[DESCRIPTION]

[Title]

COOLING METHOD, METHOD OF MANUFACTURING SEMICONDUCTOR DEVICE, PROGRAM AND SUBSTRATE PROCESSING APPARATUS

[Technical Field]

[0001]

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

[Related Art]

[0002]

In general, in a vertical type substrate processing apparatus used in a manufacturing process of a semiconductor device, a transfer chamber is provided adjacent to a process chamber in which a substrate is processed. A temperature of the substrate processed in the process chamber is lowered to a predetermined temperature while being supported by a substrate retainer in the transfer chamber.

[0003]

For example, according to Patent Document 1 below, the substrate processed in the process chamber is cooled while being supported by the substrate retainer in the transfer chamber.

[0004]

However, when the substrate is accommodated in a lower region of the substrate retainer, the substrate may be reheated by the radiant heat from components in the vicinity of the substrate. Therefore, a cooling time of lowering the temperature of the substrate to the predetermined temperature may be lengthened. As a result, a transfer operation of the substrate may be delayed.

[Related Art Document]

[Patent document]

[0005]

Patent Document 1: International Patent Publication No. WO2017/163376

[Disclosure]

[Technical Problem]

[0006]

According to the present disclosure, there is provided a technique capable of shortening a cooling time of a substrate after the substrate is processed.

[Technical Solution]

[0007]

According to one aspect of the technique of the present disclosure, there is provided a cooling method of cooling one or more substrates accommodated in a substrate retainer after processing the substrate, the cooling method including: (a) cooling a substrate by supplying a gas toward the substrate retainer located at a predetermined reference position; (b) stopping supplying the gas; and (c) cooling the substrate accommodated in a lower region of the substrate retainer.

[Advantageous Effects]

[0008]

According to some embodiments of the technique of the present disclosure, it is possible to shorten a cooling time of a substrate after the substrate is processed.

[Brief Description of Drawings]

[0009]

FIG. 1 is a diagram schematically illustrating a vertical cross-section of a substrate processing apparatus according to one or more embodiments of the present disclosure.

FIG. 2 is a diagram schematically illustrating a horizontal cross-section of a transfer chamber of the substrate processing apparatus according to the embodiments of the present disclosure.

FIG. 3A is a diagram schematically illustrating a vertical cross-section of the transfer

chamber when a boat is located at a reference position, and FIG. 3B is a diagram schematically illustrating the vertical cross-section of the transfer chamber when the boat is located at an elevated position.

FIG. 4 is a flowchart schematically illustrating a cooling step of cooling a processed wafer in the transfer chamber according to the embodiments of the present disclosure.

FIGS. 5A and 5B are diagrams schematically illustrating a vertical cross-section of a transfer chamber of the substrate processing apparatus according to a first modified example of the embodiments of the present disclosure, wherein FIG. 5A schematically illustrates the transfer chamber when the boat is located at the reference position, and FIG. 5B schematically illustrates the transfer chamber when the boat is located at the elevated position.

FIGS. 6A and 6B are diagrams schematically illustrating a vertical cross-section of a transfer chamber of the substrate processing apparatus according to a second modified example of the embodiments of the present disclosure, wherein FIG. 6A schematically illustrates the transfer chamber when the boat is located at the reference position, and FIG. 6B schematically illustrates the transfer chamber when the boat is located at the elevated position.

FIGS. 7A and 7B are diagrams schematically illustrating a vertical cross-section of a transfer chamber of the substrate processing apparatus according to a third modified example of the embodiments of the present disclosure, wherein FIG. 7A schematically illustrates the transfer chamber when the boat is located at the reference position, and FIG. 7B schematically illustrates the transfer chamber when the boat is located at the elevated position.

FIGS. 8A and 8B are diagrams schematically illustrating a vertical cross-section of a transfer chamber of the substrate processing apparatus according to a fourth modified example of the embodiments of the present disclosure, wherein FIG. 8A schematically illustrates the transfer chamber when the boat is located at the reference position, and FIG. 8B schematically illustrates the transfer chamber when the boat is located at the elevated position.

FIG. 9 is a diagram schematically illustrating a vertical cross-section of a transfer chamber of the substrate processing apparatus according to a fifth modified example of the embodiments of the present disclosure.

FIG. 10 is a flowchart schematically illustrating a cooling step of cooling the processed wafer in the transfer chamber according to the fifth modified example of the embodiments of the present disclosure.

[Detailed Description]

[0010]

<Embodiments>

Hereinafter, one or more embodiments (also simply referred to as "embodiments") according to the technique of the present disclosure will be described with reference to the drawings. The drawings used in the following descriptions are all schematic. For example, a relationship between dimensions of each component and a ratio of each component shown in the drawing may not always match the actual ones. Further, even between the drawings, the relationship between the dimensions of each component and the ratio of each component may not always match. In addition, like reference numerals represent like components in the drawings, and redundant descriptions related thereto will be omitted.

[0011]

A substrate processing apparatus according to the present embodiments is configured as a vertical type substrate processing apparatus (hereinafter, simply referred to as a "substrate processing apparatus") 1 capable of performing a substrate processing such as a heat treatment process. The substrate processing is performed as a part of a manufacturing process in a method of manufacturing a semiconductor device. As shown in FIG. 1, the substrate processing apparatus 1 includes a transfer chamber 2 and a process furnace 3 provided above the transfer chamber 2.

[0012]

The process furnace 3 includes a reaction tube 4 of a cylindrical shape and a heater 5 serving as a first heating structure (heater) installed on an outer periphery of the reaction tube 4. For example, the reaction tube 4 is made of a heat resistant material such as quartz and silicon carbide (SiC). A process chamber 6 in which a wafer W serving as a substrate is processed is provided in the reaction tube 4. A temperature detector 7 serving as a temperature detecting structure is installed in the reaction tube 4.

[0013]

A manifold 8 of a cylindrical shape is connected to a lower end opening of the reaction tube 4 via a seal (not shown) such as an O-ring. The manifold 8 is configured to support a lower end of the reaction tube 4. For example, the manifold 8 is made of a metal such as stainless steel. A lower end opening of the manifold 8 is opened or closed by a shutter 9 of a disk shape or a lid 11 of a disk shape. For example, the lid 11 is made of a metal. A seal (not shown) such as an O-ring is provided on an upper surface of the shutter 9 or an upper surface of the lid 11 so that an inner atmosphere of the reaction tube 4 is hermetically (airtightly) sealed from an outside atmosphere.

[0014]

A boat 13 serving as a substrate retainer is installed on the lid 11. A heat insulator 12 is provided below the boat 13. For example, the heat insulator 12 is made of quartz. A substrate accommodating region of the boat 13 is provided above the heat insulator 12. The boat 13 is constituted by a top plate 13a, a bottom plate 13c and a plurality of support columns 13b installed between the top plate 13a and the bottom plate 13c. For example, the boat 13 is configured to support a plurality of wafers including the wafer W in a multistage manner by placing the plurality of wafers including the wafer W in a plurality of grooves provided at the plurality of support columns 13b. Hereinafter, the plurality of wafers including the wafer W may also be simply referred to as wafers W. For example, the boat 13 is made of a heat resistant material such as quartz and SiC. When the wafers W are processed, the boat 13 is accommodated in the process chamber 6. Further, a heat

insulating region is constituted by the heat insulator 12. For example, the heat insulator 12 may be provided as a separate body from the boat 13.

[0015]

As shown in FIGS. 3A and 3B, the substrate accommodating region of the boat 13 may be divided into two regions, that is, an upper substrate accommodating region 13d and a lower substrate accommodating region 13e provided below and adjacent to the upper substrate accommodating region 13d. Some of the wafers W may be transferred into the upper substrate accommodating region 13d and accommodated in the upper substrate accommodating region 13d, and other wafers among the wafers W may be transferred into the lower substrate accommodating region 13e and accommodated in the lower substrate accommodating region 13e.

[0016]

The heat insulator 12 is connected to a rotating shaft 15 passing through the lid 11. The rotating shaft 15 is connected to a rotator 16 installed below the lid 11. By rotating the rotating shaft 15 by the rotator 16, it is possible to rotate the heat insulator 12 and the boat 13.

[0017]

A substrate transfer device 17, the boat 13 and a boat elevator 18 serving as an elevating structure are arranged in the transfer chamber 2. The substrate transfer device 17 includes an arm (tweezers) 17a capable of taking out, for example, five wafers including the wafer W. The substrate transfer device 17 is configured to be capable of transferring the wafer W between a pod 21 placed at a position of a pod opener 19 and the boat 13 by rotating the arm (tweezers) 17a up and down by a driving structure (not shown). Further, the substrate transfer device 17 is configured to be capable of performing a wafer mapping. In the present specification, the wafer mapping refers to an operation of checking the presence or absence of the wafer W and/or checking a placement state of the wafer W. In particular, since sensors (for example, light emitting structures and light receiving structures) are provided on left and right sides of a front end (tip) of the arm (tweezers) 17a of the substrate

transfer device 17, it is possible to detect the presence or absence of the wafer W by passing an arc of the wafer W between the sensors. It is also possible to detect the placement state (posture) of the wafer W by placing the sensors at three consecutive positions close to the wafer W.

[0018]

The boat elevator 18 is configured to transfer the boat 13 into or out of the reaction tube 4 by elevating or lowering the lid 11. Further, the boat elevator 18 is configured to be capable of elevating or lowering the boat 13 in the transfer chamber 2 such that the boat 13 can be located (or held) at a reference position (which is a first cooling position) or an elevated position (which is a second cooling position) described later. A configuration of the transfer chamber 2 will be described later in detail. For example, the elevated position serves as a transfer reference position when a transfer operation of the wafer W by the substrate transfer device 17 is started by taking out the wafer W accommodated in the boat 13 by the substrate transfer device 17.

[0019]

The substrate processing apparatus 1 includes a gas supplier (which is a gas supply structure or a gas supply system) 22 through which gases used in the substrate processing are supplied into the process chamber 6. The gases supplied through the gas supplier 22 may be appropriately changed in accordance with a type of a film formed by the substrate processing. The gas supplier 22 may include a source gas supplier (which is a source gas supply structure or a source gas supply system), a reactive gas supplier (which is a reactive gas supply structure or a reactive gas supply system) and an inert gas supplier (which is an inert gas supply structure or an inert gas supply system).

[0020]

The source gas supplier includes a gas supply pipe 23a. A mass flow controller (MFC) 24a serving as a flow rate controller (flow rate controlling structure) and a valve 25a serving as an opening/closing valve are sequentially provided at the gas supply pipe 23a in this order from an upstream side to a downstream side of the gas supply pipe 23a in a gas flow direction. The gas

supply pipe 23a is connected to a nozzle 26a which passes through a sidewall of the manifold 8. The nozzle 26a extends in the reaction tube 4 along the vertical direction, and the nozzle 26a is provided with a plurality of supply holes open toward the wafers W accommodated in the boat 13. A source gas is supplied to the wafers W through the plurality of supply holes of the nozzle 26a.

[0021]

A reactive gas is supplied to the wafers W through the reactive gas supplier whose configuration is similar to that of the source gas supplier via the gas supply pipe 23a, the MFC 24a, the valve 25a and the nozzle 26a. An inert gas is supplied to the wafers W through the inert gas supplier whose configuration is similar to that of the source gas supplier via a gas supply pipe 23b, an MFC 24b, a valve 25b and the nozzle 26a.

[0022]

An exhaust pipe 27 is provided at the manifold 8. A vacuum pump 31 serving as a vacuum exhaust apparatus is connected to the exhaust pipe 27 through a pressure sensor 28 serving as a pressure detector (which is a pressure detecting structure) to detect an inner pressure of the process chamber 6 and an APC (Automatic Pressure Controller) valve 29 serving as a pressure regulator (which is a pressure regulating structure). With such a configuration, it is possible to set (or adjust) the inner pressure of the process chamber 6 to a process pressure according to the substrate processing.

[0023]

Hereinafter, the configuration of the transfer chamber 2 according to the present embodiments will be described with reference to FIGS. 1 through 3B.

[0024]

As shown in FIG. 2, the transfer chamber 2 is of a planar polygonal shape configured by a ceiling, a bottom and side walls surrounding four sides of the transfer chamber 2. For example, the transfer chamber 2 is of a planar rectangular shape. A clean air supplier (which is a clean air supply

structure or a clean air supply system) 32 serving as a first blower is installed on a side surface of the transfer chamber 2. The first blower may also be referred to as a "first gas supplier" (which is a first gas supply structure or a first gas supply system). The clean air supplier 32 is configured to supply a gas such as a clean air (clean atmosphere) to the transfer chamber 2. In addition, a circulation path (not shown) through which the gas (that is, the clean air) is circulated is provided in a space located around the transfer chamber 2. The gas supplied to the transfer chamber 2 is exhausted through an exhaust structure 34 and is supplied to the transfer chamber 2 again through the clean air supplier 32 via the circulation path. A radiator (not shown) is installed in the middle of the circulation path, and the gas is cooled by passing through the radiator.

[0025]

The clean air supplier 32 is constituted by an upper clean air supplier 32a and a lower clean air supplier 32b provided below and adjacent to the upper clean air supplier 32a. The upper clean air supplier 32a is configured to supply the gas (that is, the clean air) toward the transfer chamber 2, particularly, toward the boat 13. The lower clean air supplier 32b is configured to supply the gas toward the transfer chamber 2, particularly, toward the heat insulator 12. Hereinafter, the term "clean air supplier 32" may refer to the upper clean air supplier 32a alone, may refer to the lower clean air supplier 32b alone, or may refer to both of the upper clean air supplier 32a and the lower clean air supplier 32b.

[0026]

The clean air supplier 32 is constituted by a fan (not shown) serving as a blower, a buffer region 36 serving as a buffer chamber, a filter structure 37 such as a filter and a gas supply port 38 in this order from an upstream side to a downstream side of the clean air supplier 32 in the gas flow direction. The buffer region 36 serves as a diffusion space of the gas (that is, the clean air) through which the gas is uniformly supplied (or ejected) via an entire surface of the gas supply port 38. The filter structure 37 is configured to remove particles contained in the gas. Each of the upper clean air

supplier 32a and the lower clean air supplier 32b is provided with the fan, the buffer region 36, the filter structure 37 and the gas supply port 38.

[0027]

The exhaust structure 34 and the boat elevator 18 are installed on a side surface of the transfer chamber 2 facing the clean air supplier 32. The gas (that is, the clean air) supplied into the transfer chamber 2 through the clean air supplier 32 is exhausted through the exhaust structure 34, and is supplied again through the clean air supplier 32 via the circulation path. As a result, a gas flow (which is a side flow) in a horizontal direction (that is, in a direction parallel to the wafer W) can be formed in an upper region (also referred to as a "wafer W region") in the transfer chamber 2.

[0028]

As shown in FIGS. 2, 3A and 3B, a cooling gas nozzle 39 serving as a second blower is installed on the side surface of the transfer chamber 2 where the clean air supplier 32 is installed. The second blower may also be referred to as a "second gas supplier" (which is a second gas supply structure or a second gas supply system). According to the present embodiments, the cooling gas nozzle 39 is installed in the transfer chamber 2 such that the boat 13 is located between the cooling gas nozzle 39 and the boat elevator 18, and extends upward (in a stacking loading direction of the wafers W).

[0029]

The cooling gas nozzle 39 is provided with: a first branch nozzle 39a bent and extending toward the boat 13; a second branch nozzle 39b extending toward the boat 13 on an upstream side of the first branch nozzle 39a; and a third branch nozzle 39c extending toward the boat 13 on an upstream side of the second branch nozzle 39b. A cooling gas is supplied to the transfer chamber 2, particularly, to the substrate accommodating region, through the branch nozzles 39a through 39c. Preferably, the branch nozzles 39a through 39c are configured such that the cooling gas can be supplied toward a region between the top plate 13a of the boat 13 and an uppermost wafer among the

wafers W in the upper substrate accommodating region 13d and a region between the bottom plate 13c of the boat 13 and a lowermost wafer among the wafers W in the lower substrate accommodating region 13e.

[0030]

The cooling gas nozzle 39 is connected to a transfer chamber gas supplier (which is a transfer chamber gas supply structure or a transfer chamber gas supply system) 41 through which the cooling gas is supplied to the transfer chamber 2. The transfer chamber gas supplier 41 is constituted by a gas supply pipe 23c, and an MFC 24c and a valve 25c are sequentially provided at the gas supply pipe 23c in this order from an upstream side to a downstream side of the gas supply pipe 23c in the gas flow direction. The cooling gas nozzle 39, the branch nozzles 39a through 39c and the transfer chamber gas supplier 41 may function as a cooling structure (also referred to as a "cooler") configured to cool the wafers W accommodated in the boat 13 after the wafers W are processed.

[0031]

As described above, the boat elevator 18 is configured to be capable of locating (or holding) the boat 13 at either one of the reference position shown in FIG. 3A where a first cooling step described later is performed and the elevated position shown in FIG. 3B where a second cooling step described later is performed. The elevated position is located above the reference position. With the boat 13 placed at the reference position, the cooling gas ejected through the first branch nozzle 39a is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the upper substrate accommodating region 13d, and the cooling gas ejected through the third branch nozzle 39c is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the lower substrate accommodating region 13e. In addition, with the boat 13 placed at the elevated position, the cooling gas ejected through the second branch nozzle 39b is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the lower substrate accommodating region 13e. As a result, it is possible to provide a cooling gas barrier (gas

curtain) between the bottom plate 13c and the lowermost wafer among the wafers W in the lower substrate accommodating region 13e. Therefore, it is possible to cool the wafers W accommodated in a lower region of the boat 13, and it is also possible to separate an inner atmosphere of the wafer W region from an inner atmosphere of a region corresponding to the heat insulator 12 by the gas curtain.

[0032]

A controller 42 shown in FIG. 1 is connected to components of the substrate processing apparatus 1 such as the rotator 16, the substrate transfer device 17, the boat elevator 18, the gas supplier 22 (that is, the MFCs 24a and 24b and the valves 25a and 25b), the APC valve 29, the clean air supplier 32 and the transfer chamber gas supplier 41 (that is, the MFC 24c and the valve 25c) shown in FIG. 1 through FIG. 3B. The controller 42 is configured to be capable of controlling the components described above connected thereto. For example, the controller 42 is constituted by a microprocessor (computer) including a CPU (Central Processing Unit), and is configured to be capable of controlling operations of the substrate processing apparatus 1. For example, an input/output device 43 such as a touch panel is connected to the controller 42.

[0033]

A memory 44 serving as a recording medium is connected to the controller 42. For example, a control program for controlling the operations of the substrate processing apparatus 1 or a program (for example, a recipe such as a process recipe and a cleaning recipe) configured to control the components of the substrate processing apparatus 1 according to process conditions to perform the substrate processing may be readably stored in the memory 44.

[0034]

The memory 44 may be configured by a memory embedded in the controller 42 such as a hard disk and a flash memory or configured by an external memory such as a semiconductor memory, for example, a USB memory and a memory card. In addition, a communication means such as the

Internet and a dedicated line may be used for providing the program to the computer. Upon necessity, the program may be read from the memory 44 in accordance with an instruction from the input/output device 43, and the substrate processing apparatus 1 can execute a desired process (that is, a substrate processing) in accordance with the read recipe under a control of the controller 42.

[0035]

Hereinafter, the substrate processing (also referred to as a "film-forming process") of forming a film on the wafer W will be described. The substrate processing is performed using the substrate processing apparatus 1 described above. Specifically, an example of forming the film on the wafer W by supplying the source gas and the reactive gas to the wafer W will be described. In the following description, the operations of the components constituting the substrate processing apparatus 1 are controlled by the controller 42.

[0036]

<Transfer Step>

The wafers W are transferred from the pod 21 to the boat 13 by the substrate transfer device 17 (wafer charging step). When transferring the wafer W, the gas (that is, the clean air) is supplied into the transfer chamber 2 through the clean air supplier 32. In addition, while supplying clean air through the clean air supplier 32, the cooling gas may be supplied through the branch nozzles 39a through 39c via the cooling gas nozzle 39.

[0037]

<Loading Step>

Subsequently, the shutter 9 configured to close a wafer loading/unloading port at a bottom of the process chamber 6 is retracted to a shutter storage structure (not shown) so as to open the wafer loading/unloading port of the process chamber 6. Subsequently, the lid 11 is elevated by the boat elevator 18 to transfer (load) the boat 13 from the transfer chamber 2 into the process chamber 6 (boat loading step). As a result, the lid 11 seals a lower end (that is, the lower end opening) of the

manifold 8 via the seal. In the loading step, the gas (that is, the clean air) is continuously supplied into the transfer chamber 2 through the clean air supplier 32 under the same conditions as in the transfer step.

[0038]

<Film-forming Step>

When the boat 13 is loaded into the process chamber 6, an inner atmosphere of the process chamber 6 is exhausted through the exhaust pipe 27 until the inner pressure of the process chamber 6 reaches and is maintained at a desired pressure (vacuum degree). Further, the process chamber 6 is heated by the heater 5, and the rotator 16 is operated to rotate the boat 13. In addition, the source gas and the reactive gas are supplied to the process chamber 6 by the gas supplier 22. As a result, the film is formed on a surface of the wafer W. When the film of a desired thickness is formed on the surface of the wafer W, the gas supplier 22 stops supplying the source gas and the reactive gas to the process chamber 6, and supplies the inert gas to the process chamber 6. As a result, the inner atmosphere of the process chamber 6 is replaced with the inert gas, and the inner pressure of the process chamber 6 is returned to a normal pressure. In the film-forming step, the gas (that is, the clean air) is continuously supplied into the transfer chamber 2 through the clean air supplier 32 under the same conditions as in the transfer step.

[0039]

<Unloading Step>

After the film-forming step is completed, the lid 11 is lowered by the boat elevator 18 and the lower end opening of the manifold 8 is opened. Then, the boat 13 is transferred (unloaded) from the process chamber 6 into the transfer chamber 2. Then, the wafer loading/unloading port of the process chamber 6 is closed by the shutter 9, and the boat 13 is located at the reference position (boat unloading step). In the unloading step, the gas is continuously supplied into the transfer chamber 2 through the clean air supplier 32 or through the clean air supplier 32 and the cooling gas nozzle 39

under the same conditions as in the transfer step.

[0040]

<Temperature Lowering Step (Cooling Step)>

When the boat 13 is completely transferred (unloaded) into the transfer chamber 2, a temperature lowering step (cooling step) of lowering a temperature of the wafer W (or cooling the wafer W) in the transfer chamber 2 is performed until the temperature of the wafer W reaches and is maintained at a pre-set temperature. In the present embodiments, the term “pre-set temperature” refers to a temperature at which the wafer W can be unloaded, and is stored in the memory 44 in advance. The pre-set temperature is a temperature equal to or lower than a heat resistant temperature of the arm (tweezers) 17a or the pod 21. For example, the pre-set temperature is set to 100 °C. Further, the pre-set temperature may usually be set to a temperature within a range of 60 °C or higher and 100 °C or lower depending on the material of the arm (tweezers) 17a or the pod 21. Hereinafter, the cooling step of cooling the wafer W will be described in detail with reference to a flowchart of FIG. 4. Steps S01 through S06 are performed as the cooling step.

[0041]

< Step S01>

When the film-forming step in the process chamber 6 is completed, in the unloading step, the controller 42 controls (operates) the boat elevator 18 to lower the boat 13 to the reference position. In the step S01, the gas (that is, the clean air) is supplied through the clean air supplier 32 at a predetermined flow rate. Further, according to the present embodiments, the boat 13 is lowered from the process chamber 6 to move to the reference position. However, after the boat 13 is lowered, the boat 13 may be further moved to be located at the reference position. In addition, in the step S01, the cooling gas may be supplied to the boat 13 at a predetermined flow rate through the cooling gas nozzle 39.

[0042]

<Step S02>

When the boat 13 is located at the reference position, the controller 42 controls the MFC 24c and the valve 25c such that the cooling gas is ejected through each of the branch nozzles 39a through 39c at a first flow rate for a first cooling time. With the boat 13 at the reference position, the cooling gas ejected through the first branch nozzle 39a flows between the top plate 13a of the boat 13 and the uppermost wafer among the wafers W in the upper substrate accommodating region 13d. Further, the cooling gas ejected through the third branch nozzle 39c flows between the bottom plate 13c of the boat 13 and the lowermost wafer among the wafers W in the lower substrate accommodating region 13e. Thereby, the wafers W accommodated in the boat 13 are cooled by the cooling gas ejected through each of the branch nozzles 39a through 39c. In addition, the gas curtain is provided between the boat 13 and the heat insulator 12 such that wafers among the wafers W at the lower region of the boat 13 can be cooled and the radiant heat from the heat insulator 12 can be blocked.

[0043]

In the step S02, for example, the first flow rate is set to 75 L / min. In addition, the first cooling time refers to a time until the temperature of the wafer W accommodated in the boat 13 reaches and is maintained at a temperature of 100 °C or lower. The first cooling time may be set in advance in accordance with conditions such as a process temperature of the wafer W and the first flow rate. The step S01 and the step S02 may be collectively referred to as a “first cooling step”.

[0044]

<Step S03>

After ejecting the cooling gas through the branch nozzles 39a through 39c for the first cooling time, the controller 42 controls the MFC 24c and the valve 25c to stop the supply of the cooling gas.

[0045]

<Step S04>

The controller 42 controls (operates) the boat elevator 18 to elevate the boat 13 to the elevated position. In the step S04, the supply of the cooling gas through each of the branch nozzles 39a through 39c is stopped. A step of moving the boat 13 from the reference position to the elevated position may also be referred to as a “moving step”.

[0046]

<Step S05>

With the supply of the cooling gas stopped, the controller 42 executes an operation of mapping the wafer W (that is, the wafer mapping described above). That is, the controller 42 controls (operates) the substrate transfer device 17 such that a transfer state (or the placement state) of the wafer W accommodated in the boat 13 is checked by a sensor (hereinafter, also referred to as a “wafer sensor”) provided in the substrate transfer device 17 in advance. Specifically, the controller 42 controls the substrate transfer device 17 to move up and down, and confirms whether or not an abnormality such as a popping out, a cracking and a misalignment of the wafer W has occurred based on information from the sensor. Alternatively, the substrate transfer device 17 may be provided with a temperature sensor serving as a temperature measuring structure described later to measure the temperature of the wafer W accommodated in the boat 13. An operation of measuring the temperature of the wafer W or an operation of checking the transfer state of the wafer W accommodated in the boat 13 may be performed, or both of the operation of measuring the temperature of the wafer W and the operation of checking the transfer state of the wafer W accommodated in the boat 13 may be performed. In addition, the wafer sensor and the temperature sensor described above are sensors capable of measuring an object (that is, the wafer W) without contacting the object (that is, in a non-contact manner). However, an installation position of each of the wafer sensor and the temperature sensor described above is not particularly limited to the present embodiments.

[0047]

In the present embodiments, the step S03, the step S04 and the step S05 may be collectively referred to as a “stopping step”. Further, in the stopping step, for example, the controller 42 starts the wafer mapping when a pre-set time has elapsed after the first cooling step is completed. When the boat 13 is completely elevated to the elevated position before the pre-set time has elapsed, the boat 13 is maintained in the elevated position. When the boat 13 is not completely elevated to the elevated position even after the pre-set time has elapsed, the controller 42 notifies an alarm that indicates the abnormality has occurred. Alternatively, when the boat 13 is completely elevated to the elevated position before the pre-set time has elapsed, the wafer mapping of the wafer W in the boat 13 may be started without waiting for the elapse of the pre-set time.

[0048]

After the wafer mapping is performed, the controller 42 confirms whether or not the abnormality in the placement state of the wafer W is present. When the abnormality has occurred, the controller 42 notifies the alarm that indicates the abnormality has occurred. In addition, the substrate processing may be stopped so as not to proceed to a wafer discharging step such that a restoration process in response to the abnormality can be performed immediately after the next step (that is, a step S06) is completed.

[0049]

<Step S06>

The controller 42 controls the MFC 24c and the valve 25c such that the cooling gas is ejected through each of the branch nozzles 39a through 39c at a second flow rate for a second cooling time. With the boat 13 at the elevated position, the cooling gas ejected through the second branch nozzle 39b flows between the bottom plate 13c of the boat 13 and the lowermost wafer among the wafers W in the lower substrate accommodating region 13e. The wafer W accommodated in the boat 13 is cooled by the cooling gas ejected through the second branch nozzle 39b, and the gas curtain is provided between the boat 13 and the heat insulator 12 such that the radiant heat from the

heat insulator 12 can be blocked.

[0050]

In the step S06, for example, the second flow rate is set to be lower than the first flow rate. For example, the second flow rate is set to 15 L / min. In addition, the second cooling time refers to a time (which is shorter than the first cooling time) until the temperature of the wafer among the wafers W (whose temperature has not been lowered to the pre-set temperature in the first cooling step) reaches and is maintained at a temperature of 100 °C or lower. The second cooling time may be set in advance in accordance with the conditions such as the process temperature of the wafer W, the first flow rate and the second flow rate. The step S06 may also be referred to as a "second cooling step".

[0051]

The branch nozzles 39a through 39c are branched from the cooling gas nozzle 39, and a flow rate of the cooling gas flowing through the cooling gas nozzle 39 is collectively controlled by the MFC 24c and the valve 25c. That is, the cooling gas is supplied to each of the three branch nozzles 39a through 39c by using the MFC 24c and the valve 25c. Therefore, in the first cooling step in which the boat 13 is located at the reference position, the cooling gas is supplied through the second branch nozzle 39b to a middle portion of the substrate accommodating region at the first flow rate. In addition, in the second cooling step in which the boat 13 is located at the elevated position, the cooling gas is supplied through the first branch nozzle 39a to the middle portion of the substrate accommodating region at the second flow rate, and is supplied through the third branch nozzle 39c to the heat insulating region of the heat insulator 12 at the second flow rate.

[0052]

<Wafer Discharging Step>

When the wafer W is cooled for a predetermined time, the wafer W is transferred from the boat 13 to the pod 21 by the substrate transfer device 17 (wafer discharging step). In the wafer

discharging step, the wafer W in the lower substrate accommodating region 13e may be discharged at the elevated position, then the boat 13 may be lowered to the reference position, and the wafer W in the upper substrate accommodating region 13d may be discharged.

[0053]

When the wafer discharging step is executed respectively for the types of the wafers W such as a monitor wafer, a product wafer and a dummy wafer, the boat 13 is elevated or lowered between the reference position and the elevated position each time, and the wafer W is discharged at each position. Further, in the wafer discharging step of discharging the wafer W, the cooling gas is supplied through the clean air supplier 32 at a predetermined flow rate while the wafer W is being discharged. In addition, the cooling gas may be supplied through each of the branch nozzles 39a through 39c at a predetermined flow rate. On the other hand, while the boat 13 is being elevated or lowered, the supply of the cooling gas through each of the branch nozzles 39a through 39c is stopped.

[0054]

As described above, according to the present embodiments, the cooling gas nozzle 39 through which the cooling gas is supplied is branched into the branch nozzles 39a through 39c, and the cooling gas is supplied, through each of the branch nozzles 39a through 39c, between the lowermost wafer among the wafers W in the boat 13 and the heat insulator 12 at each of the reference position (at which the wafer among the wafers W accommodated in the upper substrate accommodating region 13d is transferred) and the elevated position (at which the wafer among the wafers W accommodated in the lower substrate accommodating region 13e is transferred).

[0055]

Therefore, in both of the reference position and the elevated position, the cooling gas is supplied to a boundary between the heat insulating region and the substrate accommodating region such that the gas curtain is formed. As a result, the wafer among the wafers W in a lower region of

the substrate accommodating region can be cooled, and the radiant heat from the heat insulating region can be blocked. Further, the temperature of the wafer W accommodated in the substrate accommodating region can be prevented from being elevated again.

[0056]

According to the present embodiments, through the branch nozzles 39a through 39c, it is possible to supply the cooling gas toward the region between the top plate 13a and the substrate accommodating region, the region between the bottom plate 13c and the substrate accommodating region, and the middle portion of the substrate accommodating region, that is, the entirety of the boat 13. Therefore, it is possible to shorten the first cooling time, and it is also possible to shorten the time for performing the first cooling step.

[0057]

According to the present embodiments, since the temperature of the wafer W can be prevented from being elevated again, it is possible to shorten the time for setting the temperature of the wafer W to the pre-set temperature at which the wafer W can be transferred by the substrate transfer device 17. As a result, it is possible to start an operation of transferring the wafer W within the pre-set time. Thereby, it is possible to transfer the wafer W without delay.

[0058]

According to the present embodiments, the boat 13 can be elevated or lowered between the reference position and the elevated position provided above the reference position. With the boat 13 at the reference position, the wafer among the wafers W accommodated in the upper substrate accommodating region 13d can be transferred by the substrate transfer device 17. With the boat 13 at the elevated position, the wafer among the wafers W accommodated in the lower substrate accommodating region 13e can be transferred by the substrate transfer device 17. Therefore, it is possible to transfer the entirety of the wafers W accommodated in the boat 13 by the substrate transfer device 17 without changing a structure of the substrate transfer device 17.

[0059]

According to the present embodiments, when the boat 13 is elevated from the reference position to the elevated position, the wafer mapping can be performed. Therefore, after the first cooling step, it is possible to determine, for example, whether or not the abnormality in the wafer W has occurred while the boat 13 is being moved or whether or not the wafer W can be transferred.

[0060]

According to the present embodiments, the flow rate (that is, the second flow rate) of the cooling gas supplied in the second cooling step is smaller than the flow rate (that is, the first flow rate) of the cooling gas supplied in the first cooling step, and a supply time (that is, the second cooling time) of the cooling gas supplied in the second cooling step is shorter than a supply time (that is, the first cooling time) of the cooling gas supplied in the first cooling step. Therefore, it is possible to suppress the waste of the cooling gas. In addition, the inert gas such as N_2 gas may be used as the cooling gas.

[0061]

According to the present embodiments, in the stopping step, a time from stopping the supply of the cooling gas to executing the wafer mapping is set in advance, and the wafer mapping is started when the pre-set time has elapsed. Therefore, by starting the wafer mapping and transferring the wafer W from the boat 13 without delay in the first cooling time (which is set in advance), it is possible to check the placement state of the processed wafer W arranged in the boat 13, and it is also possible to detect whether or not the abnormality of the placement state of the processed wafer W has occurred. Alternatively, the wafer mapping may be performed immediately after the supply of the cooling gas is stopped (that is, the pre-set time may be zero).

[0062]

< Modified Examples>

The present embodiments are not limited to the examples described above, and may be

modified as described below.

[0063]

<First Modified Example>

FIGS. 5A and 5B are diagrams schematically illustrating a first modified example of the embodiments of the present disclosure. According to the first modified example, a cooling gas nozzle 45 (which corresponds to the cooling gas nozzle 39 of the embodiments described above) is provided with: a first branch nozzle 45a bent and extending toward the boat 13; a third branch nozzle 45c extending toward the boat 13 on an upstream side of the first branch nozzle 45a; and a switching valve 46a provided on an upstream side of the third branch nozzle 45c. The cooling gas nozzle 45 is further provided with a second branch nozzle 45b extending in a predetermined direction on an upstream side of the switching valve 46a. The second branch nozzle 45b extends in the predetermined direction, then is bent and extends toward the boat 13. The second branch nozzle 45b is provided with a switching valve 46b.

[0064]

According to the first modified example, as in the embodiments of the present disclosure described above, with the boat 13 at the reference position the cooling gas ejected through the first branch nozzle 45a is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the substrate accommodating region, and the cooling gas ejected through the third branch nozzle 45c is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region. With the boat 13 at the elevated position, the cooling gas ejected through the second branch nozzle 45b is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region.

[0065]

According to the first modified example, when the switching valve 46a is opened and the

switching valve 46b is closed, the cooling gas is ejected solely through the first branch nozzle 45a and the third branch nozzle 45c, and not through the second branch nozzle 45b. On the other hand, when the switching valve 46a is closed and the switching valve 46b is opened, the cooling gas is ejected through the second branch nozzle 45b, and not through the first branch nozzle 45a and the third branch nozzle 45c.

[0066]

According to the first modified example, by opening the switching valve 46a and closing the switching valve 46b in the first cooling step and by closing the switching valve 46a and opening the switching valve 46b in the second cooling step, it is possible to reliably supply the cooling gas to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region, and it is possible to prevent the cooling gas from being directly ejected toward the wafers W. It is also possible to suppress a consumption amount of the cooling gas.

[0067]

<Second Modified Example>

FIGS. 6A and 6B are diagrams schematically illustrating a second modified example of the embodiments of the present disclosure. According to the second modified example, a cooling gas nozzle (which corresponds to the cooling gas nozzle 39 of the embodiments described above) is constituted by a first cooling gas nozzle 47 and a second cooling gas nozzle 49 branched off from the first cooling gas nozzle 47. The first cooling gas nozzle 47 is provided with: a first branch nozzle 47a bent and extending toward the boat 13; and a switching valve 48a provided on an upstream side of the first branch nozzle 47a, and the second cooling gas nozzle 49 branches in a predetermined direction from the first cooling gas nozzle 47 on an upstream side of the switching valve 48a.

[0068]

According to the second modified example, the second cooling gas nozzle 49 is provided with: a second branch nozzle 49b bent and extending toward the boat 13 on the upstream side of the

first branch nozzle 47a; a third branch nozzle 49c extending toward the boat 13 on an upstream side of the second branch nozzle 49b; and a switching valve 48b provided on an upstream side of the third branch nozzle 49c. That is, the second branch nozzle 49b extends from a space between the first branch nozzle 47a and the third branch nozzle 49c toward the boat 13.

[0069]

According to the second modified example, as in the embodiments of the present disclosure described above, with the boat 13 at the reference position the cooling gas ejected through the first branch nozzle 47a is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the substrate accommodating region, and the cooling gas ejected through the third branch nozzle 49c is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region. With the boat 13 at the elevated position, the cooling gas ejected through the second branch nozzle 49b is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region.

[0070]

According to the second modified example, in the first cooling step, the switching valve 48a is opened and an opening degree of the switching valve 48b is adjusted such that the flow rate of the cooling gas supplied through the second cooling gas nozzle 49 is smaller than the flow rate of the cooling gas supplied through the first cooling gas nozzle 47. In addition, for example, a total flow rate of the cooling gas in the first cooling step may be set to 75 slm, and a flow rate ratio of the cooling gas of the first cooling gas nozzle 47 to the cooling gas of the second cooling gas nozzle 49 may be set to 5 : 1.

[0071]

According to the second modified example, in the second cooling step, the switching valve 48a is closed and the switching valve 48b is opened, and the flow rate of the cooling gas is set to be

smaller than the flow rate of the cooling gas in the first cooling step (that is, when the boat is located at the reference position). For example, a total flow rate of the cooling gas in the second cooling step may be set to 15 slm.

[0072]

According to the second modified example, in the first cooling step, the cooling gas whose flow rate is large is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the substrate accommodating region through the first branch nozzle 47a, and the cooling gas whose flow rate is small is supplied to the middle portion of the substrate accommodating region and the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region through the branch nozzles 49b and 49c. In addition, in the second cooling step, the cooling gas is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region through the second branch nozzle 49b, and the cooling gas is supplied to the heat insulator 12 through the third branch nozzle 49c.

[0073]

According to the second modified example, the opening degree of the switching valve 46b in the first cooling step is adjusted such that the flow rate of the cooling gas supplied through the second cooling gas nozzle 49 is smaller than the flow rate of the cooling gas supplied through the first cooling gas nozzle 47, and the total flow rate of the cooling gas in the second cooling step is set to be smaller than the total flow rate of the cooling gas in the first cooling step. Therefore, in both of the first cooling step and the second cooling step, the cooling gas with a reduced flow rate of an approximately same amount is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region. As a result, it is possible to suppress the consumption amount of the cooling gas.

[0074]

According to the second modified example, the switching valve 48b whose opening degree can be adjusted so as to adjust the flow rate of the cooling gas is provided in the second cooling gas nozzle 49. However, instead of the switching valve 48b, an orifice provided with a predetermined flow path resistance may be installed.

[0075]

<Third Modified Example>

FIGS. 7A and 7B are diagrams schematically illustrating a third modified example of the embodiments of the present disclosure. According to the third modified example, a cooling gas nozzle (which corresponds to the cooling gas nozzle 39 of the embodiments described above) is constituted by a first cooling gas nozzle 51 and a second cooling gas nozzle 52 branched off from the first cooling gas nozzle 51. The first cooling gas nozzle 51 is provided with: a first branch nozzle 51a bent and extending toward the boat 13; a second branch nozzle 51b extending toward the boat 13 on an upstream side of the first branch nozzle 51a; and a switching valve 53a provided on an upstream side of the second branch nozzle 51b, and the second cooling gas nozzle 52 branches in a predetermined direction from the first cooling gas nozzle 51 on an upstream side of the switching valve 53a.

[0076]

According to the third modified example, the second cooling gas nozzle 52 is provided with: a third branch nozzle 52c bent and extending toward the boat 13 on a downstream side of the first branch nozzle 51a; a fourth branch nozzle 52d extending toward the boat 13 on upstream sides of the first branch nozzle 51a and the third branch nozzle 52c and on a downstream side of the second branch nozzle 51b; and a switching valve 53b provided on an upstream side of the fourth branch nozzle 52d.

[0077]

According to the third modified example, with the boat 13 at the reference position the

cooling gas ejected through the first branch nozzle 51a is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the substrate accommodating region, and the cooling gas ejected through the second branch nozzle 51b is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region. With the boat 13 at the elevated position, the cooling gas ejected through the third branch nozzle 52c is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the substrate accommodating region, and the cooling gas ejected through the fourth branch nozzle 52d is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region.

[0078]

According to the third modified example, in the first cooling step, the switching valve 53a is opened and an opening degree of the switching valve 53b is adjusted such that the flow rate of the cooling gas supplied through the second cooling gas nozzle 52 is smaller than the flow rate of the cooling gas supplied through the first cooling gas nozzle 51. In addition, for example, the total flow rate of the cooling gas in the first cooling step may be set to 75 slm, and the flow rate ratio of the cooling gas of the first cooling gas nozzle 51 to the cooling gas of the second cooling gas nozzle 52 may be set to 5 : 1.

[0079]

According to the third modified example, in the second cooling step, the switching valve 53a is closed and the switching valve 53b is opened, and the flow rate of the cooling gas is set to be smaller than the flow rate of the cooling gas in the first cooling step. For example, the total flow rate of the cooling gas in the second cooling step may be set to 15 slm. That is, in the first cooling step, the cooling gas whose flow rate is large is ejected through the first branch nozzle 51a and the second branch nozzle 51b, and the cooling gas whose flow rate is small is ejected through the third branch nozzle 52c and the fourth branch nozzle 52d. In the second cooling step, the cooling gas whose flow

rate is small is ejected through the third branch nozzle 52c and the fourth branch nozzle 52d without ejecting the cooling gas through the first branch nozzle 51a and the second branch nozzle 51b.

[0080]

According to the third modified example, the total flow rate of the cooling gas in the second cooling step is set to be smaller than the total flow rate of the cooling gas in the first cooling step. As a result, it is possible to suppress the consumption amount of the cooling gas.

[0081]

<Fourth Modified Example>

FIGS. 8A and 8B are diagrams schematically illustrating a fourth modified example of the embodiments of the present disclosure. According to the fourth modified example, a cooling gas nozzle 54 (which corresponds to the cooling gas nozzle 39 of the embodiments described above) is provided with a flow rate adjusting valve 55, and is branched off into a first cooling gas nozzle 56 and a second cooling gas nozzle 57 on a downstream side of the flow rate adjusting valve 55. The first cooling gas nozzle 56 is provided with: a first branch nozzle 56a bent and extending toward the boat 13; a second branch nozzle 56b extending toward the boat 13 on an upstream side of the first branch nozzle 56a; and a first solenoid valve 58a provided on an upstream side of the second branch nozzle 56b. The second cooling gas nozzle 57 is provided with: a third branch nozzle 57c bent and extending toward the boat 13 on a downstream side of the first branch nozzle 56a; a fourth branch nozzle 57d branched off and extending toward the boat 13 on upstream sides of the first branch nozzle 56a and the third branch nozzle 57c and on a downstream side of the second branch nozzle 56b; and a second solenoid valve 58b provided on an upstream side of the fourth branch nozzle 57d.

[0082]

According to the fourth modified example, with the boat 13 at the reference position, the cooling gas ejected through the first branch nozzle 56a is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the substrate accommodating region, and the

cooling gas ejected through the second branch nozzle 56b is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region. With the boat 13 at the elevated position, the cooling gas ejected through the third branch nozzle 57c is supplied to the region between the top plate 13a and the uppermost wafer among the wafers W in the substrate accommodating region, and the cooling gas ejected through the fourth branch nozzle 57d is supplied to the region between the bottom plate 13c and the lowermost wafer among the wafers W in the substrate accommodating region.

[0083]

According to the fourth modified example, the solenoid valves 58a and 58b are controlled to open or close and an opening degree of the flow rate adjusting valve 55 is controlled in synchronization with a signal generated while the boat 13 is being elevated or lowered or a signal generated when the boat 13 is completely transferred to the reference position or the elevated position.

[0084]

When the boat 13 is completely transferred to the reference position (that is, in the first cooling step), the opening degree of the flow rate adjusting valve 55 is increased, the first solenoid valve 58a is opened, and the second solenoid valve 58b is closed. Further, when the boat 13 is completely transferred to the elevated position (that is, in the second cooling step), the opening degree of the flow rate adjusting valve 55 is decreased, the first solenoid valve 58a is closed, and the second solenoid valve 58b is opened. In addition, while the boat 13 is being elevated or lowered (that is, in the stopping step), the flow rate adjusting valve 55 is closed and the solenoid valves 58a and 58b are closed.

[0085]

According to the fourth modified example, in the first cooling step, for example, 75 slm of the cooling gas is supplied to the first cooling gas nozzle 56, and the cooling gas whose flow rate is

large is ejected through the first branch nozzle 56a and the second branch nozzle 56b without ejecting the cooling gas through the third branch nozzle 57c and the fourth branch nozzle 57d. In addition, in the second cooling step, for example, 15 slm of the cooling gas is supplied to the second cooling gas nozzle 57, and the cooling gas whose flow rate is small is ejected through the third branch nozzle 57c and the fourth branch nozzle 57d without ejecting the cooling gas through the first branch nozzle 56a and the second branch nozzle 56b.

[0086]

According to the fourth modified example, the total flow rate of the cooling gas in the second cooling step is set to be smaller than the total flow rate of the cooling gas in the first cooling step. As a result, it is possible to suppress the consumption amount of the cooling gas.

[0087]

<Fifth Modified Example>

FIG. 9 is a diagram schematically illustrating a fifth modified example of the embodiments of the present disclosure. According to the fifth modified example, a thermometer 59 serving as a temperature sensor is provided on a front end (tip) of the substrate transfer device 17. As the thermometer 59, for example, a radiation thermometer capable of measuring a temperature in a non-contact manner may be used.

[0088]

For example, the thermometer 59 can measure temperatures of the entirety of the wafers W accommodated in the boat 13 with the boat 13 at the elevated position. For example, as in the wafer mapping, the thermometer 59 can measure the temperatures of the wafers W while the substrate transfer device 17 is moved up and down. Alternatively, the thermometer 59 can measure the temperatures of the wafers W when the substrate transfer device 17 is moved to a predetermined position in a substrate processing region (that is, the substrate accommodating region).

[0089]

Hereinafter, a cooling step of the wafer W according to the fifth modified example will be described in detail with reference to a flowchart of FIG. 10. In FIG. 10, since steps S11 through S14 are substantially the same as the steps S01 through S04 in FIG. 4 and a step S17 (which is a second cooling step) is substantially the same as the step S06 in FIG. 4, detailed descriptions thereof will be omitted and the following will be focused on differences between the fifth modified example and the embodiments described above. Therefore, hereinafter, steps S15, S16, S18 and S19 of the fifth modified example will be mainly described in detail.

[0090]

<Step S15>

After the boat 13 is moved from the reference position to the elevated position, the thermometer 59 starts measuring the temperatures of the wafers W, and the substrate transfer device 17 is moved up and down with the thermometer 59 facing the boat 13. The thermometer 59 measures the temperatures of the entirety of the wafers W in a non-contact manner based on the synchrotron radiation from the entirety of the wafers W accommodated in the boat 13.

[0091]

<Step S16>

After the temperatures of the entirety of the wafers W are measured, the controller 42 (see FIG. 1) compares the temperatures of the entirety of the wafers W (which are measurement results obtained by the thermometer 59) with the pre-set temperature, and determines whether each of the measurement results is smaller than the pre-set temperature (for example, 100 °C). When it is determined that at least one among the measurement results is equal to or higher than the pre-set temperature, the step S17 (which is the second cooling step substantially the same as the step S06 described above) is performed. In the second cooling step (that is, the step S17) of the fifth modified example, the cooling gas may be supplied in a manner similar to the first through fourth modified examples, but detailed descriptions thereof will be omitted.

[0092]

<Step S17>

After the temperatures of the wafers W are measured in the step S15, when it is determined that at least one among the measurement results is equal to or higher than the pre-set temperature in the step S16, the step S17, which is the second cooling step substantially the same as the step S06 described above, is performed. In addition, when it is determined that at least one among measurement results of the temperatures of the entirety of the wafers W in the step S19 described later is equal to or higher than the pre-set temperature in the step S19, the step S17 (that is, the second cooling step) is performed. When performing a second or subsequent execution of the second cooling step, at least one among the flow rate and the supply time of the cooling gas may be changed from those of a first execution of the second cooling step. For example, the flow rate of the cooling gas and the supply time of supplying the cooling gas may be changed according to the deviation from the pre-set temperature (for example, 100 °C).

[0093]

<Step S18>

After the second cooling step is completed, the arm (tweezers) 17a of the substrate transfer device 17 is moved to the vicinity of the wafer W to be transferred, and the temperature of the wafer W to be transferred is measured by the thermometer 59. In the step S18 performed after the second cooling step, instead of measuring the temperatures of the entirety of the wafers W to be transferred, the temperature of the wafer among the wafers W accommodated in the lower region of the boat 13 may be measured. Preferably, the temperature of the lowermost wafer among the wafers W accommodated in the lowest region of the boat 13 may be measured.

[0094]

<Step S19>

When it is determined that the temperature of the wafer W to be transferred is lower than the

pre-set temperature, the substrate transfer device 17 starts transferring the wafer W from the boat 13. Otherwise, when it is determined that the temperature of the wafer W to be transferred is equal to or higher than the pre-set temperature, the step S17 (that is, the second cooling step) and the step S18 are performed again. When it is determined that the temperature of the wafer W to be transferred is lower than the pre-set temperature after performing the steps S17 and S18 again, the substrate transfer device 17 starts transferring the wafer W from the boat 13. Since the steps S18 and S19 are performed between the cooling step (second cooling step) and the transfer step described above, the steps S18 and S19 may also be collectively referred to as a “transfer preparation step”.

[0095]

According to the fifth modified example, the thermometer 59 capable of measuring the temperature in a non-contact manner is provided, the temperature of the wafer W to be transferred is measured using the thermometer 59 before being transferred from the boat 13, and the wafer W is transferred when the temperature of the wafer W is lower than the pre-set temperature. Therefore, after the first cooling step is completed, it is possible to confirm whether or not the wafer W is reheated by the radiant heat from the heat insulator 12. As a result, it is possible to prevent the wafer W from being transferred by the substrate transfer device 17 when the wafer W is reheated and the temperature of the wafer W is equal to or higher than the pre-set temperature, and it is also possible to prevent the arm (tweezers) 17a from being damaged by the wafer W or the radiant heat.

[0096]

In addition to the effects described above, it is possible to further check the placement state of each of the wafers W when the temperatures of the entirety of the wafers W accommodated in the boat 13 are measured and the wafer mapping is performed on the entirety of the wafers W.

[0097]

<Other Embodiments>

The technique of the present disclosure is described in detail by way of the embodiments and

the modified examples described above. However, the technique of the present disclosure is not limited thereto. The technique of the present disclosure may be modified in various ways without departing from the scope thereof. For example, the embodiments and the modified examples are described by way of an example in which the boat 13 is moved from the reference position to the elevated position. However, the first cooling step of supplying the cooling gas toward the boat 13, the stopping step of stopping the supply of the cooling gas supplied in the first cooling step and the second cooling step of cooling the processed wafer W accommodated in the lower region of the substrate accommodating region may be performed when the boat 13 is located at the reference position. In addition, in the stopping step, the wafer mapping may be performed or the temperature of the wafer W may be measured. Even in such cases, the same effects of the embodiments or the modified examples described above may be obtained similarly.

[0098]

For example, a type of the film formed on the substrate (that is, the wafer W) using the substrate processing apparatus 1 according to the embodiments described above is not particularly limited. For example, the technique of the present disclosure may be applied to processes of forming films of various types such as a nitride film (such as a silicon nitride (SiN) film), an oxide film (such as a silicon oxide (SiO) film), a film containing a metal, a film formed by a CVD (Chemical Vapor Deposition) method and a film formed by an PVD (Physical Vapor Deposition) method. In addition, for example, the substrate processing of forming the film on the substrate may include a process such as an annealing process, an oxidation process, a nitriding process and a diffusion process. Further, the substrate processing apparatus 1 according to the embodiments described above can be applied not only to a semiconductor manufacturing apparatus but also to other substrate processing apparatuses such as an LCD (liquid crystal display) manufacturing apparatus capable of processing a glass substrate.

[Description of Reference Numerals]

[0099]

1: substrate processing apparatus	2: transfer chamber
13: boat	17: substrate transfer device
39: cooling gas nozzle	41: transfer chamber gas supplier
42: controller	59: thermometer

[CLAIMS]

[Claim 1]

A cooling method of cooling one or more substrates accommodated in a substrate retainer after processing the substrate, the cooling method comprising:

(a) cooling a substrate by supplying a gas toward the substrate retainer located at a predetermined reference position;

(b) stopping supplying the gas; and

(c) cooling the substrate accommodated in a lower region of the substrate retainer.

[Claim 2]

The cooling method of claim 1, wherein (b) further comprises at least one among:

(b-1) measuring a temperature of the substrate accommodated in the substrate retainer; and

(b-2) checking a placement state of the substrate.

[Claim 3]

The cooling method of claim 2, wherein (c) is performed only when a temperature of the substrate is equal to or higher than a temperature set in advance.

[Claim 4]

The cooling method of claim 1, wherein, in (a), the gas is supplied to a top plate of the substrate retainer, a substrate accommodating region of the substrate retainer in which the substrate is loaded, and a boundary of the substrate accommodating region of the substrate retainer.

[Claim 5]

The cooling method of claim 1, wherein (a) is performed until a temperature of another

substrate accommodated in a center region of the substrate retainer becomes equal to or less than 100 °C.

[Claim 6]

The cooling method of claim 1, wherein (b) further comprises

(b-3) moving the substrate retainer from the reference position to a position at which the substrate is transferable.

[Claim 7]

The cooling method of claim 6, wherein (b-3) further comprises at least one among:

measuring a temperature of the substrate accommodated in the substrate retainer; and

checking a placement state thereof.

[Claim 8]

The cooling method of claim 6, wherein (b-3) further comprises at least one among:

measuring a temperature of the substrate accommodated in the lower region of the substrate retainer; and

checking a placement state thereof.

[Claim 9]

The cooling method of claim 6, wherein (b-3) further comprises at least one among:

measuring a temperature of another substrate accommodated at a lower end of the substrate retainer; and

checking a placement state thereof.

[Claim 10]

The cooling method of claim 1, wherein a flow rate of the gas supplied in (c) is smaller than a flow rate of the gas supplied in (a).

[Claim 11]

The cooling method of claim 1, wherein a supply time of the gas supplied in (c) is shorter than a supply time of the gas supplied in (a).

[Claim 12]

The cooling method of claim 1, wherein, in (c), the gas is supplied to at least one among: a substrate accommodating region of the substrate retainer; a heat insulating region of the substrate retainer; and a boundary between the substrate accommodating region and the heat insulating region.

[Claim 13]

The cooling method of claim 1, wherein, in (a) and (c), the gas is supplied to a top plate of the substrate retainer and a boundary of a substrate accommodating region of the substrate retainer in which the substrate is loaded.

[Claim 14]

The cooling method of claim 1, wherein in (c), the gas is supplied to a substrate accommodating region of the substrate retainer in which the substrate is loaded and a boundary of a heat insulating region of the substrate retainer.

[Claim 15]

The cooling method of claim 1, wherein (c) is performed only when a temperature of the

substrate is equal to or higher than a pre-set temperature.

[Claim 16]

The cooling method of claim 1, further comprising

(d) performing either one of:

measuring a temperature of the substrate accommodated in the substrate retainer; and

checking a placement state of the substrate before (a).

[Claim 17]

The cooling method of claim 1, wherein (b) further comprises either one of:

(b-1) measuring a temperature of the substrate accommodated in the substrate retainer when a pre-set time has elapsed; and

(b-2) checking a placement state of the substrate when the pre-set time has elapsed.

[Claim 18]

The cooling method of claim 16, wherein (c) is performed when the temperature of the substrate is equal to or higher than a predetermined temperature.

[Claim 19]

A method of manufacturing a semiconductor comprising:

(A) cooling a substrate accommodated in a substrate retainer after processing the substrate,

wherein (A) comprises:

(a) cooling the substrate by supplying a gas toward the substrate retainer located at a predetermined reference position;

(b) stopping supplying the gas; and

(c) cooling the substrate accommodated in a lower region of the substrate retainer.

[Claim 20]

A program that causes, by a computer, a substrate processing apparatus to perform:

(A) cooling a substrate accommodated in a substrate retainer after processing the substrate, wherein (A) comprises:

(a) cooling the substrate by supplying a gas toward the substrate retainer located at a predetermined reference position;

(b) stopping supplying the gas; and

(c) cooling the substrate accommodated in a lower region of the substrate retainer.

[Claim 21]

A substrate processing apparatus comprising:

a cooling structure configured to cool a substrate accommodated in a substrate retainer; and

a controller configured to be capable of controlling the cooling structure to perform:

(a) cooling the substrate by supplying a gas toward the substrate retainer located at a predetermined reference position;

(b) stopping supplying the gas; and

(c) cooling the substrate accommodated in a lower region of the substrate retainer.