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HEATING DEVICE, AND TEMPERATURE ADJUSTING DEVICE PROVIDED WITH SAME

Abstract

Provided are a heating apparatus and a temperature adjusting apparatus using the heating apparatus. A heating apparatus that heats circulation fluid that adjusts a temperature of a control target includes: a pipe where the circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound. The heating element generates heat by induction heating with the alternating current in the primary coil, and the heating element heats the circulation fluid.

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Background/Summary

TECHNICAL FIELD

[0001] The present invention relates to a heating apparatus and a temperature adjusting apparatus including the heating apparatus, and particularly relates to a heating apparatus and a temperature adjusting apparatus including the heating apparatus, which are used to adjust, for example, various manufacturing apparatuses such as a semiconductor manufacturing apparatus and various measuring apparatuses to predetermined temperatures.

BACKGROUND ART

[0002] Generally, it is necessary for, for example, the manufacture of semiconductors to control the temperature of, for example, a manufacturing apparatus in such a manner that the temperature of, for example, a spot on a workpiece to be processed by the manufacturing apparatus or a spot to be measured reaches a predetermined temperature in accordance with the manufacturing process. As an apparatus that performs such temperature control, a temperature adjusting apparatus is conventionally known which includes a circulation path where a heating medium circulates, and cools or heats a control target whose temperature needs to be adjusted by use of the heating medium that circulates along the circulation path. This type of temperature adjusting apparatus includes: for example, a chiller of the vapor-compression refrigeration cycle that cools a circulating heating medium; and, for example, a heating apparatus that heats the cooled heating medium.

[0003] For example, Patent Literature 1 discloses a hybrid chiller of an area-based parameter control system that is used to control temperatures of, for example, various apparatuses such as a semiconductor manufacturing apparatus, and processes. The hybrid chiller of the area-based parameter control system disclosed in Patent Literature 1 includes: a circulation fluid circulation circuit that supplies, to a control target, circulation fluid cooled to a predetermined temperature by a refrigeration cycle; and a second circulation fluid circulation circuit that supplies, to the control target, the circulation fluid cooled to a predetermined temperature by a coolant cooled by a cooling tower. A circulation fluid supply path that feeds the circulation fluid to the control target is provided with a heater that heats the circulation fluid.

[0004] With such a configuration, the circulation fluid that is supplied to the control target is cooled, properly using a method that cools the circulation fluid by use of the refrigeration cycle and a method that cools the circulation fluid by use of the coolant of the cooling tower. The circulation fluid cooled by the refrigeration cycle or the cooling tower is heated to a predetermined temperature by the heating apparatus such as a heater, and is supplied to the control target.

[0005] Moreover, for example, Patent Literature 2 discloses a cooling apparatus including: a first circulation system that circulates a first refrigerant in a condenser back to the condenser through a pump, a heating device, a throttle valve, and a vaporizer; and a second circulation system that includes a heat exchanger placed in the condenser, and circulates a second refrigerant that cools the first refrigerant.

[0006] The first circulation system cools a cooling target by use of the latent heat of vaporization of the first refrigerant that boils in the vaporizer. The heating device of the first circulation system is, for example, an electric heater, and heats the first refrigerant in such a manner that the first refrigerant reaches a predetermined temperature. The second circulation system includes a compressor, a second condenser, an expansion valve, and the heat exchanger, and cools and condenses the first refrigerant by use of the latent heat of vaporization of the second refrigerant in the heat exchanger provided in the condenser of the first circulation system.

[0007] Moreover, Patent Literature 2 discloses that a second heat exchanger that heats the first refrigerant by condensing the second refrigerant is provided as the heating device of the first circulation system. The second refrigerant of the second circulation system is pressurized by the compressor, is fed to the second heat exchanger, and heats the first refrigerant of the first circulation system.

[0008] Moreover, for example, Patent Literature 3 discloses a circulation cooling and heating apparatus that cools and heats circulation fluid to be supplied to a chamber of a plasm etching apparatus, and includes a tank where the circulation fluid is stored, a pump that circulates the circulation fluid between the tank and the chamber, a heat exchanger that exchanges heat between the circulation fluid and a coolant, and a heating means that heats the circulation fluid in the tank. The heating means disclosed in Patent Literature 3 includes a sheathed heater. The circulation fluid is heated by heat generated by the sheathed heater.

CITATION LIST

Patent Literature

[0009] Patent Literature 1: JP-A-2015-59726

[0010] Patent Literature 2: JP-A-2022-20088

[0011] Patent Literature 3: JP-A-2014-127534

SUMMARY OF INVENTION

Problems to be Solved by Invention

[0012] However, the above heating apparatus and temperature adjusting apparatus of the known technologies need some improvements in shortening the time required to adjust temperature and encouraging an increase in efficiency in a production process of, for example, a semiconductor manufacturing apparatus and in reducing the amount of energy consumed to adjust temperature and encouraging energy savings.

[0013] Specifically, in, for example, the manufacture of semiconductors, the temperature of a control target such as a manufacturing apparatus may be changed according to, for example, the processing process or measurement process. For example, a temperature setting for the control target may need to be changed to 130° C. after a process where temperature control is performed at a temperature setting of minus 40° C. In such a case, it takes a long time for the temperature adjusting apparatus of the known technology to change the temperature of the control target to a predetermined temperature setting. In this manner, the time required to change the temperature of the control target is the loss of time in the manufacturing process.

[0014] In other words, the temperature adjusting apparatus of the known technology needs to heat the circulation fluid with the heating apparatus including an electric heater such as a sheathed heater for a long time to change a temperature setting for a control target and increase the temperature. A process of heating the circulation fluid with, for example, the heating apparatus and increasing the temperature of the control target is performed until the temperature of the control target reaches a stable set temperature. The time required to heat the circulation fluid with, for example, the heating apparatus and increase the temperature of the control target is waiting time during which, for example, a semiconductor manufacturing apparatus cannot perform, for example, a processing process or a measurement process.

[0015] Moreover, the heating apparatus, which includes, for example, a sheathed heater, of the known technology has problems that it takes time to change a heating temperature and that accurate temperature adjustment is not easy. In other words, the sheathed heater is constructed by covering a heating element being, for example, a Nichrome wire with an insulator and a metal pipe, and is not configured in such a manner as to transfer the heat of the heating element directly to circulation fluid targeted to be heated. Hence, it takes time from when the amount of heat generated by the heating element is adjusted to when the metal pipe that transfers heat to the circulation fluid is heated to a predetermined temperature. Time is wasted until the temperature of a control target is adjusted to an exact set temperature.

[0016] Moreover, the temperature adjusting apparatus of the known technology is configured in such a manner as to cool the circulation fluid with the evaporator of the refrigeration cycle circuit and then heat the cooled circulation fluid to a predetermined temperature with the heating apparatus such as a sheathed heater. Hence, there are problems that, for example, energy that is consumed to heat the circulation fluid, that is, the amount of electric power consumed by, for example, the heating apparatus increases.

[0017] In contrast, Patent Literature 2 discloses that the second refrigerant of the second circulation system that cools the first refrigerant of the first circulation system by use of the latent heat of evaporation heats the first refrigerant by use of the latent heat of condensation in the second heat exchanger. In this manner, the first refrigerant corresponding to the circulation fluid to be supplied to the control target is heated by use of the latent heat of condensation of the second refrigerant being the refrigerant of the refrigeration cycle; therefore, the amount of energy consumed by, for example, the sheathed heater that is required to heat the circulation fluid can be reduced.
[0018] However, a method that heats circulation fluid by use of the latent heat of condensation of a refrigerant that is condensed by a condenser of a refrigeration cycle circuit as in the cooling apparatus disclosed in Patent Literature 2 has difficulty in heating the circulation fluid to a high temperature. Hence, even when the circulation fluid is heated by use of the latent heat of condensation of the refrigerant, if a temperature setting for a control target is high and it is necessary to heat the circulation fluid to a high temperature, much heating with a heating apparatus such as a sheathed heater is required, and the amount of heating of the heating apparatus cannot be significantly reduced.
[0019] Moreover, also in terms of the configuration that uses the condenser of the refrigeration cycle circuit to heat the circulation fluid, if the temperature setting for the control target is changed to significantly increase the temperature of the circulation fluid, it takes time to change the temperature, which leads to the loss of time before the start of, for example, a processing process or a measuring process.
[0020] The present invention has been made to solve such problems as described above. An object of the present invention is to provide a heating apparatus and a temperature adjusting apparatus using the heating apparatus, which can efficiently heat circulation fluid with high accuracy and can increase productivity in, for example, the manufacture of semiconductors by shortening the time required to adjust temperature, for example, upon a change in temperature setting. Moreover, another object of the present invention is to provide a temperature adjusting apparatus that can encourage energy savings by reducing the amount of energy consumed in, for example, the manufacture of semiconductors.
Solution to Problems
[0021] A heating apparatus of the present invention is a heating apparatus that heats circulation fluid that adjusts a temperature of a control target, and includes: a conductive pipe where the circulation fluid flows; and a primary coil wound on an outer periphery of the pipe, through which an alternating current flows. The pipe generates heat by induction heating with the alternating current in the primary coil, and the pipe heats the circulation fluid.
[0022] Moreover, the heating apparatus of the present invention is a heating apparatus that heats circulation fluid that adjusts a temperature of a control target, and includes: a pipe where the circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound. The heating element generates heat by induction heating with the alternating current in the primary coil, and the heating element heats the circulation fluid.
[0023] Moreover, a temperature adjusting apparatus of the present invention includes: a refrigeration cycle circuit where a compression means, a radiator, a throttle means, and an evaporator are sequentially connected and a refrigerant circulates; and a circulation fluid circuit provided with a circulating pump and a heating apparatus, in which circulation fluid that adjusts a temperature of a control target circulates. The circulation fluid circuit is formed, upstream of the heating apparatus, with a freely openable and closable low-temperature path where the circulation fluid flows through the evaporator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the heating apparatus includes: a conductive pipe where the circulation fluid flows; and a primary coil wound on an outer periphery of the pipe, through which an alternating current flows, and the pipe generates heat by induction heating with the alternating

current in the primary coil, and the pipe heats the circulation fluid.

[0024] Moreover, the temperature adjusting apparatus of the present invention includes: a refrigeration cycle circuit where a compression means, a radiator, a throttle means, and an evaporator are sequentially connected and a refrigerant circulates; and a circulation fluid circuit provided with a circulating pump and a heating apparatus, in which circulation fluid that adjusts a temperature of a control target circulates. The circulation fluid circuit is formed, upstream of the heating apparatus, with a freely openable and closable low-temperature path where the circulation fluid flows through the evaporator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the heating apparatus includes: a pipe where the circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound. The heating element generates heat by induction heating with the alternating current in the primary coil, and the heating element heats the circulation fluid.

Effects of Invention

[0025] A heating apparatus of the present invention includes: a conductive pipe where circulation fluid flows; and a primary coil wound on an outer periphery of the pipe, through which an alternating current flows. The pipe generates heat by induction heating with the alternating current in the primary coil, and the pipe heats the circulation fluid. Consequently, it is possible to transfer the heat of the pipe that generates heat by electromagnetic induction directly to the circulation fluid and efficiently heat the circulation fluid to an exact temperature. Hence, it is possible for, for example, a semiconductor manufacturing apparatus to shorten the time required to heat the circulation fluid for temperature control and execute a highly efficient processing process with little loss of time.

[0026] Moreover, the heating apparatus of the present invention may include: a pipe where circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound. The heating element may generate heat by induction heating with the alternating current in the primary coil, and the heating element may heat the circulation fluid. With such a configuration, it is possible to transfer the heat of the heating element directly to the circulation fluid and efficiently heat the circulation fluid to an exact temperature. Hence, it is possible to reduce the loss of time in a manufacturing process, and increase productivity of, for example, a semiconductor apparatus. Moreover, it is possible to reduce heat dissipation from the heating element directly to the outside of the pipe, and perform highly efficient heating with little radiation heat loss.

[0027] Moreover, in the heating apparatus of the present invention, the heating element may be formed of a conductive wire covered with an insulating member and having relative inductivity equal to or greater than one, and the conductive wire may be connected at both ends in such a manner as to configure a conductive closed loop. Consequently, it is possible to cause a large amount of induced current to flow through the conductive wire by highly efficient electromagnetic induction, cause the conductive wire to generate heat, and efficiently heat the circulation fluid to an exact temperature. Moreover, it is possible to reduce flow resistance of the circulation fluid near the heating element and efficiently circulate the circulation fluid.

[0028] Moreover, in the heating apparatus of the present invention, the heating element may be a secondary coil wound into a coil, and the secondary coil may configure a conductive closed circuit by connecting both ends of a coil path wound into a coil. Consequently, highly efficient induction heating where an induced current flows suitably through the secondary coil is made possible. Moreover, the flow resistance of the circulation fluid near the heating element is reduced, and the highly efficient circulation of the circulation fluid is achieved.

[0029] Moreover, in the heating apparatus of the present invention, the secondary coil may include a portion that is wound in such a manner that a winding diameter of the coil path is different between an upstream side and a downstream side of the pipe. Consequently, it is possible to cause suitable turbulence in the circulation fluid around the secondary coil and promote heat exchange between the heating element and the circulation fluid. Hence, highly efficient heating with the secondary coil allows the circulation fluid to be efficiently adjusted to an exact temperature in a short time.

[0030] Moreover, in the heating apparatus of the present invention, the secondary coil may be formed of at least one of an iron-based material, a nickel alloy-based material, or a ferritic stainless steel material. Consequently, it is possible to obtain the secondary coil excellent in durability and safety and increase the efficiency of induction heating of the secondary coil by concentrating an alternating magnetic field of the primary coil to the secondary coil made of a high magnetic material. Hence, the circulation fluid can be efficiently heated.

[0031] Moreover, in the heating apparatus of the present invention, the pipe may be formed of an austenitic stainless steel material. Consequently, it is possible to obtain the pipe excellent in corrosion resistance, durability, and safety, and increase the efficiency of induction heating of the secondary coil by concentrating the alternating magnetic field of the primary coil to the secondary coil.

[0032] Moreover, in the heating apparatus of the present invention, the pipe may include a bend pipe portion in the area where the primary coil is wound, and the area where the primary coil is wound may be formed in a circular shape, an elliptic shape, or a track shape. Consequently, it is possible to increase magnetic flux density in the pipe by concentrating, in the pipe, magnetic flux generated by the alternating current in the primary coil and to increase the efficiency of induction heating of the secondary coil.

[0033] Moreover, a temperature adjusting apparatus of the present invention includes: a refrigeration cycle circuit where a compression means, a radiator, a throttle means, and an evaporator are sequentially connected and a refrigerant circulates; and a circulation fluid circuit provided with a circulating pump and a heating apparatus, in which circulation fluid that adjusts a temperature of a control target circulates. The circulation fluid circuit is formed, upstream of the heating apparatus, with a freely openable and closable low-temperature path where the circulation fluid flows through the evaporator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the heating apparatus includes: a conductive pipe where the circulation fluid flows; and a primary coil wound on an outer periphery of the pipe, through which an alternating current flows, and the pipe generates heat by induction heating with the alternating current in the primary coil, and the pipe heats the circulation fluid. With such a configuration, it is possible to cool the circulation fluid flowing in the circulation fluid circuit with the refrigeration cycle circuit, efficiently heat the cooled circulation fluid to an exact temperature with the heating apparatus, and adjust temperature with high accuracy.

[0034] Moreover, the temperature adjusting apparatus of the present invention may include: a refrigeration cycle circuit where a compression means, a radiator, a throttle means, and an evaporator are sequentially connected and a refrigerant circulates; and a circulation fluid circuit provided with a circulating pump and a heating apparatus, in which circulation fluid that adjusts a temperature of a control target circulates. The circulation fluid circuit may be formed, upstream of the heating apparatus, with a freely openable and closable low-temperature path where the circulation fluid flows through the evaporator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the heating apparatus may include: a pipe where the circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound. The heating element may generate heat by induction heating with the alternating current in the primary coil, and the heating element may heat the circulation fluid. With such a configuration, it is possible to efficiently heat the circulation fluid cooled in the refrigeration cycle circuit to an exact temperature with the heating apparatus, and supply the

circulation water at the suitable temperature to the control target.
[0035] Moreover, in the temperature adjusting apparatus of the present invention, the heating element may be formed of a conductive wire covered with an insulating member and having relative inductivity equal to or greater than one, and the conductive wire may be connected at both ends in such a manner as to configure a conductive closed loop. Consequently, it is possible to efficiently heat the circulation fluid to an exact temperature by causing an induced current to efficiently flow through the conductive wire. Moreover, it is possible to reduce the flow resistance of the circulation fluid near the heating element and efficiently circulate the circulation fluid.
[0036] Moreover, in the temperature adjusting apparatus of the present invention, the heating element is a secondary coil wound into a coil, and the secondary coil configures a conductive closed circuit by connecting both ends of a coil path wound into a coil.
[0037] Consequently, the heating apparatus can perform highly efficient induction heating where an induced current flows suitably. Moreover, it is possible to reduce the flow resistance of the circulation fluid near the heating element in the pipe and efficiently circulate the circulation fluid.
[0038] Moreover, in the temperature adjusting apparatus of the present invention, the secondary coil may include a portion that is wound in such a manner that a winding diameter of the coil path is different between an upstream side and a downstream side of the pipe. Consequently, it is possible to cause suitable turbulence in the circulation fluid around the secondary coil and promote heat exchange between the heating element and the circulation fluid. Hence, highly efficient heating with the secondary coil enables efficient and accurate adjustment of the circulation fluid to an exact temperature in a short time.
[0039] Moreover, in the temperature adjusting apparatus of the present invention, the pipe may include a bend pipe portion in the area where the primary coil is wound, and the area where the primary coil is wound may be formed in a circular shape, an elliptic shape, or a track shape. Consequently, it is possible to increase magnetic flux density in the pipe by concentrating, in the pipe, magnetic flux generated by the alternating current in the primary coil and increase the efficiency of induction heating of the secondary coil.
[0040] Moreover, in the temperature adjusting apparatus of the present invention, the circulation fluid circuit may be formed, upstream of the heating apparatus, with a freely openable and closable high-temperature path where the circulation fluid flows through the radiator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the refrigerant may be carbon dioxide, and may heat the circulation fluid under supercritical pressure in the radiator, and the high-temperature path may be provided with a high-temperature tank where the circulation fluid heated by the refrigerant in the radiator is stored. With such a configuration, the temperature adjusting apparatus can adjust temperature with little loss of exhaust heat and with high efficiency by using both of cold heat and hot heat, which are generated in the refrigeration cycle circuit.
[0041] Specifically, if the temperature of the circulation fluid returning from the control target is low and the temperature of the circulation fluid needs to be increased sharply, the high-temperature path of the circulation fluid circuit is opened to allow the circulation fluid to flow along the high-temperature path. Consequently, the temperature adjusting apparatus can heat the circulation fluid by use of heat dissipated from the refrigerant flowing through the radiator of the refrigeration cycle circuit. The circulation fluid heated by the radiator of the refrigeration cycle circuit is then heated to a predetermined temperature by the heating apparatus of the circulation fluid circuit, and is supplied at the suitable temperature to the control target in such a manner that the control target reaches an exact set temperature. In this manner, the circulation fluid can be heated by use of the heat dissipation of the radiator of the refrigeration cycle circuit. Therefore, the temperature can be adjusted with high efficiency while the amount of energy to be consumed by the heating apparatus of the circulation fluid circuit is kept low.
[0042] Moreover, the refrigerant of the refrigeration cycle circuit is carbon dioxide, and heats the circulation fluid under supercritical pressure in the radiator. Therefore, the circulation fluid can be

efficiently heated to a high temperature.

[0043] Specifically, the temperature adjusting apparatus of the present invention can heat the circulation fluid, with the radiator of the refrigeration cycle circuit, to a high- temperature region that is not achievable by a condenser of, for example, a chiller of a known technology using an HFC (hydrofluorocarbon)-based refrigerant, an HFO (hydrofluoroolefin)-based refrigerant, or a mixed refrigerant of them. Hence, for example, also if the temperature setting is changed to, for example, as high as 130° C. due to a change in, for example, a processing process, it is possible to increase the temperature of the circulation fluid to a high temperature in a short time. Hence, it is possible to reduce the loss of time caused by temperature adjustment and increase productivity of, for example, a semiconductor apparatus. Moreover, the amount of heating by the heating apparatus of the circulation fluid circuit can be reduced. Therefore, it is possible to reduce the amount of energy consumed by the heating apparatus and encourage energy savings.

[0044] Moreover, the high-temperature path is provided with a high-temperature tank where the circulation fluid heated by the refrigerant in the radiator is stored.

[0045] Consequently, for example, if a temperature setting for the control target is changed due to a change in, for example, a processing process to significantly increase the temperature of the circulation fluid, the temperature of the circulation fluid that circulates in the circulation fluid circuit can be quickly increased to a predetermined temperature in a short time by supplying, to the circulation fluid circuit, the high-temperature circulation fluid stored in the high-temperature tank. Hence, it is possible to significantly shorten the time required to change the temperature setting and reduce the loss of time accompanied by the change in temperature before the start of, for example, a processing process or a measurement process.

Description

BRIEF DESCRIPTION OF DRAWINGS

[0046] FIG. **1** is a diagram illustrating a temperature adjusting apparatus according to an embodiment of the present invention.

[0047] FIG. **2** is a diagram illustrating a heating apparatus of the temperature adjusting apparatus according to the embodiment of the present invention.

[0048] FIG. **3** is a diagram illustrating another example of the heating apparatus of the temperature adjusting apparatus according to the embodiment of the present invention.

[0049] FIG. **4** is a diagram illustrating another example of the heating apparatus of the temperature adjusting apparatus according to the embodiment of the present invention.

[0050] FIG. **5** is a diagram illustrating another example of the heating apparatus of the temperature adjusting apparatus according to the embodiment of the present invention.

[0051] FIG. **6** is a diagram illustrating another example of the heating apparatus of the temperature adjusting apparatus according to the embodiment of the present invention.

[0052] FIG. **7** is a diagram illustrating a control system of the temperature adjusting apparatus according to the embodiment of the present invention.

[0053] FIG. **8** is a diagram illustrating a circulation fluid flow path of the temperature adjusting apparatus according to the embodiment of the present invention.

[0054] FIG. **9** is a diagram illustrating a circulation fluid flow path of the temperature adjusting apparatus according to the embodiment of the present invention.

[0055] FIG. **10** is a diagram illustrating a circulation fluid flow path of the temperature adjusting apparatus according to the embodiment of the present invention.

[0056] FIG. **11** is a diagram illustrating a circulation fluid flow path of the temperature adjusting apparatus according to the embodiment of the present invention.

DESCRIPTION OF EMBODIMENTS

[0057] A temperature adjusting apparatus **1** according to an embodiment of the present invention is described in detail below with appropriate reference to the drawings. Note that illustrated aspects do not limit the present invention, and are merely examples of the embodiment of the present invention.

[0058] FIG. **1** is a diagram illustrating a schematic configuration of the temperature adjusting apparatus **1** according to the embodiment of the present invention. The temperature adjusting apparatus **1** is an apparatus that is used to adjust a control target **46**, for example, various manufacturing apparatuses such as a semiconductor manufacturing apparatus, or various measuring apparatuses used in, for example, semiconductor manufacturing processes, to a predetermined temperature according to the process (refer to FIG. **1**).

[0059] The temperature adjusting apparatus **1** includes a refrigeration cycle circuit **10** that configures a vapor-compression refrigeration cycle, and cools or heats circulation fluid with a refrigerant, and a circulation fluid circuit **20** that circulate the circulation fluid cooled or heated in the refrigeration cycle circuit **10** in such a manner as to feed the circulation fluid to the control target **46**, and adjust the temperature of the control target **46**.

[0060] Examples of the circulation fluid that circulates in the circulation fluid circuit **20** includes water. The circulation fluid is cooled or heated by the refrigerant of the refrigeration cycle circuit **10**, heated to a suitable temperature by a heating apparatus **26** of the circulation fluid circuit **20**, and supplied to the control target **46** such as a semiconductor manufacturing apparatus. Consequently, the control target **46** is controlled in such a manner as to be cooled or heated by the circulation fluid adjusted to the suitable temperature and reach a suitable temperature adequate to, for example, each manufacturing process or measurement process.

[0061] Firstly, the configuration of the refrigeration cycle circuit **10** is described in detail. The refrigeration cycle circuit **10** is formed by sequentially connecting a compressor **11** as a compression means, a radiator **12**, a second radiator **13**, an expansion valve **14** as a throttle means, and an evaporator **15** via refrigerant piping **17**. The refrigeration cycle circuit **10** configures a closed circuit where the refrigerant is circulated to perform vapor-compression refrigeration cycle operation.

[0062] The compressor **11** is a compression means for compressing the refrigerant and feeding the refrigerant to the radiator **12**. Compression devices of a rotary type, a scroll type, a reciprocating type, a screw type, and various other types can be adopted as the compressor **11**.

[0063] Particularly, the compressor **11** of the rotary type is suitable to construct the temperature adjusting apparatus **1** that is made compact with low cooling capacity. Moreover, the compressor **11** may be of a two-stage compression type. The adoption of the two-stage compression type as the compressor **11** is suitable to compress a carbon dioxide refrigerant whose pressure becomes high.

[0064] The radiator **12** is a heat exchanger that exchanges heat between the refrigerant that has been compressed to a high pressure and a high temperature by the compressor **11** and the circulation fluid of the circulation fluid circuit **20**. The radiator **12** is, for example, a gas cooler. Note that the radiator **12** may be a condenser that condenses the refrigerant. The radiator **12**, for example, is provided in a high-temperature tank **39** where the circulation fluid is stored and includes a plurality of tubes where the refrigerant flows although its illustration is omitted. The tubes are, for example, steel tubes.

[0065] Specifically, the tubes of the radiator **12** each include an inlet in an upper part thereof and an outlet in a lower part thereof to allow the refrigerant to flow from up to down, are wound into, for example, an approximately spiral shape, and are provided in the high-temperature tank **39**. With such a configuration, the refrigerant that flows through the radiator **12** can heat the circulation fluid in the high-temperature tank **39** efficiently. For example, even if the circulation fluid in the high-temperature tank **39** is not supplied to the control target **46**, that is, even if the circulation fluid does not flow along a high-temperature path **38** of the circulation fluid circuit **20** provided with the high-temperature tank **39**, the refrigerant flowing through the radiator **12** can heat the circulation fluid in the high-temperature tank **39**.

[0066] In other words, such a configuration allows the radiator **12** to heat the circulation fluid stored in the high-temperature tank **39** to a high temperature without providing, for example, a circulating pump that feeds the circulation fluid to the high-temperature path **38** of the circulation fluid circuit **20** to heat the circulation fluid with the radiator **12**.

[0067] Hence, when the refrigeration cycle circuit **10** is performing operation in which the circulation fluid is cooled by use of the latent heat of evaporation of the evaporator **15**, it is possible to heat the circulation fluid in the high-temperature tank **39** to a high temperature by effectively using exhaust heat from the radiator **12** without circulating the circulation fluid along the high-temperature path **38**.

[0068] Note that the radiator **12** may be provided outside the high-temperature tank **39** as long as it has a configuration that can exchange heat between the refrigerant and the circulation fluid. For example, heat exchangers of a plate type, a shell-and-tube type, a double-pipe type, and various other types may be adopted as the radiator **12**.

[0069] The second radiator **13** is a heat exchanger that releases the heat of the refrigerant to the outside, and is provided downstream of the radiator **12**. The second radiator **13** is, for example, an air-cooled heat exchanger to which air that exchanges heat with the refrigerant is delivered by an air-blowing fan **16**. For example, the second radiator **13** may be a fin-and-tube heat exchanger although its illustration is omitted. In other words, the second radiator **13** includes a plurality of tubes such as steel tubes where the refrigerant flows, and a plurality of aluminum fins provided parallel to each other. The tubes are inserted into holes formed in the fins.

[0070] Note that the second radiator **13** may be a water-cooled heat exchanger. Moreover, heat exchangers of a plate type, a shell-and-tube type, a double-pipe type, and various other types can be adopted as the second radiator **13**. Particularly, a heat exchanger of the plate type is preferable since the efficiency of heat exchange is high and the second radiator **13** can be made compact.

[0071] The second radiator **13** is provided downstream of the radiator **12**. Therefore, the refrigerant that has dropped in temperature due to heating of the circulation fluid in the radiator **12** can be cooled to a lower temperature. Moreover, also if the circulation fluid in the high-temperature tank **39** is increased to a high temperature and there is no need to heat the circulation fluid with the refrigerant flowing through the radiator **12**, the high-temperature refrigerant that has passed through the radiator **12** can reduce in temperature to a low temperature by heat dissipation of the second radiator **13**. Consequently, the cooling capacity of the refrigeration cycle circuit **10**, that is, the ability to cool the circulation fluid by use of the latent heat of evaporation of the refrigerant in the evaporator **15**, is provided also in a state where the high-temperature tank **39** is filled with the high-temperature circulation fluid.

[0072] The expansion valve **14** is a throttle means for decompressing the high-pressure refrigerant that has reached a low temperature after passing through the radiator **12** and the second radiator **13**. Moreover, the expansion valve **14** has a function of adjusting the flow of the refrigerant. Throttle means such as an electronic expansion valve, a thermostatic expansion valve, a capillary tube, and various other types can be adopted as the expansion valve **14**. If an electronic expansion valve is adopted as the expansion valve **14**, the cooling and heating of the circulation fluid in the refrigeration cycle circuit **10** can be controlled with high efficiency.

[0073] The evaporator **15** is a heat exchanger that evaporates the low-pressure liquid refrigerant and cools the circulation fluid with the latent heat of evaporation. Heat exchangers of a plate type, a double-pipe type, a tube contact type, a shell-and-tube type, and various other types can be adopted as the evaporator **15**.

[0074] Particularly, a heat exchanger of the plate type is preferable since the efficiency of heat exchange is high and the evaporator **15** can be made compact. Moreover, the double-pipe type and the tube contact type are excellent in easy manufacturing and processing and easy obtainability of suitable compressive strength.

[0075] The refrigerant piping **17** downstream of the evaporator **15** is connected to the compressor **11** via an unillustrated accumulator. With the above configuration, the closed circuit of the refrigeration cycle circuit **10** is formed in which the compressor **11**, the radiator **12**, the second radiator **13**, the expansion valve **14**, and the evaporator **15** are sequentially connected.
[0076] The refrigerant used in the refrigeration cycle circuit **10** is, for example, carbon dioxide. The carbon dioxide refrigerant heats the circulation fluid under supercritical pressure in the radiator **12** as a gas cooler. Consequently, the circulation fluid can be efficiently heated to a high temperature.
[0077] Specifically, the radiator **12** of the refrigeration cycle circuit **10** can heat the circulation fluid to a high-temperature region that is not achievable by a condenser of, for example, a chiller of a known technology using an HFC-based refrigerant, an HFO-based refrigerant, or a mixed refrigerant of them.
[0078] For example, the temperature adjusting apparatus **1** can increase the temperature of the circulation fluid to a high temperature in a short time also if, for example, the temperature setting is changed to as high as 130° C. due to a change in, for example, a processing process. Hence, the temperature adjusting apparatus **1** can reduce the loss of time caused by temperature adjustment and increase productivity of, for example, a semiconductor apparatus. Moreover, it is possible to reduce the amount of heating by the heating apparatus **26** of the circulation fluid circuit **20**. Therefore, it is possible to reduce the amount of energy consumed by the heating apparatus **26** and encourage energy savings in, for example, the manufacture of semiconductors. Note that the temperature adjusting apparatus **1** may use, for example, an HFC-based refrigerant, an HFO-based refrigerant, or a mixed refrigerant as the refrigerant of the refrigeration cycle circuit **10**.
[0079] Moreover, the refrigeration cycle circuit **10** is provided with, for example, a refrigerant temperature sensor **18** that measures the temperature of the refrigerant, and a pressure sensor **19** that measures the pressure of the refrigerant. A control device **43** (refer to FIG. **7**) controls the number of rotations of the compressor **11** and the degree of opening of the expansion valve **14** on the basis of, for example, the temperature of the refrigerant measured by the refrigerant temperature sensor **18** and the pressure of the refrigerant measured by the pressure sensor **19** in addition to the temperature setting and measured temperature information of the control target **46**.
[0080] Next, the circulation fluid circuit **20** is described in detail. The circulation fluid circuit **20** configures a closed circuit where the circulation fluid that cools or heats the control target **46** circulates. Specifically, the circulation fluid circuit **20** includes: a plurality of circuit modules **21** that are connected to the control targets **46** and circulate the circulation fluid; a low-temperature path **31** that is connected to the circuit modules **21** and in which the circulation fluid flows through the evaporator **15** in such a manner as to be able to exchange heat with the refrigerant; and the high-temperature path **38** that is connected to the circuit modules **21** and in which the circulation fluid flows through the radiator **12** in such a manner as to be able to exchange heat with the refrigerant.
[0081] Each of the circuit modules **21** is a device that supplies the circulation fluid to the control target **46** and adjusts the temperature of the control target **46**. The each of the circuit modules **21** is formed with a basic circulation path **22** that is a basic closed circuit that circulates the circulation fluid. Specifically, the each of the circuit modules **21** is formed with the basic circulation path **22** being a closed circuit where a feed path **23** that supplies the circulation fluid to the control target **46** such as a semiconductor manufacturing apparatus, and a return path **24** that returns the circulation fluid that has cooled or heated the control target **46** are connected.
[0082] The feed path **23** of the each of the circuit modules **21** is provided with a circulating pump **25** that feeds the circulation fluid to the control target **46**, the heating apparatus **26** that heats the circulation fluid to be supplied to the control target **46** and adjusts the temperature, and a temperature sensor **27** that measure the temperature of the circulation fluid heated by the heating apparatus **26**.
[0083] The heating apparatus **26** is an induction heating type of heating means that heats the

circulation fluid. The heating apparatus **26** is described in detail below. The heating apparatus **26** is connected to an induction heating power supply **48**.

[0084] The induction heating power supply **48** is a power supply device that supplies electric power to the heating apparatus **26**. The electric power from the induction heating power supply **48** causes an alternating current to flow through the heating apparatus **26**. The circulation fluid is heated by induction heating with the alternating current.

[0085] The temperature sensor **27** is provided to the feed path **23** downstream of the heating apparatus **26**, and measures the temperature of the circulation fluid heated by the heating apparatus **26**. The circulating pump **25**, the heating apparatus **26**, and the temperature sensor **27** are connected to the control device **43**. The control device **43** controls the circulating pump **25** and the heating apparatus **26** in such a manner that the temperature of the circulation fluid measured by the temperature sensor **27** reaches a predetermined temperature. Consequently, the temperature of the control target **46** is controlled to a set temperature. Specifically, the control device **43** controls the output of the induction heating power supply **48**, that is, the electric power to be supplied to the heating apparatus **26**, and controls the heating of the circulation fluid with the heating apparatus **26**.

[0086] Moreover, the basic circulation path **22** of the each of the circuit modules **21** is provided with a solenoid valve **28** that opens and closes the feed path **23**. Consequently, if the control target **46** connected to the circuit module **21** does not require temperature control, the flow of the circulation fluid can be stopped by closing the solenoid valve **28**.

[0087] The low-temperature path **31** is a path for the refrigeration cycle circuit **10** to cool the circulation fluid. The low-temperature path **31** is connected on an inlet side thereof to a return path **24** side of the circuit module **21** and on an outlet side thereof to a feed path **23** side of the circuit module **21** in such a manner as to form a bypass path for the circulation fluid in the basic circulation path **22**.

[0088] In other words, the circulation fluid that circulates along the basic circulation path **22** of the circuit module **21** can flow into the low-temperature path **31** at a branch point being the inlet of the low-temperature path **31**. Moreover, the circulation fluid can also flow toward the feed path **23** without flowing into the low-temperature path **31**.

[0089] A junction of the outlet of the low-temperature path **31** and the basic circulation path **22** is provided with a mixing valve **30**. The mixing valve **30** is a valve that mixes the circulation fluid that has passed through the low-temperature path **31** with the circulation fluid to be supplied to the contract target **46** via the feed path **23** of the circuit module **21**. In other words, the mixing valve **30** can freely open and close the low-temperature path **31** and freely adjust the flow rate of the low-temperature path **31**.

[0090] The circulation fluid that has returned from the control target **46** is mixed with the circulation fluid cooled by the evaporation of the refrigerant by the evaporator **15** of the refrigeration cycle circuit **10** on the basis of adjustment by the mixing valve **30**. Therefore, operation that achieves a suitable temperature can be performed.

[0091] Moreover, it is also possible to perform operation that does not supply the circulation fluid cooled by the evaporator **15** to the control target **46** on the basis of adjustment by the mixing valve **30**. In other words, it is also possible to perform temperature adjustment operation in which only the circulation fluid that has returned from the control target **46**, or only the circulation fluid heated by the radiator **12**, is fed to the feed path **23**, heated by the heating apparatus **26**, supplied to the control target **46**, and circulated.

[0092] Moreover, the low-temperature path **31** is provided with a low-temperature tank **32** where the circulation fluid is stored, a low-temperature pump **33** that feeds the circulation fluid, and a low-temperature circulation path **34** that returns the circulation fluid to the inlet side of the low-temperature path **31** without feeding the circulation fluid to the control target **46**.

[0093] Specifically, for example, the low-temperature tank **32** is provided on the inlet side of the low-temperature path **31**. The low-temperature pump **33** is provided downstream of the low-temperature tank **32**. The evaporator **15** is provided downstream of the low-temperature pump **33**. The low-temperature circulation path **34** may be provided in such a manner as to connect a branch line pipe **36** provided downstream of the evaporator **15** of the low-temperature path **31**, and the low-temperature tank **32** provided on the inlet side of the low-temperature path **31**.

[0094] The low-temperature tank **32** is provided with a low-temperature sensor **37** that measures the temperature of the circulation fluid in the low-temperature tank **32**. The low-temperature pump **33** and the low-temperature sensor **37** are connected to the control device **43**. The control device **43** may control, for example, operation of the circulating pump **25** and the low-temperature pump **33** and the adjustment of the degree of opening of the mixing valve **30** by using information on the temperature of the circulation fluid measured by the low-temperature sensor **37** to make a computation.

[0095] As described above, the low-temperature path **31** is provided with the low-temperature tank **32**, the low-temperature pump **33** that feeds the circulation fluid, and the low-temperature circulation path **34** that returns the circulation fluid from the outlet side to the inlet side of the low-temperature path **31**. Hence, even if the circulation fluid in the low-temperature path **31** is not used as the circulation fluid to be supplied to the control target **46**, the circulation fluid in the low-temperature path **31** can be cooled by the refrigerant flowing through the evaporator **15** by circulating the circulation fluid in the low-temperature path **31**.

[0096] The circulation fluid cooled by the refrigerant can be stored in the low-temperature tank **32**, and the stored low-temperature circulation fluid can be supplied to the circulation fluid circuit **20** if needed. For example, if the temperature setting for the control target **46** is changed due to a change in, for example, a processing process to significantly reduce the temperature of the circulation fluid, the low-temperature circulation fluid stored in the cold tank can be supplied to the circulation fluid circuit **20**.

[0097] Consequently, the temperature of the circulation fluid that circulates in the circulation fluid circuit **20** can be quickly reduced to a predetermined temperature in a short time. Hence, the time required to change the temperature setting is significantly shortened; therefore, the loss of time accompanied by the change of the temperature before the start of, for example, a processing process or a measurement process can be reduced.

[0098] Moreover, as described above, the low-temperature path **31** is provided with the low-temperature tank **32**, the low-temperature pump **33**, and the low-temperature circulation path **34**. Hence, even if the circulation fluid in the low-temperature path **31** is not supplied to the control target **46**, it is possible to operate the refrigeration cycle circuit **10** and heat the circulation fluid in the high-temperature path **38** with the refrigerant of the radiator **12**.

[0099] The high-temperature path **38** is a path for the refrigeration cycle circuit **10** to heat the circulation fluid. The high-temperature path **38** is connected on an inlet side thereof to the return path **24** side of the circuit module **21** and on an outlet side thereof to the feed path **23** side of the circuit module **21** in such a manner as to form a bypass path for the circulation fluid in the basic circulation path **22**.

[0100] Specifically, the basic circulation path **22** of the circulation fluid circuit **20** is provided with a three-way valve **29** upstream of the branch point to the low-temperature path **31**. The three-way valve **29** is a valve that switches between whether or not the circulation fluid returning from the control target **46** is fed to the high-temperature path **38**. In other words, the three-way valve **29** can freely open and close the high-temperature path **38** and can freely adjust the flow rate of the high-temperature path **38**.

[0101] Specifically, the inlet of the high-temperature path **38** is connected to the three-way valve **29**. The outlet of the high-temperature path **38** is connected downstream of the three-way valve **29** of the basic circulation path **22** and upstream of the branch point to the low-temperature path **31**.

[0102] With such a configuration, the switching of the three-way valve **29** allows switching between operation in which the circulation fluid heated by the radiator **12** of the refrigeration cycle circuit **10** is supplied to the control target **46**, and operation in which the circulation fluid heated by the radiator **12** of the refrigeration cycle circuit **10** is not supplied to the control target **46**, and executing the operation.

[0103] The high-temperature path **38** is provided with the high-temperature tank **39** where the circulation fluid heated to a high temperature is stored, and a high-temperature sensor **42** that measures the temperature of the circulation fluid in the high-temperature tank **39**. The radiator **12** of the refrigeration cycle circuit **10** is provided in the high-temperature tank **39** in such a manner that the refrigerant can heat the circulation fluid. The high-temperature tank **39** is formed with a circulation fluid inlet in a lower part thereof, and is formed with a circulation fluid outlet in an upper part thereof. Consequently, the high-temperature circulation fluid stored in the high-temperature tank **39** can be efficiently supplied to the control target **46**.

[0104] In other words, the low-temperature circulation fluid returning from the control target **46** flows into the high-temperature path **38** via the three-way valve **29**, and flows into the high-temperature tank **39** through the inlet formed in the lower part of the high-temperature tank **39**. The high-temperature circulation fluid stored in the high-temperature tank **39** is fed to the basic circulation path **22** through the outlet formed in the upper part of the high-temperature tank **39**, and is supplied to the control target **46**.

[0105] In this manner, the temperature adjusting apparatus **1** includes the high-temperature tank **39**, and can feed the high-temperature circulation fluid stored in the high-temperature tank **39** to the basic circulation path **22**. Hence, for example, if the temperature setting for the control target **46** is changed due to a change in, for example, a processing process to significantly increase the temperature of the circulation fluid, the temperature can be changed with high efficiency.

[0106] In other words, it is possible to supply the high-temperature circulation fluid stored in the high-temperature tank **39** to the circulation fluid circuit **20** and quickly increase the temperature of the circulation fluid that circulates in the circulation fluid circuit **20** to a predetermined temperature in a short time. Hence, the temperature adjusting apparatus **1** can significantly shorten the time required to change the temperature setting and reduce the loss of time accompanied by the change in temperature before the start of, for example, a processing process or a measurement process.

[0107] Note that the control device **43** may use information on the temperature of the circulation fluid in the high-temperature tank **39**, the temperature being measured by the high-temperature sensor **42**, to perform a computation for opening and closing control over the three-way valve **29**. Consequently, the flow in the high-temperature path **38** can be controlled according to the amount of the high-temperature circulation fluid stored in the high-temperature tank **39**. Hence, if the high-temperature circulation fluid stored in the high-temperature tank **39** is less than required, it is possible to prevent the loss of time in the change of temperature, which is caused by feeding the circulation fluid that is low in temperature to the basic circulation path **22**.

[0108] Moreover, the low-temperature path **31** and the high-temperature path **38** are provided with line junction pipes **35** and **40** and the branch line pipe **36** and a branch line pipe **41**, which connect the plurality of circuit modules **21**. Specifically, the low-temperature path **31** is provided on the inlet side with the line junction pipe **35** and on the outlet side with the branch line pipe **36**. The high-temperature path **38** is provided on the inlet side with the line junction pipe **40** and on the outlet side with the branch line pipe **41**.

[0109] Consequently, the plurality of circuit modules **21**, for example, two to eight, or more circuit modules **21**, can be connected to the low-temperature path **31** and the high-temperature path **38** via the line junction pipes **35** and **40** and the branch line pipes **36** and **41**.

[0110] Each of the plurality of circuit modules **21** includes the circulating pump **25** and the heating apparatus **26**, and can circulate the circulation fluid to another control target **46**. Consequently, it is possible to cool or heat the control targets **46** in, for example, a plurality of spots to be processed or measured with high efficiency by use of one refrigeration cycle circuit **10** and adjust the control targets **46** to their suitable temperatures.

[0111] FIG. **2** is a diagram illustrating a schematic configuration of the heating apparatus **26**, and illustrates the cross section of a pipe **55**. Note that in FIG. **2**, an arrow indicates the circulation fluid flow direction. The heating apparatus **26** includes the pipe **55** where the circulation fluid flows, and a primary coil **50** wound on an outer periphery of the pipe **55** (refer to FIG. **2**)

[0112] The pipe **55** is provided to the feed path **23** (refer to FIG. **1**) of the basic circulation path **22** (refer to FIG. **1**), and serves as a channel where the circulation fluid flows.

[0113] The primary coil **50** generates an alternating magnetic field by use of an alternating current, is formed of, for example, a conductive wire covered with an insulating material, and is wound into an approximately spiral shape on the outer periphery of the pipe **55**. In other words, the primary coil **50** configures a coil-shaped conductive path on the outer periphery of the pipe **55**, and is connected at both ends to the induction heating power supply **48** (refer to FIG. **1**).

[0114] The pipe **55** is formed of, for example, a conductive material. Consequently, the pipe **55** can generate heat by induction heating with the alternating current in the primary coil **50**, and heat the circulation fluid flowing in the pipe **55**.

[0115] In other words, a magnetic field is generated by the alternating current flowing through the primary coil **50**. Eddy currents flow through the pipe **55** in such a manner as to cancel the magnetic field. The pipe **55** has electric resistance; therefore, the eddy currents flowing through the pipe **55** generates Joule heat. The circulation fluid flowing in the pipe **55** can be heated.

[0116] In this manner, the heat of the pipe **55** that generates heat by electromagnetic induction is transferred directly to the circulation fluid. Therefore, the circulation fluid can be efficiently heated to an exact temperature. Hence, it is possible for, for example, a semiconductor manufacturing apparatus to shorten the time required to heat the circulation fluid for temperature control and to execute a highly efficient processing process with little loss of time.

[0117] FIG. **3** is a diagram illustrating another example of the heating apparatus **26**, and illustrates the cross section of the pipe **55**. Note that in FIG. **3**, an arrow indicates the circulation fluid flow direction. As illustrated in FIG. **3**, the pipe **55** may be provided therein with a heating tube **52** as a heating element **51** made of a conductive material, inside an area where the primary coil **50** is wound.

[0118] For example, the heating tube **52** is an approximately tubular member provided substantially coaxially with the pipe **55**. In other words, the pipe **55** and the approximately tubular heating tube **52** provided inside the pipe **55** form a substantially double-pipe shape. Such a heating tube **52** is provided; therefore, the heating tube **52** generates heat by induction heating with the alternating current in the primary coil **50**, and as a result, the high-temperature heating tube **52** can heat the circulation fluid directly.

[0119] Note that the heating tube **52** provided inside the pipe **55** is simply required to be a member formed of a conductive material such as copper, iron, stainless steel, and other metals. It is preferable that the material forming the heating tube **52** be, for example, an iron-based material, a nickel alloy-based material, or a ferritic stainless steel material, whose relative inductivity is equal to or greater than one. Consequently, highly efficient induction heating is performed. Moreover, the shape of the heating tube **52** is not limited to a tubular shape.

[0120] Moreover, for example, a metal plate formed with through-holes as in, for example, punched metal may be used as the material forming the heating tube **52**. Consequently, the holes formed in the heating tube **52** can be used as channels through which the circulation fluid passes. The heating tube **52** in such a form makes it possible to obtain the heating element **51** where the flow resistance of the circulation fluid is small and which can efficiently heat the circulation fluid.

[0121] FIG. **4** is a diagram illustrating still another example of the heating apparatus **26**, and illustrates the cross section of the pipe **55**. Note that in FIG. **4**, an arrow indicates the circulation fluid flow direction. As illustrated in FIG. **4**, the heating element **51** provided inside the pipe **55** may be a heating loop **53** having a closed loop form formed of a conductive wire.

[0122] Specifically, both ends of the conductive wire forming the heating loop **53** are connected together in such a manner as to configure a conductive closed circuit. Such a form enables an induced current to efficiently flow through the heating element **51** and the efficiency of induction heating of the heating element **51** to increase. Moreover, it is possible to reduce the flow resistance of the circulation fluid near the heating element **51** and efficiently circulate the circulation fluid.

[0123] Moreover, the heating loop **53** may be formed of a conductive wire such as an iron wire, a nickel alloy wire, or a ferritic stainless steel wire, whose relative inductivity is equal to or greater than one. The use of a conductive wire made of such a ferromagnetic material enables concentration of magnetic flux to the heating element **51** and highly efficient induction heating. Moreover, the use of an iron wire can keep the manufacturing cost of the heating loop **53** low, and therefore, is suitable also from the perspective of the productivity of the heating loop **53**.

[0124] Moreover, the conductive wire forming the heating loop **53** is covered with, for example, enamel, a glass tube, or a resin material. In other words, the conductive wire is coated or covered with, for example, a resin material. Consequently, leakage of an induced current to the outside of the conductive wire is prevented, and safe and highly efficient induction heating is performed.

[0125] FIG. **5** is a diagram illustrating yet another example of the heating apparatus **26**, and illustrates the cross section of the pipe **55**. Note that in FIG. **5**, an arrow indicates the circulation fluid flow direction. As illustrated in FIG. **5**, a secondary coil **54** made of a conductive material may be provided as the heating element **51** inside the pipe **55**. Specifically, the secondary coil **54** is a member being, for example, a conductive wire rod wound into a coil.

[0126] With such a configuration, the secondary coil **54** being the heating element **51** generates heat by induction heating with the alternating current in the primary coil **50**. The heat of the secondary coil **54** that has reached a high temperature is transferred directly to the circulation fluid. The circulation fluid can be efficiently heated to an exact temperature. Hence, it is possible to reduce the loss of time in a manufacturing process and increase the productivity of, for example, a semiconductor apparatus.

[0127] Note that, the heating element **51** such as the heating tube **52** (refer to FIG. **3**), the heating loop **53** (refer to FIG. **4**), or the secondary coil **54** is fixed to an inner periphery of the pipe **55** with, for example, an unillustrated insulating support member. In other words, the heating element **51** such as the secondary coil **54** is not in contact with the primary coil **50** where the alternating current flows, and is provided in the pipe **55** where the circulation fluid flows. Hence, it is possible to reduce heat dissipation from, for example, the secondary coil **54** being the heating element **51** directly to the outside of the pipe **55**, and perform highly efficient heating with little radiation heat loss.

[0128] Moreover, the heating apparatus **26** is configured in such a manner that the heating element **51** such as the secondary coil **54** is provided in a noncontact manner with the primary coil **50** to which the induction heating power supply **48** (refer to FIG. **1**) is connected and to which an alternating current is supplied. Hence, it is excellent also from the perspective of safety and reliability against, for example, current leakage and damage to electric wiring.

[0129] Moreover, the heating element **51** wound into a coil is adopted in this manner; therefore, the flow resistance of the circulation fluid in the heating element **51** is reduced to enable highly efficient circulation of the circulation fluid.

[0130] Moreover, the secondary coil **54** as the heating element **51** configures a conductive closed circuit by connecting both ends of a coil path wound into a coil. Consequently, highly efficient induction heating where an induced current flows suitably is made possible.

[0131] Moreover, the secondary coil **54** may include a portion that is wound in such a manner that the winding diameter of the coil path is different between an upstream side and a downstream side of the pipe **55**. Specifically, the secondary coil **54** may be formed with a large-diameter winding portion where the winding diameter of the coil path is large, and a small-diameter winding portion where the winding diameter of the coil path is small.

[0132] For example, the large-diameter winding portion and the small-diameter winding portion, which have different winding diameters, are formed in this manner. Therefore, it is possible to cause suitable turbulence in the circulation fluid around the secondary coil **54** and promote heat exchange between the heating element **51** and the circulation fluid. Hence, highly efficient heating with the secondary coil **54** allows the circulation fluid to be efficiently adjusted to an exact temperature in a short time.

[0133] Specifically, the secondary coil **54** may be wound into an approximately conical or approximately cup shape having a coil winding diameter that reduces gradually. Such a form prevents the circulation fluid flowing in the pipe **55** to pass through a position away from the secondary coil **54** as the heating element **51**, and causes the circulation fluid to pass through the secondary coil **54** in proximity to a heating portion of the secondary coil **54**.

[0134] In other words, the circulation water is prevented from passing through the secondary coil **54** while remaining at a low temperature without being heated by the secondary coil **54**. The circulation fluid passing through the secondary coil **54** is suitably heated in proximity to the secondary coil **54**. Hence, the secondary coil **54** can efficiently heat the circulation fluid to an exact temperature.

[0135] Note that as illustrated in FIG. **5**, the secondary coil **54** wound into an approximately conical spiral shape may be provided in such a manner that the small-diameter winding portion whose winding diameter is small is on the upstream side of the flow of the circulation fluid and the large-diameter winding portion whose winding diameter is large is on the downstream side. Moreover, conversely, the secondary coil **54** may be provided in such a manner that the large-diameter winding portion whose winding diameter is large is on the upstream side of the pipe **55** and the small-diameter winding portion whose winding diameter is small is on the downstream side.

[0136] Moreover, as in the above-mentioned heating loop **53**, the secondary coil **54** may be formed of a ferromagnetic material whose relative inductivity is equal to or greater than one, or preferably much greater than one. For example, the secondary coil **54** may be formed of at least one of, for example, a ferritic stainless steel material, an iron-based material, or a nickel alloy-based material.

[0137] The ferritic stainless steel material enables obtaining the secondary coil **54** excellent in corrosion resistance, durability, and safety, and increasing the efficiency of induction heating of the secondary coil **54** by concentrating an alternating magnetic field of the primary coil **50** to the secondary coil **54** made of a high magnetic material. Hence, the circulation fluid can be efficiently heated. Moreover, the iron-based material also has an advantage that the production cost of the secondary coil **54** can be reduced in addition to that an increase in the efficiency of induction heating can be encouraged. Moreover, the secondary coil **54** may be covered with an insulating member as in the above-mentioned heating loop **53**.

[0138] Moreover, the pipe **55** may be formed of a non-magnetic material such as an austenitic stainless steel material. Consequently, it is possible to obtain the pipe **55** excellent in corrosion resistance, durability, and safety, and increase the efficiency of induction heating of the secondary coil **54** by concentrating an alternating magnetic field of the primary coil **50** to the secondary coil **54**.

[0139] FIG. **6** is a diagram illustrating a schematic configuration of the heating apparatus **26**, and illustrates an example of a schematic form of the pipe **55** and the primary coil **50**. As illustrated in FIG. **6**, the pipe **55** forming the heating apparatus **26** may include a bend pipe portion **56** in an area where the primary coil **50** is wound, and the area where the primary coil **50** is wound may be formed in an approximately circular shape, an approximately elliptic shape, or an approximately track shape. Consequently, it is possible to increase magnetic flux density in the pipe **55** by concentrating, in the pipe **55**, magnetic flux generated by the alternating current in the primary coil **50**.

[0140] In other words, the pipe **55** is formed with the bend pipe portion **56**; therefore, one end of the area of the pipe **55** where the primary coil **50** is wound and the other end are close to each other.

Consequently, magnetic flux generated outside the pipe **55** is generated at close range in such a manner that the vicinity of the one end and the vicinity of the other end, which are close to each other, are connected together. Hence, it is possible to reduce the magnetic flux along the outer periphery of the pipe **55** and concentrate the alternating magnetic flux in the pipe **55**. It is possible to increase eddy currents generated in the heating element **51** such as the heating tube **52** (refer to FIG. **3**), the heating loop **53** (refer to FIG. **4**), or the secondary coil **54** (refer to FIG. **5**) and increase the efficiency of induction heating.
[0141] FIG. **7** is a block diagram illustrating a control system of the temperature adjusting apparatus **1**. As illustrated in FIG. **7**, the temperature adjusting apparatus **1** includes the control device **43** that controls the constituent equipment. The control device **43** is a control means including a microprocessor, and executes a predetermined computation to control the temperature of the control target **46** (refer to FIG. **1**).
[0142] Inputs of the control device **43** are connected to sensors such as the refrigerant temperature sensor **18** that detects the temperature of the refrigerant, the pressure sensor **19** that detects the pressure of the refrigerant, the temperature sensor **27** that detects the temperature of the circulation fluid to be supplied to the control target **46**, the low-temperature sensor **37** that detects the temperature of the circulation fluid in the low-temperature path **31**, the high-temperature sensor **42** that detects the temperature of the circulation fluid in the high-temperature path **38**, and a temperature sensor **47** that detects the temperature of the control target **46**.
[0143] Outputs of the control device **43** are connected to, for example, the compressor **11**, the expansion valve **14**, and the air-blowing fan **16** of the refrigeration cycle circuit **10**, and the circulating pump **25**, the heating apparatus **26**, the solenoid valve **28**, the three-way valve **29**, the mixing valve **30**, and the low-temperature pump **33** of the circulation fluid circuit **20**.
[0144] Moreover, the control device **43** is provided with an input device **44** that inputs a temperature setting for the control target **46** and other pieces of operation information, and a display device **45** that displays information on the temperature of each portion and other pieces of control information.
[0145] Note that the control device **43** may be connected to, for example, other unillustrated sensors, information input equipment, display devices, control target equipment, and recording devices.
[0146] The control device **43** executes predetermined computations on the basis of inputs of, for example, the refrigerant temperature sensor **18**, the pressure sensor **19**, the temperature sensor **27**, the low-temperature sensor **37**, the high-temperature sensor **42**, the temperature sensor **47**, and the input device **44**, and controls, for example, the compressor **11**, the expansion valve **14**, the air-blowing fan **16**, the circulating pump **25**, the heating apparatus **26**, the solenoid valve **28**, the three-way valve **29**, the mixing valve **30**, and the low-temperature pump **33**.
[0147] Next, a method for adjusting temperature with the temperature adjusting apparatus **1** is described in detail with reference to FIGS. **8** to **11**.
[0148] FIG. **8** is a diagram illustrating a circulation fluid flow path, and illustrates an example where the circulation fluid cooled or heated in the refrigeration cycle circuit **10** is not used. Note that in FIGS. **8** to **11**, the path where the circulation fluid flows is indicated by thick lines, and the circulation fluid flow direction is indicated by arrows.
[0149] As illustrated in FIG. **8**, the three-way valve **29** closes the high-temperature path **38**, and the mixing valve **30** closes the low-temperature path **31**. Therefore, it is also possible to not supply, to the control target **46**, the circulation fluid cooled by the evaporator **15** and the circulation fluid heated by the radiator **12**. In other words, the circulation fluid circulates along the basic circulation path **22** without flowing along the low-temperature path **31** and the high-temperature path **38**. In this manner, it is also possible to perform the temperature adjustment operation where the circulation fluid flowing along the low-temperature path **31** or the high-temperature path **38** is not fed to the feed path **23**, but only the circulation fluid that has returned from the control target **46** is

fed directly to the feed path **23**, heated by the heating apparatus **26**, fed to the control target **46**, and circulated.

[0150] FIG. **9** is a diagram illustrating a circulation fluid flow path in a case where the temperature adjustment operation is performed by use of the circulation fluid cooled in the refrigeration cycle circuit **10**. As illustrated in FIG. **9**, if the control target **46** needs to be cooled, the control device **43** (refer to FIG. **7**) controls the mixing valve **30**, and opens the low-temperature path **31** of the circulation fluid circuit **20** to allow the circulation fluid to flow along the low-temperature path **31**.

[0151] As a result, a part of the circulation fluid that has returned from the control target **46** flows along the low-temperature path **31**, and is cooled by use of the latent heat of the refrigerant that evaporates in the evaporator **15** of the refrigeration cycle circuit **10**. The circulation fluid cooled in the refrigeration cycle circuit **10** then merges with the circulation fluid in the basic circulation path **22** that has not flowed along the low-temperature path **31**, is heated to a predetermined temperature by the heating apparatus **26**, and is supplied at the suitable temperature to the control target **46** in such a manner that the control target **46** reaches a set temperature.

[0152] FIG. **10** is a diagram illustrating another example of using the circulation fluid cooled in the refrigeration cycle circuit **10**. As illustrated in FIG. **10**, the mixing valve **30** may be controlled in such a manner as to open the low-temperature path **31** 100%. In other words, the circulation fluid returning from the control target **46** does not pass directly through the mixing valve **30**, but all the circulation fluid returning from the control target **46** passes through the low-temperature path **31**. Only the circulation fluid cooled by the refrigerant in the refrigeration cycle circuit **10** is then fed to the feed path **23** through the mixing valve **30**.

[0153] With such a flow path, it is possible to feed, to the circulation fluid circuit **20**, a large amount of circulation fluid cooled to a low temperature in the refrigeration cycle circuit **10** and stored in the low-temperature tank **32** and to quickly reduce the temperature of the circulation fluid to be supplied to the control target **46**. Hence, it is possible to reduce the loss of time in, for example, the process of changing the temperature setting and increase productivity of, for example, a semiconductor apparatus.

[0154] FIG. **11** is a diagram illustrating a circulation fluid flow path in a case where the temperature adjustment operation is performed by use of the circulation fluid heated in the refrigeration cycle circuit **10**. If the temperature of the circulation fluid returning from the control target **46** is low and needs to be increased sharply, the control device **43** (refer to FIG. **7**) controls the three-way valve **29** to open the high-temperature path **38** of the circulation fluid circuit **20**. Consequently, the circulation fluid returning from the control target **46** flows along the high-temperature path **38**. The circulation fluid in the high-temperature tank **39** that has increased to a high temperature by use of the heat dissipated from the refrigerant flowing through the radiator **12** of the refrigeration cycle circuit **10** is then fed to the basic circulation path **22** (refer to FIG. **11**).

[0155] The circulation fluid heated in the refrigeration cycle circuit **10** is then fed to the feed path **23** via the mixing valve **30**, heated to a predetermined temperature by the heating apparatus **26**, and supplied at the suitable temperature to the control target **46** in such a manner that the control target **46** reaches an exact set temperature.

[0156] In this manner, the heat dissipation of the radiator **12** of the refrigeration cycle circuit **10** is used to heat the circulation fluid. The circulation fluid is stored in the high-temperature tank **39**. The high-temperature circulation fluid stored in the high-temperature tank **39** is supplied to the basic circulation path **22**. Therefore, the temperature of the circulation fluid flowing along the basic circulation path **22** can be changed to a high temperature in a short time. Hence, it is possible to keep the amount of energy consumed by the heating apparatus **26** of the circulation fluid circuit **20** low, and adjust temperature with high efficiency.

[0157] When the control device **43** opens the three-way valve **29**, the high-temperature circulation fluid stored in the high-temperature tank **39** is fed to the basic circulation path **22**. After the temperature of the circulation fluid circulating along the basic circulation path **22** increases to a

predetermined temperature in a short time, the control device **43** may close the three-way valve **29** to perform normal temperature adjustment operation where the circulation fluid does not flow along the high-temperature path **38**, as illustrated in FIGS. **8**, **9**, and **10**.
[0158] In other words, as illustrated in FIG. **8**, the operation that adjusts temperature may be performed by only the heating apparatus **26** heating the circulation fluid circulating along the basic circulation path **22** without using the refrigeration cycle circuit **10**. Moreover, as illustrated in FIG. **9**, the operation that adjusts temperature may be performed by mixing the low-temperature refrigerant flowing along the low-temperature path **31** with the circulation fluid circulating along the basic circulation path **22**. Moreover, as illustrated in FIG. **10**, the temperature adjustment operation may be performed in which the mixing valve **30** opens the low-temperature path **31** 100%, and all the circulation fluid circulating along the basic circulation path **22** is fed to the feed path **23** via the low-temperature path **31**.
[0159] In other words, as illustrated in FIG. **11**, after the temperature is changed with a large temperature difference due to a change in, for example, a processing process, the temperature can be adjusted by use of cooling capacity and heating capacity as small as matching the amount of heat dissipated and the amount of heat absorbed from the control target **46**, as illustrated in FIGS. **8**, **9**, and **10**.
[0160] In this manner, the temperature adjusting apparatus **1** can change a temperature setting efficiently in a short time by circulating the circulation fluid along a suitable path according to the state of the control target **46**, and can adjust the temperature of the control target **46** efficiently with a little amount of energy consumed.
[0161] As described above, the temperature adjusting apparatus **1** according to the embodiment can adjust the temperature of the control target **46** such as a semiconductor manufacturing apparatus with high efficiency and with little loss of exhaust heat by use of both cold heat and hot heat, which are generated in the refrigeration cycle circuit **10**.
[0162] Note that the present invention is not limited to the above embodiment. The present invention can undergo various modifications and implementations within the scope that does not depart from the gist of the present invention.
LIST OF REFERENCE NUMBERS
[0163] **1** Temperature adjusting apparatus [0164] **10** Refrigeration cycle circuit [0165] **11** Compressor [0166] **12** Radiator [0167] **13** Second radiator [0168] **14** Expansion valve [0169] **15** Evaporator [0170] **16** Air-blowing fan [0171] **17** Refrigerant piping [0172] **18** Refrigerant temperature sensor [0173] **19** Pressure sensor [0174] **20** Circulation fluid circuit [0175] **21** Circuit module [0176] **22** Basic circulation path [0177] **23** Feed path [0178] **24** Return path [0179] **25** Circulating pump [0180] **26** Heating apparatus [0181] **27** Temperature sensor [0182] **28** Solenoid valve [0183] **29** Three-way valve [0184] **30** Mixing valve [0185] **31** Low-temperature path [0186] **32** Low-temperature tank [0187] **33** Low-temperature pump [0188] **34** Low-temperature circulation path [0189] **35** Line junction pipe [0190] **36** Branch line pipe [0191] **37** Low-temperature sensor [0192] **38** High-temperature path [0193] **39** High-temperature tank [0194] **40** Line junction pipe [0195] **41** Branch line pipe [0196] **42** High-temperature sensor [0197] **43** Control device [0198] **44** Input device [0199] **45** Display device [0200] **46** Control target [0201] **47** Temperature sensor [0202] **48** Induction heating power supply [0203] **50** Primacy coil [0204] **51** Heating element [0205] **52** Heating tube [0206] **53** Heating loop [0207] **54** Secondary coil [0208] **55** Pipe [0209] **56** Bend pipe portion

Claims

1-2. (canceled)
3. A heating apparatus that heats circulation fluid that adjusts a temperature of a control target, the heating apparatus comprising: a pipe where the circulation fluid flows; a primary coil wound on an

outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound, wherein the heating element generates heat by induction heating with the alternating current in the primary coil, and the heating element heats the circulation fluid, the heating element is formed of a conductive wire covered with an insulating member and having relative inductivity equal to or greater than one, and the conductive wire is connected at both ends in such a manner as to configure a conductive closed loop.

4. A heating apparatus that heats circulation fluid that adjusts a temperature of a control target, the heating apparatus comprising: a pipe where the circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound, wherein the heating element generates heat by induction heating with the alternating current in the primary coil, and the heating element heats the circulation fluid, the heating element is a secondary coil wound into a coil, and the secondary coil configures a conductive closed circuit by connecting both ends of a coil path wound into a coil.

5. The heating apparatus according to claim 4, wherein the secondary coil includes a portion that is wound in such a manner that a winding diameter of the coil path is different between an upstream side and a downstream side of the pipe.

6. The heating apparatus according to claim 4, wherein the secondary coil is formed of at least one of an iron-based material, a nickel alloy-based material, or a ferritic stainless steel material.

7. The heating apparatus according to claim 6, wherein the pipe is formed of an austenitic stainless steel material.

8. The heating apparatus according to claim 3, wherein the pipe includes a bend pipe portion in the area where the primary coil is wound, and the area where the primary coil is wound is formed in a circular shape, an elliptic shape, or a track shape.

9-10. (canceled)

11. A temperature adjusting apparatus comprising: a refrigeration cycle circuit where a compression means, a radiator, a throttle means, and an evaporator are sequentially connected and a refrigerant circulates; and a circulation fluid circuit provided with a circulating pump and a heating apparatus, in which circulation fluid that adjusts a temperature of a control target circulates, wherein the circulation fluid circuit is formed, upstream of the heating apparatus, with a freely openable and closable low-temperature path where the circulation fluid flows through the evaporator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the heating apparatus includes: a pipe where the circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound, the heating element generates heat by induction heating with the alternating current in the primary coil, and the heating element heats the circulation fluid, the heating element is formed of a conductive wire covered with an insulating member and having relative inductivity equal to or greater than one, and the conductive wire is connected at both ends in such a manner as to configure a conductive closed loop.

12. A temperature adjusting apparatus comprising: a refrigeration cycle circuit where a compression means, a radiator, a throttle means, and an evaporator are sequentially connected and a refrigerant circulates; and a circulation fluid circuit provided with a circulating pump and a heating apparatus, in which circulation fluid that adjusts a temperature of a control target circulates, wherein the circulation fluid circuit is formed, upstream of the heating apparatus, with a freely openable and closable low-temperature path where the circulation fluid flows through the evaporator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the heating apparatus includes: a pipe where the circulation fluid flows; a primary coil wound on an outer periphery of the pipe, through which an alternating current flows; and a conductive heating element provided inside an area of the pipe where the primary coil is wound, the heating element generates heat by induction heating with the alternating current in the primary coil, and the heating element heats the circulation fluid, the heating element is a secondary coil wound into a coil, and the secondary coil configures a conductive closed circuit by connecting both ends of a coil path wound into a coil.

13. The temperature adjusting apparatus according to claim 12, wherein the secondary coil includes a portion that is wound in such a manner that a winding diameter of the coil path is different between an upstream side and a downstream side of the pipe.

14. The temperature adjusting apparatus according to claim 11, wherein the pipe includes a bend pipe portion in the area where the primary coil is wound, and the area where the primary coil is wound is formed in a circular shape, an elliptic shape, or a track shape.

15. The temperature adjusting apparatus according to claim 11, wherein the circulation fluid circuit is formed, upstream of the heating apparatus, with a freely openable and closable high-temperature path where the circulation fluid flows through the radiator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the refrigerant is carbon dioxide, and heats the circulation fluid under supercritical pressure in the radiator, and the high-temperature path is provided with a high-temperature tank where the circulation fluid heated by the refrigerant in the radiator is stored.

16. The heating apparatus according to claim 4, wherein the pipe includes a bend pipe portion in the area where the primary coil is wound, and the area where the primary coil is wound is formed in a circular shape, an elliptic shape, or a track shape.

17. The temperature adjusting apparatus according to claim 12, wherein the pipe includes a bend pipe portion in the area where the primary coil is wound, and the area where the primary coil is wound is formed in a circular shape, an elliptic shape, or a track shape.

18. The temperature adjusting apparatus according to claim 12, wherein the circulation fluid circuit is formed, upstream of the heating apparatus, with a freely openable and closable high-temperature path where the circulation fluid flows through the radiator in such a manner that heat is exchangeable between the circulation fluid and the refrigerant, the refrigerant is carbon dioxide, and heats the circulation fluid under supercritical pressure in the radiator, and the high-temperature path is provided with a high-temperature tank where the circulation fluid heated by the refrigerant in the radiator is stored.