100. The operation controller 100 is configured to, when a cooling

thermal load on the third heat medium flowing through one of the plurality of third circulation circuits 13 exceeds a cooling load threshold, instruct the first flow control valve 51 corresponding to the first heat exchanger 21 coupled to that third circulation circuit 13 to increase a flow rate of the first heat medium from a rated flow rate to an excess flow rate.

[0050] The rated flow rate of the first heat medium is a predetermined flow rate, and the excess flow rate of the first heat medium is a flow rate higher than the rated flow rate. Since the supply temperature of the first heat medium cooled by the cooling device 7 remains the same, increasing the flow rate of the first heat medium to the first heat exchanger 21 from the rated flow rate to the excess flow rate can increase a cooling capacity in the first heat exchanger 21.

[0051] The operation controller 100 includes at least one computer. The operation controller 100 includes a memory 100a in which a program and the like are stored, and an arithmetic device 100b configured to execute arithmetic operations according to instructions included in the program. The memory 100a 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 100b include a CPU (central processing unit) and a GPU (graphic processing unit). However, a specific configuration of the operation controller 100 is not limited to these examples.

[0052] The operation controller 100 monitors the temperature of the first heat medium in order to determine whether or not the cooling thermal load on the third heat medium flowing through each third circulation circuit 13 exceeds the cooling load threshold. More specifically, the temperature control system 1 includes a plurality of first heat-medium outlet temperature measuring devices 55 configured to measure the temperature of the first heat medium flowing through the first circulation circuit 11. The plurality of first heat-medium outlet temperature measuring devices 55 are coupled to the plurality of first branch lines 33 of the first circulation circuit 11, respectively, and are located downstream of the plurality of first heat exchangers 21 in the flow direction of the first heat medium. The plurality of first heat-medium outlet temperature measuring devices 55 are configured to

individually measure the temperature of the first heat medium that has passed through the plurality of first heat exchangers 21.

[0053] The plurality of first heat-medium outlet temperature measuring devices 55 are electrically coupled to the operation controller 100, so that measured values of the temperature of the first heat medium are transmitted to the operation controller 100. During operation of the temperature control system 1, the operation controller 100 monitors the measured values of the temperature of the first heat medium transmitted from the plurality of first heat-medium outlet temperature measuring devices 55, and determines whether or not the cooling thermal load on the third heat medium flowing through any one of the plurality of third circulation circuits 13 exceeds the cooling load threshold.

[0054] In the present embodiment, when the temperature of the first heat medium that has passed through the first heat exchanger 21 coupled to one of the plurality of third circulation circuits 13 exceeds a cooling temperature threshold, the operation controller 100 instructs the first flow control valve 51 corresponding to the first heat exchanger 21 coupled to that third circulation circuit 13 to increase the flow rate of the first heat medium from the rated flow rate to the excess flow rate.

[0055] The temperature of the first heat medium measured by the first heat-medium outlet temperature measuring device 55 reflects the cooling thermal load on the third heat medium flowing through the corresponding third circulation circuit 13. The cooling temperature threshold related to the temperature of the first heat medium corresponds to the cooling load threshold related to the cooling thermal load on the third heat medium. The operation controller 100 determines whether or not the cooling thermal load on the third heat medium flowing through the third circulation circuit 13 exceeds the cooling load threshold based on a comparison between the temperature of the first heat medium and the cooling temperature threshold. Therefore, based on the measured value of the temperature of the first heat medium, the operation controller 100 can instruct the first flow control valve 51 to temporarily increase the flow rate of the first heat medium delivered to the corresponding first heat exchanger 21.

[0056] The operation of increasing the flow rate of the first heat medium delivered to the first heat exchanger 21 coupled to the third circulation circuit 13 through which the third heat medium having the increased cooling thermal load flows can temporarily increase the cooling capacity of the corresponding first heat exchanger 21. An increase in the cooling thermal load usually occurs temporarily, and thus, the cooling thermal load does not increase simultaneously in all of the plurality of third circulation circuits 13. Therefore, even if a temporary increase in the cooling thermal load occurs, the cooling device 7 can process a total cooling thermal load within its rated cooling capacity.

[0057] The determination of the increase in the cooling thermal load on the third heat medium flowing through the third circulation circuit 13 may be based on an external signal or a signal from the third circulation circuit 13 side (a temperature or a signal from a control device on the third circulation circuit 13 side), other than the temperature of the first heat medium. For example, the operation controller 100 receives a signal indicating a target processing temperature in the semiconductor manufacturing apparatus 2 from the semiconductor manufacturing apparatus 2. When the target processing temperature in the semiconductor manufacturing apparatus 2 falls below a predetermined processing cooling temperature threshold, the operation controller 100 instructs the first flow control valve 51 corresponding to the semiconductor manufacturing apparatus 2 to increase the flow rate of the first heat medium from the rated flow rate to the excess flow rate.

[0058] In one embodiment, as shown in FIG. 2, the temperature control system 1 may include a plurality of third heat-medium outlet temperature measuring devices 58 configured to measure cooling thermal loads on the third heat medium flowing through the plurality of third circulation circuits 13. The plurality of third heat-medium outlet temperature measuring devices 58 are coupled to the plurality of third circulation circuits 13, respectively, and are located downstream of the plurality of first heat exchangers 21 in the flow direction of the third heat medium. The plurality of third heat-medium outlet temperature measuring devices 58 are configured to individually measure the temperature of the third heat medium that has passed through the plurality of first heat exchangers 21.

[0059] The plurality of third heat-medium outlet temperature measuring devices 58 are electrically coupled to the operation controller 100, so that measured values of the temperature of the third heat medium are transmitted to the operation controller 100. During operation of the temperature control system 1, the operation controller 100 monitors the measured values of the temperature of the third heat medium transmitted from the plurality of third heat-medium outlet temperature measuring devices 58, and determines whether or not the cooling thermal load on the third heat medium flowing through any one of the plurality of third circulation circuits 13 exceeds the cooling load threshold.

[0060] More specifically, when the temperature of the third heat medium that has passed through the first heat exchanger 21 coupled to one of the plurality of third circulation circuits 13 exceeds the cooling temperature threshold, the operation controller 100 instructs the first flow control valve 51 corresponding to the first heat exchanger 21 coupled to that third circulation circuit 13 to increase the flow rate of the first heat medium from the rated flow rate to the excess flow rate. The temperature of the third heat medium measured by the third heat-medium outlet temperature measuring device 58 reflects the cooling thermal load on the third heat medium. The operation controller 100 determines whether or not the cooling thermal load on the third heat medium flowing through the third circulation circuit 13 exceeds the cooling load threshold based on a comparison between the temperature of the third heat medium and the cooling temperature threshold. Therefore, based on the measured value of the temperature of the third heat medium, the operation controller 100 can instruct the first flow control valve 51 to temporarily increase the flow rate of the first heat medium delivered to the corresponding first heat exchanger 21.

[0061] In the embodiments shown in FIG. 1 and FIG. 2, the operation controller 100 is configured to, when a predetermined first flow-rate increase time has elapsed since the flow rate of the first heat medium is increased to the excess flow rate, instruct the corresponding first flow control valve 51 to decrease the flow rate of the first heat medium to the rated flow rate. The increase in the cooling thermal load on the third heat medium flowing through the third circulation circuit 13 is temporary. Therefore, decreasing the flow rate

of the first heat medium to the rated flow rate after the predetermined first flow-rate increase time has elapsed can suppress an increase in power of the entire temperature control system 1. A condition for returning the excess flow rate to the rated flow rate may be the temperature of the first heat medium, a signal from the semiconductor manufacturing apparatus 2, or the temperature of the third heat medium, other than the time.

[0062] FIG. 3 is a schematic diagram showing yet another embodiment of the semiconductor manufacturing system including the temperature control system 1 and a plurality of semiconductor manufacturing apparatuses 2. Configuration and operation of the present embodiment, which are not specifically described, are the same as those of the embodiment described with reference to FIG. 1, and therefore redundant description thereof will be omitted. The temperature control system 1 of the present embodiment includes a plurality of first variable speed pumps 59, instead of the plurality of first flow control valves 51, as the plurality of first variable flow-rate devices that are coupled to the plurality of first heat exchangers 21 in series, respectively, by the first circulation circuit 11. In the present embodiment, the above-described first pump 14 may not be provided.

[0063] The plurality of first variable speed pumps 59 are coupled to the plurality of first branch lines 33, respectively. The plurality of first variable speed pumps 59 are located upstream of the plurality of first heat exchangers 21 and downstream of the cooling device 7 in the flow direction of the first heat medium. The plurality of first variable speed pumps 59 are electrically coupled to the operation controller 100. The operation controller 100 is configured to individually control rotational speeds of the plurality of first variable speed pumps 59.

[0064] When the temperature of the first heat medium that has passed through the first heat exchanger 21 coupled to one of the plurality of third circulation circuits 13 exceeds the cooling temperature threshold, the operation controller 100 increases the flow rate of the first heat medium from the rated flow rate to the excess flow rate by increasing the rotational speed of the first variable speed pump 59 corresponding to the first heat exchanger 21 coupled to that third circulation circuit 13. This operation makes it possible

to increase the flow rate of the first heat medium sent to the first heat exchanger 21 coupled to the third circulation circuit 13 through which the third heat medium having the increased cooling thermal load flows, and can therefore temporarily increase the cooling capacity of the corresponding first heat exchanger 21.

[0065] The operation controller 100 is configured to decrease the flow rate of the first heat medium to the rated flow rate by decreasing the rotational speed of the corresponding first variable speed pump 59 when the predetermined first flow-rate increase time has elapsed since the flow rate of the first heat medium is increased to the excess flow rate.

[0066] The plurality of third heat-medium outlet temperature measuring devices 58 described with reference to FIG. 2 are applicable to the embodiment described with reference to FIG. 3.

[0067] FIG. 4 is a schematic diagram showing yet another embodiment of the semiconductor manufacturing system including the temperature control system 1 and the plurality of semiconductor manufacturing apparatuses 2. The configuration and operation of the present embodiment, which are not specifically described, are the same as those of the embodiment described with reference to FIG. 1, and therefore redundant description thereof will be omitted. The temperature control system 1 includes a plurality of second flow control valves 61 as a plurality of second variable flow-rate devices coupled to the plurality of second heat exchangers 22 in series, respectively, by the second circulation circuit 12. The plurality of second flow control valves 61 are coupled to the plurality of second branch lines 43. The plurality of second flow control valves 61 are located upstream of the plurality of second heat exchangers 22 and downstream of the heating device 8 in a flow direction of the second heat medium.

[0068] The plurality of second flow control valves 61 are electrically coupled to the operation controller 100. The operation controller 100 is configured to, when a heating thermal load on the third heat medium flowing through one of the plurality of third circulation circuits 13 exceeds a heating load threshold, instruct the second flow control valve 61 corresponding to the second heat exchanger 22 coupled to that third circulation

circuit 13 to increase a flow rate of the second heat medium from a rated flow rate to an excess flow rate.

[0069] The rated flow rate of the second heat medium is a predetermined flow rate, and the excess flow rate of the second heat medium is a flow rate higher than the rated flow rate. Since the supply temperature of the second heat medium heated by the heating device 8 remains the same, increasing the flow rate of the second heat medium to the second heat exchanger 22 from the rated flow rate to the excess flow rate can increase a heating capacity in the second heat exchanger 22.

[0070] The operation controller 100 monitors the temperature of the second heat medium in order to determine whether or not the heating thermal load on the third heat medium flowing through each third circulation circuit 13 exceeds the heating load threshold. More specifically, the temperature control system 1 includes a plurality of second heat-medium outlet temperature measuring devices 62 configured to measure the temperature of the second heat medium flowing through the second circulation circuit 12. The plurality of second heat-medium outlet temperature measuring devices 62 are coupled to the plurality of second branch lines 43 of the second circulation circuit 12, respectively, and are located downstream of the plurality of second heat exchangers 22 in the flow direction of the second heat medium. The plurality of second heat-medium outlet temperature measuring devices 62 are configured to individually measure the temperature of the second heat medium that has passed through the plurality of second heat exchangers 22.

[0071] The plurality of second heat-medium outlet temperature measuring devices 62 are electrically coupled to the operation controller 100, so that measured values of the temperature of the second heat medium are transmitted to the operation controller 100. During operation of the temperature control system 1, the operation controller 100 monitors the measured values of the temperature of the second heat medium transmitted from the plurality of second heat-medium outlet temperature measuring devices 62, and determines whether or not the heating thermal load on the third heat medium flowing through any one of the plurality of third circulation circuits 13 exceeds the heating load threshold.

[0072] In the present embodiment, when the temperature of the second heat medium that has passed through the second heat exchanger 22 coupled to one of the plurality of third circulation circuits 13 falls below a heating temperature threshold, the operation controller 100 instructs the second flow control valve 61 corresponding to the second heat exchanger 22 coupled to that third circulation circuit 13 to increase the flow rate of the second heat medium from the rated flow rate to the excess flow rate.

[0073] The temperature of the second heat medium measured by the second heat-medium outlet temperature measuring device 62 reflects the heating thermal load on the third heat medium flowing through the corresponding third circulation circuit 13. The heating temperature threshold related to the temperature of the second heat medium corresponds to the heating load threshold related to the heating thermal load on the third heat medium. The operation controller 100 determines whether or not the heating thermal load on the third heat medium flowing through the third circulation circuit 13 exceeds the heating load threshold based on a comparison between the temperature of the second heat medium and the heating temperature threshold. Therefore, based on the measured value of the temperature of the second heat medium, the operation controller 100 can instruct the second flow control valve 61 to temporarily increase the flow rate of the second heat medium delivered to the corresponding second heat exchanger 22.

[0074] The operation of increasing the flow rate of the second heat medium sent to the second heat exchanger 22 coupled to the third circulation circuit 13 through which the third heat medium having the increased heating thermal load flows can temporarily increase the heating capacity of the corresponding second heat exchanger 22. An increase in the heating thermal load usually occurs temporarily, and thus, the heating thermal load does not increase simultaneously in all of the plurality of third circulation circuits 13. Therefore, even if a temporary increase in the heating thermal load occurs, the heating device 8 can process a total heating thermal load within its rated heating capacity.

[0075] The determination of the increase in the heating thermal load on the third heat medium flowing through the third circulation circuit 13 may be based on an external signal

or a signal from the third circulation circuit 13 side (a temperature or a signal from a control device on the third circulation circuit 13 side), other than the temperature of the second heat medium. For example, the operation controller 100 receives a signal indicating a target processing temperature in the semiconductor manufacturing apparatus 2 from the semiconductor manufacturing apparatus 2. When the target processing temperature in the semiconductor manufacturing apparatus 2 exceeds a predetermined processing heating temperature threshold, the operation controller 100 instructs the second flow control valve 61 corresponding to that semiconductor manufacturing apparatus 2 to increase the flow rate of the second heat medium from the rated flow rate to the excess flow rate.

[0076] In an embodiment, as shown in FIG. 5, the temperature control system 1 may include a plurality of third heat-medium outlet temperature measuring devices 71 configured to measure heating thermal loads on the third heat medium flowing through the plurality of third circulation circuits 13. The plurality of third heat-medium outlet temperature measuring devices 71 are coupled to the plurality of third circulation circuits 13, respectively, and are located downstream of the plurality of second heat exchangers 22 in the flow direction of the third heat medium. The plurality of third heat-medium outlet temperature measuring devices 71 are configured to individually measure the temperature of the third heat medium that has passed through the plurality of second heat exchangers 22.

[0077] The plurality of third heat-medium outlet temperature measuring devices 71 are electrically coupled to the operation controller 100, so that measured values of the temperature of the third heat medium are transmitted to the operation controller 100. During operation of the temperature control system 1, the operation controller 100 monitors the measured values of the temperature of the third heat medium transmitted from the plurality of third heat-medium outlet temperature measuring devices 71, and determines whether or not the heating thermal load on the third heat medium flowing through any one of the plurality of third circulation circuits 13 exceeds the heating load threshold.

[0078] More specifically, when the temperature of the third heat medium that has passed

through the second heat exchanger 22 coupled to one of the plurality of third circulation circuits 13 falls below the heating temperature threshold, the operation controller 100 instructs the second flow control valve 61 corresponding to the second heat exchanger 22 coupled to that third circulation circuit 13 to increase the flow rate of the second heat medium from the rated flow rate to the excess flow rate. The temperature of the third heat medium measured by the third heat-medium outlet temperature measuring device 71 reflects the heating thermal load on the third heat medium. The operation controller 100 determines whether or not the heating thermal load on the third heat medium flowing through the third circulation circuit 13 exceeds the heating load threshold based on a comparison between the temperature of the third heat medium and the heating temperature threshold. Therefore, based on the measured value of the temperature of the third heat medium, the operation controller 100 can instruct the second flow control valve 61 to temporarily increase the flow rate of the second heat medium delivered to the corresponding second heat exchanger 22.

[0079] In the embodiments shown in FIG. 4 and FIG. 5, the operation controller 100 is configured to, when a predetermined second flow-rate increase time has elapsed since the flow rate of the second heat medium is increased to the excess flow rate, instruct the corresponding second flow control valve 61 to decrease the flow rate of the second heat medium to the rated flow rate. The increase in the heating thermal load on the third heat medium flowing through the third circulation circuit 13 is temporary. Therefore, decreasing the flow rate of the second heat medium to the rated flow rate after the predetermined second flow-rate increase time has elapsed can suppress an increase in power of the entire temperature control system 1. A condition for returning the excess flow rate to the rated flow rate may be the temperature of the second heat medium, a signal from the semiconductor manufacturing apparatus 2, or the temperature of the third heat medium, other than the time.

[0080] FIG. 6 is a schematic diagram showing yet another embodiment of the semiconductor manufacturing system including the temperature control system 1 and the

plurality of semiconductor manufacturing apparatuses 2. Configuration and operation of the present embodiment, which are not specifically described, are the same as those of the embodiment described with reference to FIG. 4, and therefore redundant description thereof will be omitted. The temperature control system 1 of the present embodiment includes a plurality of second variable speed pumps 74, instead of the plurality of second flow control valves 61, as a plurality of second variable flow-rate devices coupled to the plurality of second heat exchangers 22 in series, respectively, by the second circulation circuit 12. In the present embodiment, the above-described second pump 15 may not be provided.

[0081] The plurality of second variable speed pumps 74 are coupled to the plurality of second branch lines 43, respectively. The plurality of second variable speed pumps 74 are located upstream of the plurality of second heat exchangers 22 and downstream of the heating device 8 in the flow direction of the second heat medium. The plurality of second variable speed pumps 74 are electrically coupled to the operation controller 100. The operation controller 100 is configured to individually control rotational speeds of the plurality of second variable speed pumps 74.

[0082] When the temperature of the second heat medium that has passed through the second heat exchanger 22 coupled to one of the plurality of third circulation circuits 13 falls below the heating temperature threshold, the operation controller 100 increases the flow rate of the second heat medium from the rated flow rate to the excess flow rate by increasing the rotational speed of the second variable speed pump 74 corresponding to the second heat exchanger 22 coupled to that third circulation circuit 13. This operation makes it possible to increase the flow rate of the second heat medium sent to the second heat exchanger 22 coupled to the third circulation circuit 13 through which the third heat medium having the increased heating thermal load flows, and can therefore temporarily increase the heating capacity of the corresponding second heat exchanger 22.

[0083] The operation controller 100 is configured to decrease the flow rate of the second heat medium to the rated flow rate by decreasing the rotational speed of the corresponding second variable speed pump 74 when the predetermined second flow-rate increase time has

elapsed since the flow rate of the second heat medium is increased to the excess flow rate.

[0084] The plurality of third heat-medium outlet temperature measuring devices 71 described with reference to FIG. 5 are applicable to the embodiment described with reference to FIG. 6.

[0085] FIG. 7 is a diagram showing an embodiment in which the embodiment described with reference to FIG. 1 and the embodiment described with reference to FIG. 4 are combined. FIG. 8 is a diagram showing an embodiment in which the embodiment described with reference to FIG. 3 and the embodiment described with reference to FIG. 6 are combined. According to the embodiments shown in FIG. 7 and FIG. 8, even if a temporary increase in thermal load occurs, the cooling device 7 or the heating device 8 can process a total thermal load within its rated capacity.

[0086] The plurality of third heat-medium outlet temperature measuring devices 58 described with reference to FIG. 2 and the plurality of third heat-medium outlet temperature measuring devices 71 described with reference to FIG. 5 are also applicable to the embodiments described with reference to FIG. 7 and FIG. 8.

[0087] 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

[0088] The present invention is applicable to a temperature control system configured to control a temperature of a heat medium used for semiconductor manufacturing apparatus, such as an etching apparatus, a CVD apparatus, and a PVD apparatus.

Reference Signs List

[0089]

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 heat-medium supply line

32 first heat-medium return line

33 first branch line

41 second heat-medium supply line

42 second heat-medium return line

43 second branch line

51 first flow control valve (first variable flow-rate device)

55 first heat-medium outlet temperature measuring device

58 third heat-medium outlet temperature measuring device

59 first variable speed pump (first variable flow-rate device)

61 second flow control valve (second variable flow-rate device)

62 second heat-medium outlet temperature measuring device

71 third heat-medium outlet temperature measuring device

74 second variable speed pump (second variable flow-rate device)

100 operation controller