DESCRIPTION

Title of Invention: SUBSTRATE PROCESSING DEVICE

Technical Field

[0001] Exemplary embodiments of the present disclosure relate to a substrate processing apparatus.

Background Art

[0002] A substrate processing apparatus may include a substrate support capable of controlling the temperature of a substrate placed thereon. The substrate processing apparatus described in Patent Literature 1 below controls the temperature of a substrate by supplying to a substrate support a heat transfer medium adjusted to a first temperature and a heat transfer medium adjusted to a second temperature higher than the first temperature.

Citation List

Patent Literature

[0003] [Patent Literature 1] Japanese Unexamined Patent Application Publication No. 2016-12593

Summary of Invention

Technical Problem

[0004] The present disclosure provides a technique for controlling the temperature of a substrate.

Solution to Problem

[0005] In one exemplary embodiment, a substrate processing apparatus is provided. The substrate processing apparatus includes a processing chamber, a substrate support, a plurality of supply pipes, one or more

recovery pipes, one or more flow rate controllers, and a controller. The substrate support is disposed in the processing chamber. The substrate support includes an upper surface, a lower surface, and one or more partition walls. The upper surface supports a substrate placed thereon. The lower surface is a surface opposite to the upper surface. The one or more partition walls extend downward from the lower surface. The one or more partition walls and the lower surface define one or more spaces. The plurality of supply pipes each have an open end. The open end is opened toward the lower surface to supply a heat transfer medium to the lower surface. The open end is disposed in a corresponding one of the one or more spaces. The one or more recovery pipes are connected to the one or more spaces, respectively, to recover the heat transfer medium from the one or more spaces, respectively. The one or more flow rate controllers are connected to the plurality of supply pipes. The controller is configured to control the one or more flow rate controllers to adjust a flow rate of the heat transfer medium supplied to the plurality of supply pipes. The one or more partition walls include an outer peripheral wall. The outer peripheral wall separates an interior of the substrate support from an exterior of the substrate support. The one or more spaces include one space in which the open end of each of two or more supply pipes among the plurality of supply pipes is disposed.

Advantageous Effects of Invention

[0006] According to one exemplary embodiment, a technique for controlling the temperature of a substrate is provided.

Brief Description of Drawings

[0007] [Fig. 1] is a diagram for explaining an example configuration of

a plasma processing system according to one exemplary embodiment.

[Fig. 2] is a diagram for explaining an example configuration of a capacitively coupled plasma processing apparatus according to one exemplary embodiment.

[Fig. 3] is an enlarged cross-sectional view of a part of a substrate support according to one exemplary embodiment.

[Fig. 4] is an exploded perspective view of a substrate support according to one exemplary embodiment.

[Fig. 5] is a perspective view of a heat exchanger according to one exemplary embodiment.

[Fig. 6] Fig. 6(a) is a plan view of a cell portion of an example heat exchanger, and Fig. 6(b) is a perspective view of the cell portion of the example heat exchanger.

[Fig. 7] is a cross-sectional view of a substrate support according to one exemplary embodiment.

[Fig. 8] is a cross-sectional view of a substrate support according to another exemplary embodiment.

[Fig. 9] is a cross-sectional view of a substrate support according to yet another exemplary embodiment.

[Fig. 10] is a cross-sectional view of a substrate support according to yet another exemplary embodiment.

[Fig. 11] is a diagram schematically showing a circulation supply system of a heat transfer medium in a substrate processing apparatus according to one exemplary embodiment.

[Fig. 12] is a diagram schematically showing a circulation supply system of a heat transfer medium in a substrate processing apparatus according

to another exemplary embodiment.

[Fig. 13] Fig. 13(a) is a graph showing an example of a relationship between time and a flow rate of a heat transfer medium, and Fig. 13(b) is a graph showing an example of a relationship between time and a temperature of a substrate.

[Fig. 14] is an enlarged cross-sectional view of a part of a substrate support according to yet another exemplary embodiment.

Description of Embodiments

[0008] Various exemplary embodiments will now be described in detail with reference to the drawings. In the figures, like reference numerals denote like or corresponding components.

[0009] Various exemplary embodiments will now be described in detail with reference to the drawings. In the figures, like reference numerals denote like or corresponding components.

[0010] Fig. 1 illustrates an example configuration of a plasma processing system. In an embodiment, the plasma processing system includes a plasma processing apparatus 1 and a controller 2. The plasma processing system is an example substrate processing system, and the plasma processing apparatus 1 is an example substrate processing apparatus. The plasma processing apparatus 1 includes a plasma processing chamber 10, a substrate support 11, and a plasma generator 12. The plasma processing chamber 10 has a plasma processing space. The plasma processing chamber 10 further has at least one gas inlet for supplying at least one process gas into the plasma processing space and at least one gas outlet for exhausting gases from the plasma processing space. The gas inlet is connected to a gas supply 20 described below and

the gas outlet is connected to a gas exhaust system 40 described below. The substrate support 11 is disposed in a plasma processing space and has a substrate supporting surface for supporting a substrate.

[0011] The plasma generator 12 is configured to generate a plasma from the at least one process gas supplied into the plasma processing space. The plasma formed in the plasma processing space may be, for example, a capacitively coupled plasma (CCP), an inductively coupled plasma (ICP), an electron-cyclotron-resonance (ECR) plasma, a helicon wave plasma (HWP), or a surface wave plasma (SWP). Various types of plasma generators may also be used, such as an alternating current (AC) plasma generator and a direct current (DC) plasma generator. In an embodiment, AC signal (AC power) used in the AC plasma generator has a frequency in a range of 100 kHz to 10 GHz. Hence, examples of the AC signal include a radio frequency (RF) signal and a microwave signal. In an embodiment, the RF signal has a frequency in a range of 100 kHz to 150 MHz.

[0012] The controller 2 processes computer executable instructions causing the plasma processing apparatus 1 to perform various steps described in this disclosure. The controller 2 may be configured to control individual components of the plasma processing apparatus 1 such that these components execute the various steps. In an embodiment, the functions of the controller 2 may be partially or entirely incorporated into the plasma processing apparatus 1. The controller 2 may include a processor 2a1, a storage 2a2, and a communication interface 2a3. The controller 2 is implemented in, for example, a computer 2a. The processor 2a1 may be configured to read a program

from the storage 2a2, and then perform various controlling operations by executing the program. This program may be preliminarily stored in the storage 2a2 or retrieved from any medium, as appropriate. The resulting program is stored in the storage 2a2, and then the processor 2a1 reads to execute the program from the storage 2a2. The medium may be of any type which can be accessed by the computer 2a or may be a communication line connected to the communication interface 2a3. The processor 2a1 may be a central processing unit (CPU). The storage 2a2 may include a random access memory (RAM), a read only memory (ROM), a hard disk drive (HDD), a solid state drive (SSD), or any combination thereof. The communication interface 2a3 can communicate with the plasma processing apparatus 1 via a communication line, such as a local area network (LAN).

[0013] An example configuration of a capacitively coupled plasma processing apparatus, which is an example of the plasma processing apparatus 1, will now be described. Fig. 2 illustrates the example configuration of the capacitively coupled plasma processing apparatus.

[0014] The capacitively coupled plasma processing apparatus 1 includes a plasma processing chamber 10, a gas supply 20, an electric power source 30, and a gas exhaust system 40. The plasma processing apparatus 1 further includes a substrate support 11 and a gas introduction unit. The gas introduction unit is configured to introduce at least one process gas into the plasma processing chamber 10. The gas introduction unit includes a showerhead 13. The substrate support 11 is disposed in a plasma processing chamber 10. The showerhead 13 is disposed above the substrate support 11. In an embodiment, the

showerhead 13 functions as at least part of the ceiling of the plasma processing chamber 10. The plasma processing chamber 10 has a plasma processing space 10s that is defined by the showerhead 13, the sidewall 10a of the plasma processing chamber 10, and the substrate support 11. The plasma processing chamber 10 is grounded. The showerhead 13 and the substrate support 11 are electrically insulated from the housing of the plasma processing chamber 10.

[0015] The substrate support 11 includes a body 111 and a ring assembly 112. The body 111 has a central region 111a for supporting a substrate W and an annular region 111b for supporting the ring assembly 112. An example of the substrate W is a wafer. The annular region 111b of the body 111 surrounds the central region 111a of the body 111 in plan view. The substrate W is disposed on the central region 111a of the body 111, and the ring assembly 112 is disposed on the annular region 111b of the body 111 so as to surround the substrate W on the central region 111a of the body 111. Thus, the central region 111a is also called a substrate supporting surface for supporting the substrate W, while the annular region 111b is also called a ring supporting surface for supporting the ring assembly 112.

[0016] In an embodiment, the body 111 includes a base 1110 and an electrostatic chuck 1111. The base 1110 includes a conductive member. The conductive member of the base 1110 can function as a lower electrode. The electrostatic chuck 1111 is disposed on the base 1110. The electrostatic chuck 1111 includes a ceramic member 1111a and an electrostatic electrode 1111b disposed in the ceramic member 1111a. The ceramic member 1111a has the central region 111a. In an

embodiment, the ceramic member 1111a also has the annular region 111b. Any other member, such as an annular electrostatic chuck or an annular insulting member, surrounding the electrostatic chuck 1111 may have the annular region 111b. In this case, the ring assembly 112 may be disposed on either the annular electrostatic chuck or the annular insulating member, or both the electrostatic chuck 1111 and the annular insulating member. At least one RF/DC electrode coupled to an RF source 31 and/or a DC source 32 described below may be disposed in the ceramic member 1111a. In this case, the at least one RF/DC electrode functions as the lower electrode. If a bias RF signal and/or DC signal described below are supplied to the at least one RF/DC electrode, the RF/DC electrode is also called a bias electrode. It is noted that the conductive member of the base 1110 and the at least one RF/DC electrode may each function as a lower electrode. The electrostatic electrode 1111b may also function as a lower electrode. The substrate support 11 accordingly includes at least one lower electrode.

[0017] The ring assembly 112 includes one or more annular members. In an embodiment, the annular members include one or more edge rings and at least one cover ring. The edge ring is composed of a conductive or insulating material, whereas the cover ring is composed of an insulating material.

[0018] The showerhead 13 is configured to introduce at least one process gas from the gas supply 20 into the plasma processing space 10s. The showerhead 13 has at least one gas inlet 13a, at least one gas diffusing space 13b, and a plurality of gas feeding ports 13c. The process gas supplied to the gas inlet 13a passes through the gas diffusing

space 13b and is then introduced into the plasma processing space 10s from the gas feeding ports 13c. The showerhead 13 further includes at least one upper electrode. The gas introduction unit may include one or more side gas injectors provided at one or more openings formed in the sidewall 10a, in addition to the showerhead 13.

[0019] The gas supply 20 may include at least one gas source 21 and at least one flow controller 22. In an embodiment, the gas supply 20 is configured to supply at least one process gas from the corresponding gas source 21 through the corresponding flow controller 22 into the showerhead 13. Each flow controller 22 may be, for example, a mass flow controller or a pressure-controlled flow controller. The gas supply 20 may include a flow modulation device that can modulate or pulse the flow of the at least one process gas.

[0020] The electric power source 30 include an RF source 31 coupled to the plasma processing chamber 10 through at least one impedance matching circuit. The RF source 31 is configured to supply at least one RF signal (RF power) to at least one lower electrode and/or at least one upper electrode. A plasma is thereby formed from at least one process gas supplied into the plasma processing space 10s. Thus, the RF source 31 can function as at least part of the plasma generator 12. The bias RF signal supplied to the at least one lower electrode causes a bias potential to occur in the substrate W, which potential then attracts ionic components in the plasma to the substrate W.

[0021] In an embodiment, the RF source 31 includes a first RF generator 31a and a second RF generator 31b. The first RF generator 31a is coupled to the at least one lower electrode and/or the at least one upper

electrode through the at least one impedance matching circuit and is configured to generate a source RF signal (source RF power) for generating a plasma. In an embodiment, the source RF signal has a frequency in a range of 10 MHz to 150 MHz. In an embodiment, the first RF generator 31a may be configured to generate two or more source RF signals having different frequencies. The resulting source RF signal(s) is supplied to the at least one lower electrode and/or the at least one upper electrode.

[0022] The second RF generator 31b is coupled to the at least one lower electrode through the at least one impedance matching circuit and is configured to generate a bias RF signal (bias RF power). The bias RF signal and the source RF signal may have the same frequency or different frequencies. In an embodiment, the bias RF signal has a frequency which is less than that of the source RF signal. In an embodiment, the bias RF signal has a frequency in a range of 100 kHz to 60 MHz. In an embodiment, the second RF generator 31b may be configured to generate two or more bias RF signals having different frequencies. The resulting bias RF signal(s) is supplied to the at least one lower electrode. In various embodiments, at least one of the source RF signal and the bias RF signal may be pulsed.

[0023] The electric power source 30 may also include a DC source 32 coupled to the plasma processing chamber 10. The DC source 32 includes a first DC generator 32a and a second DC generator 32b. In an embodiment, the first DC generator 32a is connected to the at least one lower electrode and is configured to generate a first DC signal. The resulting first DC signal is applied to the at least one lower electrode. In

an embodiment, the second DC generator 32b is connected to the at least one upper electrode and is configured to generate a second DC signal. The resulting second DC signal is applied to the at least one upper electrode.

[0024] In various embodiments, the first and second DC signals may be pulsed. In this case, a sequence of voltage pulses is applied to the at least one lower electrode and/or the at least one upper electrode. The voltage pulses have rectangular, trapezoidal, or triangular waveform, or a combined waveform thereof. In an embodiment, a waveform generator for generating a sequence of voltage pulses from the DC signal is disposed between the first DC generator 32a and the at least one lower electrode. The first DC generator 32a and the waveform generator thereby functions as a voltage pulse generator. In the case that the second DC generator 32b and the waveform generator functions as a voltage pulse generator, the voltage pulse generator is connected to the at least one upper electrode. The voltage pulse may have positive polarity or negative polarity. A sequence of voltage pulses may also include one or more positive voltage pulses and one or more negative voltage pulses in a cycle. The first and second DC generators 32a, 32b may be disposed in addition to the RF source 31, or the first DC generator 32a may be disposed in place of the second RF generator 31b.

[0025] The gas exhaust system 40 may be connected to, for example, a gas outlet 10e provided in the bottom wall of the plasma processing chamber 10. The gas exhaust system 40 may include a pressure regulation valve and a vacuum pump. The pressure regulation valve enables the pressure in the plasma processing space 10s to be adjusted.

The vacuum pump may be a turbo-molecular pump, a dry pump, or a combination thereof.

[0026] The substrate support 12 will now be described in detail with reference to Fig. 3. The substrate support 12 is disposed in the processing chamber 10. Fig. 3 is an enlarged cross-sectional view of a part of the substrate support according to one exemplary embodiment.

[0027] The substrate support 12 has a substantially disk shape. As shown in Fig. 3, the substrate support 12 includes an upper surface 15, a lower surface 16, and one or more partition walls 17. The upper surface 15 supports a substrate W placed thereon. The upper surface 15 includes a central region 12a and an annular region 12b. In the example shown in Fig. 3, the central region 12a is the upper surface of the electrostatic chuck 121, and the annular region 12b is a peripheral region of the upper surface of the base 120. The lower surface 16 is a surface opposite to the upper surface 15. The one or more partition walls 17 extend downward from the lower surface 16. The one or more partition walls 17 and the lower surface 16 define one or more spaces 18. The one or more partition walls 17 include an outer peripheral wall 17a. The outer peripheral wall 17a separates an interior of the substrate support 12 from an exterior of the substrate support 12.

[0028] In one embodiment, the one or more partition walls 17 may include a plurality of partition walls 17. The lower surface 16 and the plurality of partition walls 17 may define, as the one or more spaces 18, a plurality of spaces 18 separated from each other. In the following description, unless otherwise specified, an example in which the lower surface 16 and the plurality of partition walls 17 define the plurality of

spaces 18 will be described.

[0029] The plasma processing apparatus 1 includes a plurality of supply pipes 50 and one or more recovery pipes 60. In one embodiment, the one or more recovery pipes 60 may include a plurality of recovery pipes 60. The plurality of supply pipes 50 each have an open end 50a. The plurality of recovery pipes 60 each have an open end 60a. The open end 50a is opened toward the lower surface 16 to supply a heat transfer medium to the lower surface 16. The open end 50a is disposed in a corresponding one of the plurality of spaces 18. The plurality of spaces 18 include one space 18 in which the open end 50a of each of two or more supply pipes 50 among the plurality of supply pipes 50 is disposed. The plurality of recovery pipes 60 are connected to the plurality of spaces 18, respectively, to recover the heat transfer medium from the plurality of spaces 18, respectively. The plurality of recovery pipes 60 each have an open end 60a. Each of the plurality of recovery pipes 60 may include an expanded portion 60b. The expanded portion 60b is continuous with the open end 60a. The expanded portion 60b is widened such that an inner dimension of each of the plurality of recovery pipes 60 is maximized at the open end 60a.

[0030] Fig. 4 is an exploded perspective view of the substrate support according to one exemplary embodiment. As shown in Fig. 4, the base 120 has a substantially disk shape. The base 120 may include a main portion 120a and a flange portion 120b. The main portion 120a is a portion having a substantially circular planar shape. The flange portion 120b is a portion having an annular planar shape. The flange portion 120b is continuous with the main portion 120a so as to surround the

outer periphery of the main portion 120a. The base 120 may be formed from metal.

[0031] The base 120 may be formed from stainless steel (e.g., SUS304). Since stainless steel has low thermal conductivity, heat from the electrostatic chuck 121 is suppressed from escaping through the base 120. The base 120 may be formed from aluminum. Since aluminum has low resistivity, when the base 120 is used as a radio frequency electrode, power loss in the base 120 can be reduced. The base 120 may also be formed from an alloy or a metal matrix composite (MMC) containing titanium, molybdenum, and chromium as main components.

[0032] In one embodiment, as shown in Fig. 4, the upper surface 15 of the substrate support 12 includes a plurality of zones 15z. The plurality of zones 15z may include a plurality of zones arranged in a radial direction. In one example, the plurality of zones 15z may include a first zone 151, a second zone 152, and a third zone 153. The first zone 151 intersects a central axis of the substrate support 12. The second zone 152 extends so as to surround the first zone 151. The third zone 153 extends so as to surround the second zone 152. The plurality of zones 15z may include a plurality of zones arranged in a circumferential direction. A part of the plurality of zones 15z may be arranged in the radial direction, and another part may be arranged in the circumferential direction. In one example, the plurality of zones 15z may include a first zone 151, a second zone group, and a third zone group. The second zone group includes a plurality of zones arranged in the circumferential direction so as to surround the first zone 151. The third zone group includes a plurality of zones arranged in the circumferential direction so as to

surround the second zone group.

[0033] In one embodiment, the lower surface 16 of the substrate support 12 includes one or more lower surface regions 16z each extending below a corresponding zone 15z among the plurality of zones 15z (see Fig. 3). In one example, the lower surface 16 of the substrate support 12 may include a first lower surface region 161, a second lower surface region 162, and a third lower surface region 163. The first lower surface region 161 intersects the central axis of the substrate support 12. The first lower surface region 161 extends below the first zone 151. Each of the second lower surface region 162 and the third lower surface region 163 has an annular shape surrounding the first lower surface region 161 and is a lower surface region concentric with the central axis of the substrate support 12. The second lower surface region 162 extends below the second zone 152. The third lower surface region 163 extends below the third zone 153. The third lower surface region 163 has an annular shape surrounding the second lower surface region 162.

[0034] In one embodiment, the plurality of supply pipes 50 form a plurality of supply pipe groups 50g respectively corresponding to the plurality of zones 15z. Each of the plurality of supply pipe groups 50g includes at least one supply pipe 50 having an open end 50a that opens toward a corresponding lower surface region 16z among the plurality of lower surface regions 16z. The plurality of recovery pipes 60 form a plurality of recovery pipe groups 60g respectively corresponding to the plurality of supply pipe groups 50g.

[0035] In one example, the plurality of supply pipes 50 form a first supply pipe group 501, a second supply pipe group 502, and a third

supply pipe group 503 respectively corresponding to the first zone 151, the second zone 152, and the third zone 153. The first supply pipe group 501 includes at least one supply pipe 50 having an open end 50a that opens toward the first lower surface region 161. The second supply pipe group 502 includes at least one supply pipe 50 having an open end 50a that opens toward the second lower surface region 162. The third supply pipe group 503 includes at least one supply pipe 50 having an open end 50a that opens toward the third lower surface region 163. The plurality of recovery pipes 60 form a first recovery pipe group 601, a second recovery pipe group 602, and a third recovery pipe group 603 respectively corresponding to the first lower surface region 161, the second lower surface region 162, and the third lower surface region 163 (see Fig. 3).

[0036] Fig. 5 is a perspective view of the heat exchanger according to one exemplary embodiment. In one embodiment, the plurality of supply pipes 50 and the plurality of recovery pipes 60 may form a heat exchanger 19. The base 120 may be mounted on the heat exchanger 19. The heat exchanger 19 may include a main portion 19a and a flange portion 19b. The main portion 19a is a region having a substantially circular planar shape. The flange portion 19b is a region having an annular planar shape and is continuous with the main portion 19a so as to surround the outer periphery of the main portion 19a. As shown in Fig. 3, the flange portion 120b of the base 120 is disposed on the flange portion 19b of the heat exchanger 19. An O-ring 12e is sandwiched between the flange portion 19b and the flange portion 120b. The O-ring 12e is pressed between the flange portion 19b and the flange portion

120b, thereby sealing a gap between the flange portion 19b and the flange portion 120b.

[0037] Fig. 6(a) is a plan view of a cell portion of an example heat exchanger, and Fig. 6(b) is a perspective view of the cell portion of the example heat exchanger. The main portion 19a of the heat exchanger 19 provides a plurality of cell portions 19c. The plurality of cell portions 19c are disposed below the lower surface 16 of the substrate support 12. Each of the plurality of cell portions 19c is composed of at least one corresponding supply pipe 50 among the plurality of supply pipes 50 and at least one corresponding recovery pipe 60 among the plurality of recovery pipes 60. The number of supply pipes 50 and the number of recovery pipes 60 included in each cell portion 19c may each be one or more. Also, the number of supply pipes 50 and the number of recovery pipes 60 need not be equal. For example, a cell portion 19c may be composed of a plurality of supply pipes 50 and one recovery pipe 60. In one embodiment, the expanded portions 60b of adjacent recovery pipes 60 among the plurality of recovery pipes 60 are connected to each other at their ends. Each expanded portion 60b may form the bottom surface of the main portion 19a.

[0038] Each of the plurality of cell portions 19c may have a substantially rectangular planar shape whose width increases from the center of the heat exchanger 19 toward the outside in plan view. Each of the plurality of cell portions 19c provides a substantially rectangular recess 19d in plan view. The plurality of recesses 19d provided by the plurality of cell portions 19c are defined by the expanded portions 60b. The planar shape of the plurality of cell portions 19c is not limited to a

rectangle, and may be a circle or a polygon such as a triangle or a hexagon.

[0039] In each cell portion 19c, the supply pipe 50 extends such that its central axis coincides with the central axis of the recess 19d. In the heat exchanger 19, the plurality of supply pipes 50 extend parallel to each other. An inner surface defining each of the plurality of recesses 19d surrounds the outer peripheral surface of the corresponding supply pipe 50. That is, the expanded portion 60b surrounds the outer peripheral surface of the supply pipe 50 corresponding to the recovery pipe 60 of the expanded portion 60b.

[0040] The heat exchanger 19 may be formed from a material containing resin, ceramic, or metal as a main component. The heat exchanger 19 may be formed from a material having low thermal conductivity, for example, ceramic or resin, in order to suppress the influence of adjacent cell portions 19c. The heat exchanger 19 may be formed from partially different materials in order to partially change the strength and/or thermal conductivity of the heat exchanger 19. The heat exchanger 19 may be formed from the same material as the base 120. The base 120 and the heat exchanger 19 may be integrally formed using, for example, a 3D printer.

[0041] Fig. 7 is a cross-sectional view of the substrate support according to one exemplary embodiment. Fig. 7 is a cross-sectional view of the substrate support 12 taken along line VII-VII shown in Fig. 4. The cross-section of Fig. 7 is along the lower surface 16 of the substrate support 12. In one embodiment shown in Fig. 7, the plurality of partition walls 17 include one or more cylindrical partition walls 17b located

inside the outer peripheral wall 17a.

[0042] In one example, the one or more cylindrical partition walls 17b include, as a plurality of cylindrical partition walls 17b, two cylindrical partition walls 171 and 172. The cylindrical partition wall 172 extends so as to surround the cylindrical partition wall 171. The lower surface 16 and the cylindrical partition wall 171 define a space 18a. The space 18a intersects the central axis of the substrate support 12. The lower surface 16, the cylindrical partition wall 171, and the cylindrical partition wall 172 define a space 18b. The space 18b surrounds the space 18a. Each of the plurality of plate-shaped partition walls 17c is interposed between the space on its inner side and the space on its outer side. The cylindrical partition wall 171 is interposed between the space 18a on its inner side and the space 18b on its outer side among the plurality of spaces 18. The lower surface 16, the cylindrical partition wall 172, and the outer peripheral wall 17a define a space 18c. The cylindrical partition wall 172 is interposed between the space 18b on its inner side and the space 18c on its outer side among the plurality of spaces 18.

[0043] In one embodiment shown in Fig. 7, each of the one or more cylindrical partition walls 17b extends downward from a portion between two adjacent lower surface regions 16z among the plurality of lower surface regions 16z. The cylindrical partition wall 171 extends downward from a portion between the adjacent first lower surface region 161 and second lower surface region 162. The cylindrical partition wall 172 extends downward from a portion between the adjacent second lower surface region 162 and third lower surface region 163.

[0044] Fig. 8 is a cross-sectional view of a substrate support according

to another exemplary embodiment. Fig. 8 shows a cross-sectional view of a substrate support 12A. In one embodiment shown in Fig. 8, the plurality of partition walls 17 include a plurality of plate-shaped partition walls 17c located inside the outer peripheral wall 17a. The plurality of plate-shaped partition walls 17c extend radially from the central axis of the substrate support 12 and are arranged along the circumferential direction with respect to the central axis.

[0045] In one example, the plurality of plate-shaped partition walls 17c include six plate-shaped partition walls 173. The plurality of plate-shaped partition walls 17c may be arranged at equal angular intervals along the circumferential direction with respect to the central axis. Two adjacent plate-shaped partition walls 17c in the circumferential direction among the plurality of plate-shaped partition walls 17c and the lower surface 16 define a plurality of spaces 18d. Each of the plurality of spaces 18d has a fan shape when viewed from a direction along the central axis. The plurality of spaces 18d are arranged along the circumferential direction with respect to the central axis. Each of the plurality of plate-shaped partition walls 17c is interposed between two spaces 18d on both sides thereof in the circumferential direction among the plurality of spaces 18d.

[0046] Fig. 9 is a cross-sectional view of a substrate support according to yet another exemplary embodiment. Fig. 9 shows a cross-sectional view of a substrate support 12B. In one embodiment shown in Fig. 9, the plurality of partition walls 17 include one or more cylindrical partition walls 17b and a plurality of plate-shaped partition walls 17d. The one or more cylindrical partition walls 17b have a cylindrical shape and are

located inside the outer peripheral wall 17a. In one example, the one or more cylindrical partition walls 17b include a cylindrical partition wall 171.

[0047] In one example, the plurality of plate-shaped partition walls 17d include six plate-shaped partition walls 174. The plurality of plate-shaped partition walls 17d extend radially with respect to the central axis of the substrate support 12 between the cylindrical partition wall 171 and the outer peripheral wall 17a, and are arranged along the circumferential direction. The plurality of plate-shaped partition walls 17d connect the cylindrical partition wall 171 and the outer peripheral wall 17a. The plurality of plate-shaped partition walls 17d may be arranged at equal angular intervals along the circumferential direction with respect to the central axis.

[0048] In one embodiment, the lower surface 16, the cylindrical partition wall 171, the outer peripheral wall 17a, and the plate-shaped partition walls 17d define a plurality of spaces 18e. The plurality of spaces 18e are arranged along the circumferential direction with respect to the central axis. In one example, each of the plurality of spaces 18e has an annular sector shape. The cylindrical partition wall 171 is interposed between the plurality of spaces 18a on its inner side and the plurality of spaces 18e on its outer side among the plurality of spaces 18. Each of the plurality of plate-shaped partition walls 17d is interposed between two spaces 18e on both sides thereof in the circumferential direction among the plurality of spaces 18e. In one embodiment shown in Fig. 9, the cylindrical partition wall 171 extends downward from a portion between the first lower surface region 161 and the second lower

surface region 162 among the plurality of lower surface regions 16z. The first lower surface region 161 is a lower surface region that intersects the central axis of the substrate support 12. The second lower surface region 162 is an annular lower surface region adjacent to the first lower surface region 161.

[0049] Fig. 10 is a cross-sectional view of a substrate support according to yet another exemplary embodiment. Fig. 10 shows a cross-sectional view of a substrate support 12C. In one embodiment shown in Fig. 10, the one or more partition walls 17 include only the outer peripheral wall 17a. The lower surface 16 and the outer peripheral wall 17a define a single space 18f. In the single space 18f, the open end 50a of each of two or more supply pipes 50 among the plurality of supply pipes 50 is disposed.

[0050] Reference is now made to Fig. 11. Fig. 11 is a diagram schematically showing a circulation supply system of a heat transfer medium in a substrate processing apparatus according to one exemplary embodiment. In one example, a circulation device C for the heat transfer medium is connected to the plurality of supply pipes 50 and at least one recovery pipe 60. For example, the circulation device C is a chiller unit. The circulation device C adjusts the temperature of the heat transfer medium. The circulation device C is provided outside the processing chamber 10. The heat transfer medium is supplied from the circulation device C to the plurality of supply pipes 50. The heat transfer medium supplied from the plurality of supply pipes 50 to the lower surface 16 is recovered by the at least one recovery pipe 60 (see Fig. 3). The heat transfer medium recovered by the recovery pipe 60 is returned to the

circulation device C.

[0051] The plasma processing apparatus 1 includes one or more flow rate controllers B1. The one or more flow rate controllers B1 are connected to the plurality of supply pipes 50. The controller 2 controls an opening degree of the one or more flow rate controllers B1 to adjust a flow rate of the heat transfer medium supplied to the plurality of supply pipes 50. As one example, the flow rate controller B1 is a solenoid valve. The plasma processing apparatus 1 may include one or more flow meters F1. The one or more flow meters F1 are connected to the plurality of supply pipes 50. For example, the controller 2 controls the opening degree of the one or more flow rate controllers B1 based on flow rate information obtained from the one or more flow meters F1.

[0052] In the plasma processing apparatus 1, the flow velocity of the heat transfer medium supplied to the lower surface 16 of the substrate support 12 is adjusted by adjusting the flow rate of the heat transfer medium supplied to the plurality of supply pipes 50. The temperature of the substrate W on the substrate support 12 changes in accordance with the flow velocity of the heat transfer medium supplied to the lower surface 16. Therefore, the plasma processing apparatus 1 makes it possible to control the temperature of the substrate W.

[0053] In one embodiment, the plasma processing apparatus 1 includes a plurality of common supply pipes 51 and a plurality of common recovery pipes 61. The plurality of common supply pipes 51 are connected to the plurality of supply pipe groups 50g, respectively. The plurality of common recovery pipes 61 are connected to the plurality of recovery pipe groups 60g, respectively. In one embodiment, the one or

more flow rate controllers B1 include a plurality of flow rate controllers B1. In one embodiment, the one or more flow meters F1 include a plurality of flow meters F1.

[0054] Each of the plurality of common supply pipes 51 is connected between the circulation device C and a corresponding flow rate controller B1 among the plurality of flow rate controllers B1. Each of the plurality of common supply pipes 51 is connected to the corresponding supply pipe group 50g among the plurality of supply pipe groups 50g via the corresponding flow rate controller B1 among the plurality of flow rate controllers B1. The plurality of common recovery pipes 61 are connected to the circulation device C. Each of the plurality of common recovery pipes 61 is connected to the corresponding recovery pipe group 60g among the plurality of recovery pipe groups 60g. The plurality of flow meters F1 measure the flow rates of the heat transfer medium flowing through the plurality of common supply pipes 51, respectively. The controller 2 can control the opening degree of the corresponding flow rate controller B1 based on flow rate information obtained from each of the plurality of flow meters F1. In this embodiment, the flow velocity of the heat transfer medium is adjusted for each of the plurality of zones 15z of the upper surface 15 of the substrate support 12. Therefore, it is possible to individually control the temperatures of a plurality of regions of the substrate W located above the plurality of zones 15z, respectively.

[0055] In one embodiment, the plasma processing apparatus 1 includes a common supply line 52, a common recovery line 62, and a bypass flow rate controller B2. The common supply line 52 is connected to the

plurality of common supply pipes 51. The common supply line 52 is connected between the circulation device C and each of the plurality of common supply pipes 51. The common recovery line 62 is connected to the plurality of common recovery pipes 61. The common recovery line 62 is connected between the circulation device C and each of the plurality of common recovery pipes 61. The bypass flow rate controller B2 is connected between the common supply line 52 and the common recovery line 62. That is, a bypass flow path 82 including the bypass flow rate controller B2 is connected between the common supply line 52 and the common recovery line 62. As one example, the bypass flow rate controller B2 is a solenoid valve. A flow meter F2 may be provided in the bypass flow path 82.

[0056] Each of the plurality of flow rate controllers B1 is configured to adjust the flow rate of the heat transfer medium supplied to one supply pipe group 50g by adjusting its opening degree. The one supply pipe group 50g is the supply pipe group 50g for the corresponding zone 15z among the plurality of zones 15z among the plurality of supply pipe groups 50g. The controller 2 is configured to control the opening degree of each of the plurality of flow rate controllers B1 and to control the opening degree of the bypass flow rate controller B2 so as to maintain the total flow rate of the heat transfer medium supplied to the plurality of common supply pipes 51 and the heat transfer medium bypassed from the common supply line 52 to the common recovery line 62. For example, the controller 2 adjusts the opening degree of each of the plurality of flow rate controllers B1 and the opening degree of the bypass flow rate controller B2 based on flow rate information obtained from

each of the plurality of flow meters F1 and the flow meter F2.

[0057] In this embodiment, even when the flow rate of the heat transfer medium supplied to one zone among the plurality of zones 15z is changed, the flow rate of the heat transfer medium bypassed from the common supply line 52 to the common recovery line 62 is adjusted so as to maintain the total flow rate of the heat transfer medium. As a result, a change in the flow rate of the heat transfer medium supplied to one zone among the plurality of zones 15z does not affect the flow rate of the heat transfer medium supplied to the other zones. Therefore, in this embodiment, the independent controllability of the temperatures of the plurality of regions of the substrate W located above the respective plurality of zones 15z is enhanced.

[0058] Reference is now made to Figs. 12 and 13. Fig. 12 is a diagram schematically showing a circulation supply system of a heat transfer medium in a substrate processing apparatus according to another exemplary embodiment. Fig. 13(a) is a graph showing an example of a relationship between time and a flow rate of a heat transfer medium in the embodiment of Fig. 12. Fig. 13(b) is a graph showing an example of a relationship between time and a temperature of a substrate in the embodiment of Fig. 12. The differences of the embodiment of Fig. 12 from the embodiment of Fig. 11 will now be described.

[0059] A plasma processing apparatus 1A shown in Fig. 12 is another example substrate processing apparatus. The plasma processing apparatus 1A includes a plurality of bypass flow rate controllers B2. Each of the plurality of bypass flow rate controllers B2 is connected between one supply pipe group 50g and one recovery pipe group 60g. In

one example, each of the plurality of bypass flow rate controllers B2 is disposed in a bypass flow path 81 connecting one supply pipe group 50g and one recovery pipe group 60g. The one supply pipe group 50g is the supply pipe group 50g for the corresponding zone 15z among the plurality of supply pipe groups 50g. The one recovery pipe group 60g is the recovery pipe group 60g for the corresponding zone 15z among the plurality of recovery pipe groups 60g. The controller 2 controls the alternating opening and closing of each of the plurality of flow rate controllers B1 and the alternating opening and closing of each of the plurality of bypass flow rate controllers B2.

[0060] As shown in Fig. 13(a) and Fig. 13(b), during a period T1 in which each of the plurality of flow rate controllers B1 is open, the heat transfer medium is supplied to the supply pipe group 50g of the corresponding zone 15z, and the temperature of a region of the substrate W above the zone 15z decreases. During the period T1, the corresponding bypass flow rate controller B2 is closed.

[0061] On the other hand, during a period T2 in which each of the plurality of flow rate controllers B1 is closed, the supply of the heat transfer medium to the supply pipe group 50g of the corresponding zone 15z is stopped, and the temperature of the region of the substrate W above the zone 15z increases. During the period T2, the bypass flow rate controller B2 is opened so as to maintain the flow rate of the heat transfer medium supplied to the common supply pipe 51.

[0062] When the sum of the period T1 and the period T2 is taken as one cycle, one cycle in the present embodiment is, for example, 1 second to 0.05 seconds (1 Hz to 20 Hz). Also, when the value obtained by dividing

the period T1 by the sum of the period T1 and the period T2 (T1/(T1+T2)) is taken as the duty ratio, the duty ratio in the present embodiment is, for example, 0.1 to 0.8. This makes it possible to suppress the temperature fluctuation of the region of the substrate W above the zone 15z corresponding to each of the plurality of flow rate controllers B1 to within 2°C.

[0063] The controller 2 adjusts the time length of the period T1 during which each of the plurality of flow rate controllers B1 is open in the alternating opening and closing of each of the plurality of flow rate controllers B1, thereby adjusting the time-averaged value of the flow rate of the heat transfer medium supplied to the supply pipe group 50g of the corresponding zone 15z. This adjusts the time-averaged value of the temperature of the region of the substrate W above the corresponding zone 15z.

[0064] Therefore, according to the plasma processing apparatus 1A, it is possible to individually control the temperatures of the plurality of regions of the substrate W located above the respective plurality of zones 15z. Also, by the opening and closing of each of the plurality of bypass flow rate controllers B2, the flow rate of the heat transfer medium supplied to the corresponding common supply pipe 51 is maintained. As a result, a change in the flow rate of the heat transfer medium supplied to one zone among the plurality of zones 15z does not affect the flow rate of the heat transfer medium supplied to the other zones. Therefore, in the plasma processing apparatus 1A, the independent controllability of the temperatures of the plurality of regions of the substrate W located above the respective plurality of zones 15z is enhanced.

[0065] Reference is now made to Fig. 14. Fig. 14 is an enlarged cross-sectional view of a part of a substrate support according to yet another exemplary embodiment. As shown in Fig. 14, a plasma processing apparatus 1B includes a drive unit 90. The drive unit 90 may be, for example, a unit in which a motor and a ball screw are combined. The drive unit 90 is configured to move the open end 50a of at least one supply pipe 50 among the plurality of supply pipes 50 along the lower surface 16. In one embodiment, the drive unit 90 may be configured to integrally move the open end 50a of each supply pipe of at least one supply pipe group 50g. In one embodiment, the drive unit 90 may move one or more cell portions 19c included in a corresponding zone up and down.

[0066] In the plasma processing apparatus 1B, the position of the lower surface region 16z to which the heat transfer medium is supplied from the open end 50a of the supply pipe 50 is adjusted by the drive unit 90. Therefore, in the plasma processing apparatus 1B, the independent controllability of the temperatures of the plurality of regions of the substrate W located above the plurality of zones 15z, respectively is enhanced.

[0067] Although various exemplary embodiments have been described above, various additions, omissions, substitutions, and changes may be made without being limited to the above-described exemplary embodiments. Also, it is possible to combine elements in different embodiments to form other embodiments.

[0068] Various exemplary embodiments included in the present disclosure will now be described in [E1] to [E11] below.

[0069] [E1]

A substrate processing apparatus, comprising:

a processing chamber;

a substrate support disposed in the processing chamber, the substrate support including an upper surface that supports a substrate placed thereon, a lower surface opposite to the upper surface, and one or more partition walls extending downward from the lower surface, wherein the one or more partition walls and the lower surface define one or more spaces;

a plurality of supply pipes each having an open end that is opened toward the lower surface to supply a heat transfer medium to the lower surface, the open end being disposed in a corresponding one of the one or more spaces;

one or more recovery pipes connected to the one or more spaces, respectively, to recover the heat transfer medium from the one or more spaces, respectively;

one or more flow rate controllers connected to the plurality of supply pipes; and

a controller configured to control the one or more flow rate controllers to adjust a flow rate of the heat transfer medium supplied to the plurality of supply pipes,

wherein the one or more partition walls include an outer peripheral wall that separates an interior of the substrate support from an exterior of the substrate support, and

the one or more spaces include one space in which the open end of each of two or more supply pipes among the plurality of supply pipes

is disposed.

[0070] [E2]

The substrate processing apparatus according to E1, wherein

the one or more partition walls include a plurality of partition walls including the outer peripheral wall,

the plurality of partition walls and the lower surface define, as the one or more spaces, a plurality of spaces separated from each other,

each of the plurality of supply pipes has the open end disposed in a corresponding one of the plurality of spaces, and

the one or more recovery pipes include a plurality of recovery pipes connected to the plurality of spaces, respectively.

[0071] [E3]

The substrate processing apparatus according to E2, wherein

the plurality of partition walls include one or more cylindrical partition walls located inside the outer peripheral wall, and

each of the one or more cylindrical partition walls has a cylindrical shape and is interposed between a space on an inner side thereof and a space on an outer side thereof among the plurality of spaces.

[0072] [E4]

The substrate processing apparatus according to E3, wherein

the upper surface of the substrate support includes a plurality of zones,

the lower surface of the substrate support includes a plurality of lower surface regions each extending below a corresponding zone among the plurality of zones,

the plurality of supply pipes form a plurality of supply pipe groups respectively corresponding to the plurality of zones,

each of the plurality of supply pipe groups includes at least one supply pipe having an open end that opens toward a corresponding lower surface region among the plurality of lower surface regions,

the plurality of recovery pipes form a plurality of recovery pipe groups respectively corresponding to the plurality of supply pipe groups,

the substrate processing apparatus further comprises:

a plurality of common supply pipes connected to the plurality of supply pipe groups, respectively; and

a plurality of common recovery pipes connected to the plurality of recovery pipe groups, respectively,

the one or more flow rate controllers include a plurality of flow rate controllers connected to the plurality of common supply pipes, respectively,

the plurality of lower surface regions include:

a lower surface region that intersects a central axis of the substrate support; and

one or more annular lower surface regions having an annular shape surrounding the lower surface region and concentric with the central axis, and

each of the one or more cylindrical partition walls extends downward from a portion between two adjacent lower surface regions among the plurality of lower surface regions.

[0073] [E5]

The substrate processing apparatus according to any one of E2 to

E4, wherein

the plurality of partition walls include a plurality of plate-shaped partition walls located inside the outer peripheral wall,

the plurality of plate-shaped partition walls extend radially from a central axis of the substrate support and are arranged along a circumferential direction with respect to the central axis, and

each of the plurality of plate-shaped partition walls is interposed between two spaces on both sides thereof in the circumferential direction among the plurality of spaces.

[0074] [E6]

The substrate processing apparatus according to E5, wherein

the upper surface of the substrate support includes a plurality of zones,

the lower surface of the substrate support includes a plurality of lower surface regions each extending below a corresponding zone among the plurality of zones,

the plurality of supply pipes form a plurality of supply pipe groups respectively corresponding to the plurality of zones,

each of the plurality of supply pipe groups includes at least one supply pipe having an open end that opens toward a corresponding lower surface region among the plurality of lower surface regions,

the plurality of recovery pipes form a plurality of recovery pipe groups respectively corresponding to the plurality of supply pipe groups,

the substrate processing apparatus further comprises:

a plurality of common supply pipes connected to the plurality of supply pipe groups, respectively; and

a plurality of common recovery pipes connected to the plurality of recovery pipe groups, respectively,

the one or more flow rate controllers include a plurality of flow rate controllers connected to the plurality of common supply pipes, respectively, and

the plurality of lower surface regions include:

a lower surface region that intersects a central axis of the substrate support; and

one or more annular lower surface regions having an annular shape surrounding the lower surface region and concentric with the central axis.

[0075] [E7]

The substrate processing apparatus according to E2, wherein

the plurality of partition walls include:

one or more cylindrical partition walls having a cylindrical shape and located inside the outer peripheral wall; and

a plurality of plate-shaped partition walls extending radially with respect to a central axis of the substrate support between one of the one or more cylindrical partition walls and the outer peripheral wall, and arranged along a circumferential direction,

each of the one or more cylindrical partition walls is interposed between a space on an inner side thereof and a space on an outer side thereof among the plurality of spaces, and

each of the plurality of plate-shaped partition walls is interposed between two spaces on both sides thereof in the circumferential direction among the plurality of spaces.

[0076] [E8]

The substrate processing apparatus according to E7, wherein

the upper surface of the substrate support includes a plurality of zones,

the lower surface of the substrate support includes a plurality of lower surface regions each extending below a corresponding zone among the plurality of zones,

the plurality of supply pipes form a plurality of supply pipe groups respectively corresponding to the plurality of zones,

each of the plurality of supply pipe groups includes at least one supply pipe having an open end that opens toward a corresponding lower surface region among the plurality of lower surface regions,

the plurality of recovery pipes form a plurality of recovery pipe groups respectively corresponding to the plurality of supply pipe groups,

the substrate processing apparatus further comprises:

a plurality of common supply pipes connected to the plurality of supply pipe groups, respectively; and

a plurality of common recovery pipes connected to the plurality of recovery pipe groups, respectively,

the one or more flow rate controllers include a plurality of flow rate controllers connected to the plurality of common supply pipes, respectively,

the plurality of lower surface regions include:

a lower surface region that intersects a central axis of the substrate support; and

one or more annular lower surface regions having an

annular shape surrounding the lower surface region and concentric with the central axis, and

one cylindrical partition wall among the one or more cylindrical partition walls extends downward from a portion between an annular lower surface region adjacent to the lower surface region that intersects the central axis among the one or more annular lower surface regions and the lower surface region that intersects the central axis.

[0077] [E9]

The substrate processing apparatus according to any one of E4, E6, and E8, further comprising:

a common supply line connected to the plurality of common supply pipes;

a common recovery line connected to the plurality of common recovery pipes; and

a bypass flow rate controller connected between the common supply line and the common recovery line,

wherein each of the plurality of flow rate controllers is configured to adjust, by an opening degree thereof, a flow rate of the heat transfer medium supplied to a supply pipe group, among the plurality of supply pipe groups, for a corresponding zone among the plurality of zones, and

the controller is configured to control the opening degree of each of the plurality of flow rate controllers and to control the opening degree of the bypass flow rate controller to maintain a total flow rate of the heat transfer medium supplied to the plurality of common supply pipes and the heat transfer medium bypassed from the common supply line to the

common recovery line.

[0078] [E10]

The substrate processing apparatus according to any one of E4, E6, and E8, further comprising:

a common supply line connected to the plurality of common supply pipes;

a common recovery line connected to the plurality of common recovery pipes; and

a plurality of bypass flow rate controllers,

wherein each of the plurality of bypass flow rate controllers is connected between a supply pipe group for a corresponding zone, among the plurality of supply pipe groups, and a recovery pipe group for the corresponding zone, among the plurality of recovery pipe groups, and

the controller:

adjusts a time during which the plurality of flow rate controllers are open in an alternating opening and closing of each of the plurality of flow rate controllers, thereby adjusting a time-averaged value of a flow rate of the heat transfer medium supplied to the supply pipe group for the corresponding zone, among the plurality of supply pipe groups, and

controls the opening and closing of the plurality of bypass flow rate controllers to maintain the flow rate of the heat transfer medium supplied to each of the plurality of common supply pipes.

[0079] [E11]

The substrate processing apparatus according to any one of E1 to E10, further comprising:

at least one drive unit configured to move the open end of at least one supply pipe among the plurality of supply pipes along the lower surface.

[0080] From the foregoing description, it will be appreciated that various exemplary embodiments of the present disclosure are described herein for purposes of illustration, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various exemplary embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

Reference Signs List

[0081] 1: plasma processing apparatus, 2: controller, 10: processing chamber, 12, 12A, 12B: substrate support, 15: upper surface, 15z: zone, 16: lower surface, 16z: lower surface region, 17: partition wall, 17a: outer peripheral wall, 17b: cylindrical partition wall, 17c, 17d, 17e: plate-shaped partition wall, 18, 18a, 18b, 18c, 18d, 18e, 18f: space, 50: supply pipe, 50a: open end, 50g: supply pipe group, 51: common supply pipe, 52: common supply line, 60: recovery pipe, 60a: open end, 60g: recovery pipe group, 61: common recovery pipe, 62: common recovery line, 90: drive unit, B1: flow rate controller, B2: bypass flow rate controller, W: substrate.

CLAIMS

[Claim 1]

A substrate processing apparatus, comprising:

a processing chamber;

a substrate support disposed in the processing chamber, the substrate support including an upper surface that supports a substrate placed thereon, a lower surface opposite to the upper surface, and one or more partition walls extending downward from the lower surface, wherein the one or more partition walls and the lower surface define one or more spaces;

a plurality of supply pipes each having an open end that is opened toward the lower surface to supply a heat transfer medium to the lower surface, the open end being disposed in a corresponding one of the one or more spaces;

one or more recovery pipes connected to the one or more spaces, respectively, to recover the heat transfer medium from the one or more spaces, respectively;

one or more flow rate controllers connected to the plurality of supply pipes; and

a controller configured to control the one or more flow rate controllers to adjust a flow rate of the heat transfer medium supplied to the plurality of supply pipes,

wherein the one or more partition walls include an outer peripheral wall that separates an interior of the substrate support from an exterior of the substrate support, and

the one or more spaces include one space in which the open end

of each of two or more supply pipes among the plurality of supply pipes is disposed.

[Claim 2]

The substrate processing apparatus according to claim 1, wherein

the one or more partition walls include a plurality of partition walls including the outer peripheral wall,

the plurality of partition walls and the lower surface define, as the one or more spaces, a plurality of spaces separated from each other,

each of the plurality of supply pipes has the open end disposed in a corresponding one of the plurality of spaces, and

the one or more recovery pipes include a plurality of recovery pipes connected to the plurality of spaces, respectively.

[Claim 3]

The substrate processing apparatus according to claim 2, wherein

the plurality of partition walls include one or more cylindrical partition walls located inside the outer peripheral wall, and

each of the one or more cylindrical partition walls has a cylindrical shape and is interposed between a space on an inner side thereof and a space on an outer side thereof among the plurality of spaces.

[Claim 4]

The substrate processing apparatus according to claim 3, wherein

the upper surface of the substrate support includes a plurality of

zones,

the lower surface of the substrate support includes a plurality of lower surface regions each extending below a corresponding zone among the plurality of zones,

the plurality of supply pipes form a plurality of supply pipe groups respectively corresponding to the plurality of zones,

each of the plurality of supply pipe groups includes at least one supply pipe having an open end that opens toward a corresponding lower surface region among the plurality of lower surface regions,

the plurality of recovery pipes form a plurality of recovery pipe groups respectively corresponding to the plurality of supply pipe groups,

the substrate processing apparatus further comprises:

a plurality of common supply pipes connected to the plurality of supply pipe groups, respectively; and

a plurality of common recovery pipes connected to the plurality of recovery pipe groups, respectively,

the one or more flow rate controllers include a plurality of flow rate controllers connected to the plurality of common supply pipes, respectively,

the plurality of lower surface regions include:

a lower surface region that intersects a central axis of the substrate support; and

one or more annular lower surface regions having an annular shape surrounding the lower surface region and concentric with the central axis, and

each of the one or more cylindrical partition walls extends

downward from a portion between two adjacent lower surface regions among the plurality of lower surface regions.

[Claim 5]

The substrate processing apparatus according to claim 2, wherein

the plurality of partition walls include a plurality of plate-shaped partition walls located inside the outer peripheral wall,

the plurality of plate-shaped partition walls extend radially from a central axis of the substrate support and are arranged along a circumferential direction with respect to the central axis, and

each of the plurality of plate-shaped partition walls is interposed between two spaces on both sides thereof in the circumferential direction among the plurality of spaces.

[Claim 6]

The substrate processing apparatus according to claim 5, wherein

the upper surface of the substrate support includes a plurality of zones,

the lower surface of the substrate support includes a plurality of lower surface regions each extending below a corresponding zone among the plurality of zones,

the plurality of supply pipes form a plurality of supply pipe groups respectively corresponding to the plurality of zones,

each of the plurality of supply pipe groups includes at least one supply pipe having an open end that opens toward a corresponding lower surface region among the plurality of lower surface regions,

the plurality of recovery pipes form a plurality of recovery pipe groups respectively corresponding to the plurality of supply pipe groups,

the substrate processing apparatus further comprises:

a plurality of common supply pipes connected to the plurality of supply pipe groups, respectively; and

a plurality of common recovery pipes connected to the plurality of recovery pipe groups, respectively,

the one or more flow rate controllers include a plurality of flow rate controllers connected to the plurality of common supply pipes, respectively, and

the plurality of lower surface regions include:

a lower surface region that intersects a central axis of the substrate support; and

one or more annular lower surface regions having an annular shape surrounding the lower surface region and concentric with the central axis.

[Claim 7]

The substrate processing apparatus according to claim 2, wherein

the plurality of partition walls include:

one or more cylindrical partition walls having a cylindrical shape and located inside the outer peripheral wall; and

a plurality of plate-shaped partition walls extending radially with respect to a central axis of the substrate support between one of the one or more cylindrical partition walls and the outer peripheral wall, and arranged along a circumferential direction,

each of the one or more cylindrical partition walls is interposed between a space on an inner side thereof and a space on an outer side thereof among the plurality of spaces, and

each of the plurality of plate-shaped partition walls is interposed between two spaces on both sides thereof in the circumferential direction among the plurality of spaces.

[Claim 8]

The substrate processing apparatus according to claim 7, wherein

the upper surface of the substrate support includes a plurality of zones,

the lower surface of the substrate support includes a plurality of lower surface regions each extending below a corresponding zone among the plurality of zones,

the plurality of supply pipes form a plurality of supply pipe groups respectively corresponding to the plurality of zones,

each of the plurality of supply pipe groups includes at least one supply pipe having an open end that opens toward a corresponding lower surface region among the plurality of lower surface regions,

the plurality of recovery pipes form a plurality of recovery pipe groups respectively corresponding to the plurality of supply pipe groups,

the substrate processing apparatus further comprises:

a plurality of common supply pipes connected to the plurality of supply pipe groups, respectively; and

a plurality of common recovery pipes connected to the

plurality of recovery pipe groups, respectively,

the one or more flow rate controllers include a plurality of flow rate controllers connected to the plurality of common supply pipes, respectively,

the plurality of lower surface regions include:

a lower surface region that intersects a central axis of the substrate support; and

one or more annular lower surface regions having an annular shape surrounding the lower surface region and concentric with the central axis, and

one cylindrical partition wall among the one or more cylindrical partition walls extends downward from a portion between an annular lower surface region adjacent to the lower surface region that intersects the central axis among the one or more annular lower surface regions and the lower surface region that intersects the central axis.

[Claim 9]

The substrate processing apparatus according to any one of claims 4, 6, and 8, further comprising:

a common supply line connected to the plurality of common supply pipes;

a common recovery line connected to the plurality of common recovery pipes; and

a bypass flow rate controller connected between the common supply line and the common recovery line,

wherein each of the plurality of flow rate controllers is configured to adjust, by an opening degree thereof, a flow rate of the

heat transfer medium supplied to a supply pipe group, among the plurality of supply pipe groups, for a corresponding zone among the plurality of zones, and

the controller is configured to control the opening degree of each of the plurality of flow rate controllers and to control the opening degree of the bypass flow rate controller to maintain a total flow rate of the heat transfer medium supplied to the plurality of common supply pipes and the heat transfer medium bypassed from the common supply line to the common recovery line.

[Claim 10]

The substrate processing apparatus according to any one of claims 4, 6, and 8, further comprising:

a common supply line connected to the plurality of common supply pipes;

a common recovery line connected to the plurality of common recovery pipes; and

a plurality of bypass flow rate controllers,

wherein each of the plurality of bypass flow rate controllers is connected between a supply pipe group for a corresponding zone, among the plurality of supply pipe groups, and a recovery pipe group for the corresponding zone, among the plurality of recovery pipe groups, and

the controller:

adjusts a time during which the plurality of flow rate controllers are open in an alternating opening and closing of each of the plurality of flow rate controllers, thereby adjusting a time-averaged value of a flow rate of the heat transfer medium supplied to the supply

pipe group for the corresponding zone, among the plurality of supply pipe groups, and

controls the opening and closing of the plurality of bypass flow rate controllers to maintain the flow rate of the heat transfer medium supplied to each of the plurality of common supply pipes.

[Claim 11]

The substrate processing apparatus according to any one of claims 1 to 8, further comprising:

at least one drive unit configured to move the open end of at least one supply pipe among the plurality of supply pipes along the lower surface.