

DESCRIPTION

Title of Invention: SUBSTRATE PROCESSING SYSTEM AND TEACHING METHOD FOR CONVEYANCE ROBOT

5 **Technical Field**

[0001] Exemplary embodiments of the present disclosure relate to a substrate processing system and a teaching method for a transfer robot.

Background Art

10 [0002] Substrate processing systems capable of performing various types of processing such as plasma processing on a substrate are known. A substrate processing system includes a process module and a transfer module. A process module has a chamber and a substrate support. The substrate support is provided in the chamber and supports a substrate placed on the substrate support. Patent Literature 1 below adjusts the position of a substrate placed on a substrate support using a camera.

Citation List

Patent Literature

[0003] [Patent Literature 1] Japanese Translation of PCT International Application Publication No. 2022-520038

20 **Summary of Invention**

Technical Problem

[0004] The present disclosure provides a technique for reducing deviation of a substrate.

Solution to Problem

25 [0005] In one exemplary embodiment, a substrate processing system is provided. The substrate processing system includes a chamber, a

substrate support, a transfer module, a controller, and a position detector. The chamber provides a processing space therein. The substrate support is disposed in the processing space. The transfer module has an end effector. The end effector is configured to support a substrate. The transfer module includes a transfer robot configured to transfer the substrate to the processing space. The controller is configured to control the substrate support and the transfer module. The substrate support has a substrate support surface, a ring support surface, a plurality of lifter pins, and a drive unit. The substrate support surface is configured to support the substrate. The ring support surface extends so as to surround the substrate support surface and is configured to support a ring member. The plurality of lifter pins are configured to protrude upward from the ring support surface. The drive unit is configured to move the plurality of lifter pins up and down. The ring member provides a plurality of recesses respectively corresponding to the plurality of lifter pins. The position detector is configured to detect the position of the ring member disposed on the ring support surface. The controller is configured to perform (a), (b), (c), and (d). (a) includes controlling the drive unit to move the plurality of lifter pins upward in order to cause the ring member to self-guide so that the tips of the plurality of lifter pins are respectively positioned within the plurality of recesses by lifting the ring member disposed on the ring support surface from the ring support surface by the plurality of lifter pins. (b) includes controlling, after (a), the drive unit to move the plurality of lifter pins downward in order to lower the ring member lifted by the plurality of lifter pins onto the ring support surface. (c) includes detecting, after (b), the position of the ring member that is

disposed on the ring support surface, by the position detector. (d) includes controlling, after (c), the transfer module to transfer the substrate supported on the end effector to the substrate support surface based on the position of the ring member detected by the position detector.

Advantageous Effects of Invention

[0006] According to one exemplary embodiment, deviation of a position at which a substrate is placed is reduced.

Brief Description of Drawings

[0007] [FIG. 1] is a diagram showing a substrate processing system according to one exemplary embodiment.

[FIG. 2] is a diagram showing an end effector according to one exemplary embodiment.

[FIG. 3] is a diagram for explaining an example structure of a capacitively coupled plasma processing apparatus.

[FIG. 4] is a diagram schematically showing a plasma processing apparatus according to one exemplary embodiment.

[FIG. 5] is a partially enlarged cross-sectional view of a substrate support of a plasma processing apparatus according to one exemplary embodiment.

[FIG. 6] is a diagram schematically showing a configuration of a ring member according to one exemplary embodiment.

[FIG. 7] FIG. 7(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to one exemplary embodiment.

FIG. 7(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to one exemplary

embodiment.

[FIG. 8] FIG. 8(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to another exemplary embodiment. FIG. 8(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to another exemplary embodiment.

[FIG. 9] FIG. 9(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to yet another exemplary embodiment. FIG. 9(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to yet another exemplary embodiment.

[FIG. 10] FIG. 10(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to yet another exemplary embodiment. FIG. 10(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to yet another exemplary embodiment.

[FIG. 11] is a flowchart of a teaching method for a transfer robot according to one exemplary embodiment.

Description of Embodiments

[0008] 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] FIG. 1 is a diagram showing a substrate processing system according to one exemplary embodiment. As shown in FIG. 1, a substrate processing system PS includes a transfer module VTM, a position detector PD, a controller MC, and a plurality of process modules

PM1 to PM6. In one embodiment, the substrate processing system PS may further include a loader module LM and at least one loadlock module. The substrate processing system PS includes two loadlock modules LL1 and LL2 as the at least one loadlock module. The substrate processing system PS may further include at least one load port, a substrate inspection module CM, an aligner AN, and a storage SR. The substrate processing system PS includes four load ports LP1 to LP4 as the at least one load port.

[0010] The loader module LM is an example of an atmospheric transfer module. In one embodiment, the loader module LM includes a transfer chamber ACH. The transfer chamber ACH is an example of another transfer chamber. The pressure in the transfer chamber ACH of the loader module LM can be set to atmospheric pressure. The loader module LM may have an FFU (Fan Filter Unit). The loader module LM is, for example, an EFEM (Equipment Front End Module). The loader module LM is disposed between each of the load ports LP1 to LP4 and each of the loadlock modules LL1 and LL2. The load ports LP1 to LP4 are arranged along one of a pair of edges along the longitudinal direction of the loader module LM. The loadlock modules LL1 and LL2 are arranged along the other of the pair of edges along the longitudinal direction of the loader module LM. Each of the load ports LP1 to LP4 is configured to support a cassette CST placed thereon. The cassette CST is a container that accommodates a plurality of substrates W therein. The cassette CST is, for example, a FOUP (Front-Opening Unified Pod).

[0011] In one embodiment, the loader module LM includes a transfer robot TR3. The transfer robot TR3 is an example of another transfer

robot. The transfer robot TR3 is provided in the transfer chamber ACH of the loader module LM. The transfer robot TR3 may include an articulated arm AR31 and an end effector FK31. The end effector FK31 is attached to the tip of the articulated arm AR31. The end effector FK31 is configured to support a substrate W. The transfer robot TR3 is configured to transfer the substrate W through the transfer chamber ACH. For example, the transfer robot TR3 transfers the substrate W based on an operation instruction output by the controller MC described later. The transfer robot TR3 transfers the substrate W between any two of the cassette CST placed on at least one of the load ports LP1 to LP4, the loadlock modules LL1 and LL2, the aligner AN, and the storage SR. [0012] The aligner AN is disposed along one of a pair of edges along the short-side direction of the loader module LM. The aligner AN may be disposed along an edge along the longitudinal direction of the loader module LM. The aligner AN may also be disposed inside the transfer chamber ACH of the loader module LM. The aligner AN has a stage, an optical sensor, and the like. The stage of the aligner AN is rotatable and supports a substrate W placed thereon. The aligner AN detects the angular position of a marker (e.g., a notch) of the substrate W on the stage and the center position of the substrate W on the stage using the optical sensor. The controller MC controls the rotation of the stage of the aligner AN to correct the angular position of the marker (e.g., a notch) of the substrate W on the stage to a reference angular position in order to correct the amount of deviation of the angular position of the substrate W. The controller MC also controls the position of the end effector FK31 when receiving the substrate W from the aligner AN onto the end effector

FK31 in order to position the center of the substrate W at a predetermined position on the end effector FK31.

[0013] The storage SR is disposed along an edge along the longitudinal direction of the loader module LM. The storage SR may be disposed along an edge along the short-side direction of the loader module LM. The storage SR may also be provided inside the loader module LM. The storage SR is configured to accommodate the substrate W therein.

[0014] The substrate inspection module CM may be provided inside the loader module LM or the transfer module VTM. The substrate inspection module CM may be connected to the loader module LM below the load ports LP1 to LP4. The substrate inspection module CM is not limited to the above-described locations and can be installed at any location. The substrate inspection module CM is configured to acquire an image of the substrate W.

[0015] In one embodiment, the loadlock modules LL1 and LL2 are connected to the loader module LM. Each of the loadlock modules LL1 and LL2 may be connected to the loader module LM via a gate valve G3. In the example shown in FIG. 1, each of the loadlock modules LL1 and LL2 is connected to the transfer module VTM via a gate valve G2. Each of the loadlock modules LL1 and LL2 may be disposed between the transfer module VTM and the loader module LM. Each of the loadlock modules LL1 and LL2 provides a preliminary decompression chamber.

[0016] The transfer module VTM has at least one transfer chamber and at least one transfer robot. In the example shown in FIG. 1, the transfer module VTM has a transfer chamber VCH and a transfer robot TR as the at least one transfer chamber and the at least one transfer robot. The

transfer chamber VCH is configured to be depressurizable. The transfer robot TR is configured to transfer the substrate W through the transfer chamber VCH.

5 [0017] Each of the plurality of process modules PM1 to PM6 has a chamber 10 and a substrate support 11 (see FIG. 3). The chamber 10 provides a processing space therein. The chamber 10 is connected to the transfer module VTM. In the example shown in FIG. 1, the process modules PM1 to PM6 are connected to the transfer module VTM via gate valves G1. The transfer robot TR is configured to transfer the
10 substrate W to the processing space 10s.

[0018] The transfer robot TR may include articulated arms AR11 and AR12 and end effectors FK11 and FK12. The end effector FK11 is attached to the tip of the articulated arm AR11 and is configured to support a substrate W. The end effector FK12 is attached to the tip of
15 the articulated arm AR12 and is configured to support a substrate W placed thereon. For example, the transfer robot TR transfers the substrate W based on an operation instruction output by the controller MC described later. The transfer robot TR supports the substrate W by the end effector FK11 or FK12. The transfer robot TR is configured to
20 transfer the substrate W between paths to the loadlock modules LL1 and LL2 and the process modules PM1 to PM6. In one embodiment, a ring member R is an edge ring ER (focus ring) or a cover ring CR. The edge ring ER is used to surround the substrate W on the substrate support 11. The cover ring CR is used to surround the edge ring ER. Details of the
25 edge ring ER and the cover ring CR will be described later.

[0019] In one embodiment, each of the process modules PM1 to PM6 is

configured to perform dedicated processing on the substrate W. At least one of the process modules PM1 to PM6 is a substrate processing apparatus such as a plasma processing apparatus 1 described later.

[0020] The controller MC is configured to control each part of the substrate processing system PS. The controller MC may be a computer including a processor, a storage, an input device, a display, and the like. The controller MC performs a control program stored in the storage and controls each part of the substrate processing system PS based on recipe data stored in the storage. Transfer methods according to various exemplary embodiments described later are performed in the substrate processing system PS by the controller MC controlling each part of the substrate processing system PS. The controller MC is configured to control the transfer module VTM and the substrate support 11. The controller MC may be connected to the position detector PD.

[0021] FIG. 2 is a diagram showing an end effector according to one exemplary embodiment. The end effector is also referred to as a transfer fork or a transfer pick. FIG. 2 shows, as an example, the configuration of the end effector FK11, it may also be the configuration of the end effector FK12. The end effector FK11 has a horseshoe shape when viewed from the direction in which the substrate W is supported. In one embodiment, the end effector FK11 includes a main body FKM and a pair of tip portions FKB. The pair of tip portions FKB protrude from the main body FKM. A gap is defined between the pair of tip portions FKB. The substrate W is supported on the end effector FK11 so that the central axis of the substrate W passes through the gap.

[0022] In one embodiment, the position detector PD includes a pair of

distance sensors FS1 and FS2. The pair of distance sensors FS1 and FS2 may be connected to the transfer module VTM and/or the controller MC. In one example, the distance sensors FS1 and FS2 are optical fiber displacement sensors. In one embodiment, the pair of distance sensors FS1 and FS2 are respectively disposed at the pair of tip portions FKB. The tips FSa of the pair of distance sensors FS1 and FS2 are located at the pair of tip portions FKB, respectively.

[0023] Each of the distance sensors FS1 and FS2 measures the distance between its tips FSa and an object. Each of the distance sensors FS1 and FS2 emits measurement light toward an object and receives reflected light through its tips FSa. A unit controller (not shown) connected to the distance sensors FS1 and FS2 measures the distance from the tips FSa to the object. The unit controller may be a part of the transfer module VTM or the controller MC. The tips FSa of the distance sensors FS1 and FS2 are arranged to emit measurement light downward below the end effector FK11. In one example, when the distance between the tips FSa of the distance sensors FS1 and FS2 and an object becomes short while the end effector FK11 is being moved in the horizontal direction, the position detector PD detects the position of the object in the horizontal direction. As the position of the object, the coordinates in the transfer module VTM of the tips FSa of each of the distance sensors FS1 and FS2 when the distance between the tips FSa of each of the distance sensors FS1 and FS2 and the object becomes short may be acquired.

[0024] Reference is now made to FIGS. 3 and 4. The plasma processing system shown in FIG. 3 can be employed as a part of the substrate processing system PS. The example of the plasma processing apparatus

shown in FIG. 4 is employed as at least one process module among the process modules PM1 to PM6.

[0025] FIG. 3 is a diagram for explaining an example structure of a plasma processing system. In one embodiment, the plasma processing system includes a plasma processing apparatus 1 and a controller 2. The plasma processing system is an example of a substrate processing system, and the plasma processing apparatus 1 is an example of a 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 also 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 discharging gas from the plasma processing space. The gas inlet is connected to a gas supply 20 described later, and the gas outlet is connected to an exhaust system 40 described later. The substrate support 11 is disposed in the plasma processing space and has a substrate support surface for supporting a substrate.

[0026] The plasma generator 12 is configured to generate plasma from at least one process gas supplied into the plasma processing space. The plasma formed in the plasma processing space may be capacitively coupled plasma (CCP: Capacitively Coupled Plasma), inductively coupled plasma (ICP: Inductively Coupled Plasma), ECR plasma (Electron-Cyclotron-Resonance Plasma), helicon wave plasma (HWP: Helicon Wave Plasma), or surface wave plasma (SWP: Surface Wave Plasma), and the like. Various types of plasma generators including an

AC (Alternating Current) plasma generator and a DC (Direct Current) plasma generator may also be used. In one embodiment, the AC signal (AC power) used in the AC plasma generator has a frequency within a range of 100 kHz to 10 GHz. Thus, the AC signal includes an RF (Radio Frequency) signal and a microwave signal. In one embodiment, the RF signal has a frequency within a range of 100 kHz to 150 MHz.

[0027] The controller 2 processes computer-executable instructions that cause the plasma processing apparatus 1 to perform various steps described in the present disclosure. The controller 2 may be configured to control each element of the plasma processing apparatus 1 to perform the various steps described herein. In one embodiment, some or all of the controller 2 may be included in 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 by, for example, a computer 2a. The processor 2a1 may be configured to perform various control operations by loading a program from the storage 2a2 and performing the loaded program. The program may be prestored in the storage 2a2 or may be obtained through a medium as appropriate. The obtained program is stored in the storage 2a2, loaded from the storage 2a2 by the processor 2a1, and performed. The medium may be one of various storage media readable by the computer 2a, or a communication line connected to the communication interface 2a3. The processor 2a1 may be a CPU (Central Processing Unit). The storage 2a2 may include a RAM (Random Access Memory), a ROM (Read Only Memory), an HDD (Hard Disk Drive), an SSD (Solid State Drive), or a combination of these. The communication interface 2a3 may

communicate with the plasma processing apparatus 1 through a communication line such as a LAN (Local Area Network). The controller 2 may also serve as the controller MC.

[0028] An example structure of a capacitively coupled plasma processing apparatus as an example of the plasma processing apparatus 1 will now be described. FIG. 4 is a diagram for explaining an example structure of the capacitively coupled plasma processing apparatus.

[0029] The capacitively coupled plasma processing apparatus 1 includes a plasma processing chamber 10, a gas supply 20, a power supply 30, and an exhaust system 40. The plasma processing apparatus 1 also includes a substrate support 11 and a gas inlet unit. The gas inlet unit is configured to introduce at least one process gas into the plasma processing chamber 10. The gas inlet unit includes a shower head 13. The substrate support 11 is disposed in the plasma processing chamber 10. The shower head 13 is disposed above the substrate support 11. In one embodiment, the shower head 13 defines at least a part of the ceiling of the plasma processing chamber 10. The plasma processing chamber 10 has a plasma processing space 10s defined by the shower head 13, a side wall 10a of the plasma processing chamber 10, and the substrate support 11. The plasma processing chamber 10 is grounded. The shower head 13 and the substrate support 11 are electrically insulated from the housing of the plasma processing chamber 10.

[0030] The substrate support 11 includes a main body 5. In one embodiment, the substrate support may include a ring member R. The main body 5 has a central region 5a for supporting a substrate W and an annular region 5b for supporting the ring member R. A wafer is an

example of the substrate W. The annular region 5b of the main body 5 surrounds the central region 5a of the main body 5 in a plan view. The substrate W is disposed on the central region 5a of the main body 5, and the ring member R is disposed on the annular region 5b of the main body 5 to surround the substrate W on the central region 5a of the main body 5. Thus, the central region 5a is also referred to as a substrate support surface for supporting the substrate W, and the annular region 5b is also referred to as a ring support surface for supporting the ring member R.

[0031] In one embodiment, the main body 5 includes a base 50 and an electrostatic chuck 51. The base 50 includes a conductive member. The conductive member of the base 50 can function as a lower electrode. The electrostatic chuck 51 is disposed on the base 50. The electrostatic chuck 51 includes a ceramic member 51a and an electrostatic electrode 51b disposed inside the ceramic member 51a. The ceramic member 51a has the central region 5a. In one embodiment, the ceramic member 51a also has the annular region 5b. Note that another member surrounding the electrostatic chuck 51, such as an annular electrostatic chuck or an annular insulating member, may have the annular region 5b. In this case, the ring member R may be disposed on the annular electrostatic chuck or the annular insulating member, or may be disposed on both the electrostatic chuck 51 and the annular insulating member. At least one RF/DC electrode coupled to an RF power supply 31 and/or a DC power supply 32 described later may also be disposed inside the ceramic member 51a. In this case, the at least one RF/DC electrode functions as a lower electrode. When a bias RF signal and/or a DC signal described later is supplied to the at least one RF/DC electrode, the RF/DC electrode

is also referred to as a bias electrode. Note that the conductive member of the base 50 and the at least one RF/DC electrode may function as a plurality of lower electrodes. The electrostatic electrode 51b may also function as a lower electrode. Thus, the substrate support 11 includes at least one lower electrode.

[0032] The ring member R includes one or more annular members. In one embodiment, the one or more annular members include one or more edge rings ER and at least one cover ring CR. The edge ring ER is formed from a conductive material or an insulating material, and the cover ring CR is formed from an insulating material.

[0033] The substrate support 11 may also include a temperature control module configured to adjust at least one of the electrostatic chuck 51, the ring member R, and the substrate to a target temperature. The temperature control module may include a heater, a heat transfer medium, a channel 50a, or a combination of these. A heat transfer fluid such as brine or gas flows through the channel 50a. In one embodiment, the channel 50a is formed in the base 50, and one or more heaters are disposed in the ceramic member 51a of the electrostatic chuck 51. The substrate support 11 may also include a heat transfer gas supply configured to supply a heat transfer gas into a gap between the back surface of the substrate W and the central region 5a.

[0034] The shower head 13 is configured to introduce at least one process gas from the gas supply 20 into the plasma processing space 10s. The shower head 13 has at least one gas inlet 13a, at least one gas diffusion chamber 13b, and a plurality of gas introduction ports 13c. The process gas supplied to the gas inlet 13a passes through the gas diffusion

chamber 13b and is introduced into the plasma processing space 10s through the plurality of gas introduction ports 13c. The shower head 13 also includes at least one upper electrode. In addition to the shower head 13, the gas inlet unit may include one or more side gas injectors (SGI: Side Gas Injector) installed in one or more openings formed in the side wall 10a.

[0035] The gas supply 20 may include at least one gas source 21 and at least one flow rate controller 22. In one embodiment, the gas supply 20 is configured to supply at least one process gas from the corresponding gas source 21 to the shower head 13 through the corresponding flow rate controller 22. Each flow rate controller 22 may include, for example, a mass flow controller or a pressure control type flow rate controller. Furthermore, the gas supply 20 may include at least one flow rate modulation device that modulates or pulses the flow rate of at least one process gas.

[0036] The power supply 30 includes an RF power supply 31 coupled to the plasma processing chamber 10 through at least one impedance matching circuit. The RF power supply 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. This causes plasma to be formed from at least one process gas supplied to the plasma processing space 10s. Thus, the RF power supply 31 can function as at least a part of the plasma generator 12. Also, by supplying a bias RF signal to at least one lower electrode, a bias potential is generated in the substrate W, and ionic components in the formed plasma can be drawn into the substrate W.

[0037] In one embodiment, the RF power supply 31 includes a first RF

generator 31a and a second RF generator 31b. The first RF generator 31a is coupled to at least one lower electrode and/or at least one upper electrode through at least one impedance matching circuit and is configured to generate a source RF signal (source RF power) for plasma generation. In one embodiment, the source RF signal has a frequency within a range of 10 MHz to 150 MHz. In one embodiment, the first RF generator 31a may be configured to generate a plurality of source RF signals having different frequencies. The generated one or more source RF signals are supplied to at least one lower electrode and/or at least one upper electrode.

[0038] The second RF generator 31b is coupled to at least one lower electrode through at least one impedance matching circuit and is configured to generate a bias RF signal (bias RF power). The frequency of the bias RF signal may be the same as or different from the frequency of the source RF signal. In one embodiment, the bias RF signal has a frequency lower than the frequency of the source RF signal. In one embodiment, the bias RF signal has a frequency within a range of 100 kHz to 60 MHz. In one embodiment, the second RF generator 31b may be configured to generate a plurality of bias RF signals having different frequencies. The generated one or more bias RF signals are supplied to at least one lower electrode. Also, in various embodiments, at least one of the source RF signal and the bias RF signal may be pulsed.

[0039] The power supply 30 may also include a DC power supply 32 coupled to the plasma processing chamber 10. The DC power supply 32 includes a first DC generator 32a and a second DC generator 32b. In one embodiment, the first DC generator 32a is connected to at least one

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

5 The generated second DC signal is applied to at least one upper electrode.

[0040] In various embodiments, the first and second DC signals may be pulsed. In this case, a sequence of voltage pulses is applied to at least one lower electrode and/or at least one upper electrode. The voltage

10 pulses may have a pulse waveform of rectangular, trapezoidal, triangular, or a combination of these. In one embodiment, a waveform generator for generating a sequence of voltage pulses from a DC signal is connected between the first DC generator 32a and at least one lower electrode. Thus, the first DC generator 32a and the waveform generator

15 constitute a voltage pulse generator. When the second DC generator 32b and the waveform generator constitute a voltage pulse generator, the voltage pulse generator is connected to at least one upper electrode. The voltage pulses may have a positive polarity or a negative polarity. Also, the sequence of voltage pulses may include one or more positive-polarity

20 voltage pulses and one or more negative-polarity voltage pulses within one cycle. Note that the first and second DC generators 32a and 32b may be provided in addition to the RF power supply 31, and the first DC generator 32a may be provided in place of the second RF generator 31b.

[0041] The exhaust system 40 can be connected to, for example, a gas

25 outlet 10e provided at the bottom of the plasma processing chamber 10. The exhaust system 40 may include a pressure control valve and a

vacuum pump. The pressure in the plasma processing space 10s is regulated by the pressure control valve. The vacuum pump may include a turbomolecular pump, a dry pump, or a combination of these.

[0042] Reference is now made to FIG. 5. FIG. 5 is a partially enlarged cross-sectional view of a substrate support of a plasma processing apparatus according to one exemplary embodiment. The substrate support 11 includes a substrate support surface 51c and a ring support surface 51d. The substrate support surface 51c is configured to support the substrate W. The substrate support surface 51c is a substantially circular surface. The ring support surface 51d is configured to support the ring member R. The ring support surface 51d is an annular surface that extends outside the substrate support surface 51c and around the substrate support surface 51c. In one embodiment, the ring support surface 51d is positioned lower than the substrate support surface 51c. A step is formed between the substrate support surface 51c and the ring support surface 51d. In one embodiment, the position of the edge of the substrate support surface 51c may be detected by the position detector PD.

[0043] The electrostatic chuck 51 includes the substrate support surface 51c and the ring support surface 51d. The electrostatic chuck 51 is configured to electrostatically attract and hold the substrate W on the substrate support surface 51c and the edge ring ER on the ring support surface 51d, respectively. The edge ring ER is an example of the ring member R. The edge ring ER has an annular shape. The substrate W is disposed in a region surrounded by the edge ring ER. The edge ring ER is formed from, for example, a conductive material such as silicon or

silicon carbide. The edge ring ER may be formed from an insulating material such as quartz. The position of the edge ring ER is detected by the position detector PD.

[0044] The electrostatic chuck 51 has a dielectric portion 51e, a first chuck electrode 51f, and a second chuck electrode 51g. The dielectric portion 51e is formed from a ceramic such as aluminum oxide. The dielectric portion 51e has a substantially disk shape and provides the substrate support surface 51c and the ring support surface 51d.

[0045] The first chuck electrode 51f and the second chuck electrode 51g are disposed inside the dielectric portion 51e and below the substrate support surface 51c. When a voltage is applied to the first chuck electrode 51f, the electrostatic chuck 51 generates an electrostatic attraction force to attract and hold the substrate W to the substrate support surface 51c. The second chuck electrode 51g is disposed inside the dielectric portion 51e and below the ring support surface 51d. When a voltage is applied to the second chuck electrode 51g, the electrostatic chuck 51 generates an electrostatic attraction force to attract and hold the edge ring ER to the ring support surface 51d. Note that in the illustrated example, the electrostatic chuck 51 includes a monopolar electrostatic chuck that holds the substrate W and a bipolar electrostatic chuck that holds the edge ring ER. However, a bipolar electrostatic chuck may be used in place of the monopolar electrostatic chuck, and a monopolar electrostatic chuck may be used in place of the bipolar electrostatic chuck.

[0046] A cover ring CR is disposed outside the edge ring ER to surround the edge ring ER. The cover ring CR is an example of the ring member

R. The cover ring CR has an annular shape. The cover ring CR covers the upper surface of an insulator 27. The cover ring CR is formed from, for example, an insulating material such as quartz. The cover ring CR may be formed from a conductive material such as silicon or silicon carbide. The outer peripheral portion of the edge ring ER is disposed to overlap with the inner peripheral portion of the cover ring CR when viewed from above. The outer peripheral portion of the cover ring CR is disposed outside the outer peripheral portion of the edge ring ER and surrounds the outer peripheral portion of the edge ring ER.

[0047] The substrate support 11 includes a plurality of lifter pins 71 and a drive unit 72. The plurality of lifter pins 71 are configured to protrude upward from the ring support surface 51d. The drive unit 72 is configured to move the plurality of lifter pins 71 up and down. The plurality of lifter pins 71 are respectively inserted into a plurality of through-holes 71h formed in the base 50 and the insulator 27. The cover ring CR may provide a plurality of holes CRh through which the plurality of lifter pins 71 are respectively inserted. As the drive unit 72, for example, a motor such as a DC motor, a stepping motor, or a linear motor, an air-driven mechanism such as an air cylinder, or a piezo actuator can be used. The controller MC raises and lowers the plurality of lifter pins 71 when transferring the ring member R between the transfer robot TR and the substrate support 11.

[0048] In one embodiment, the substrate support 11 may include a plurality of lifter pins 73 and a drive unit 74. The plurality of lifter pins 73 are configured to protrude upward from the substrate support surface 51c. The drive unit 74 is configured to move the plurality of lifter pins

73 up and down. The plurality of lifter pins 73 are respectively inserted into a plurality of through-holes 73h formed in the base 50 and the electrostatic chuck 51. As the drive unit 74, the same configuration as the drive unit 72 can be used. The controller MC raises and lowers the plurality of lifter pins 73 when transferring the substrate W between the transfer robot TR and the substrate support 11.

[0049] Reference is now made to FIG. 6, FIG. 7(a), and FIG. 7(b). FIG. 6 is a diagram schematically showing a configuration of a ring member according to one exemplary embodiment. The ring member R provides a plurality of recesses 8 respectively corresponding to the plurality of lifter pins 71. In the following, an edge ring ER that provides a plurality of recesses 8 will be described as an example of the ring member R. The plurality of recesses 8 may be arranged at equal intervals along the circumference of the edge ring ER. In one embodiment, the plurality of recesses 8 include three or more recesses 8. In the example shown in FIG. 6, the plurality of recesses 8 include three recesses 8.

[0050] In one embodiment, each of the plurality of recesses 8 includes a first width W1 and a second width W2. The first width W1 is along the radial direction D1 of the edge ring ER. The second width W2 is along the circumferential direction D2 of the edge ring ER. As shown in FIG. 6, the first width W1 may be larger than the second width W2. Each of the plurality of recesses 8 may have a groove shape extending along the radial direction D1. The first width W1 and the second width W2 are larger than the diameter of the tip 71a of each of the plurality of lifter pins 71. Each of the plurality of recesses 8 is configured so that the tip 71a of each of the plurality of lifter pins 71 is positioned therein. Note

that the first width W1 and the second width W2 may be defined at the opening 8a of each of the plurality of recesses 8, or may be defined at the bottom surface of each of the plurality of recesses 8.

[0051] FIG. 7(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to one exemplary embodiment.

FIG. 7(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to one exemplary embodiment. In one embodiment, the inner surface 80 defining each of the plurality of recesses 8 may include a tapered surface 81. The tapered surface 81 widens as it approaches the opening 8a of each of the plurality of recesses 8. In one embodiment, as shown in FIG. 7(a), in a cross-section orthogonal to the radial direction D1, the inner surface 80 is curved to widen as it approaches the opening 8a. The tip 71a of each of the plurality of lifter pins 71 is curved along the curved inner surface 80.

[0052] Reference is now made to FIG. 8(a) and FIG. 8(b) to describe a plurality of recesses 8A according to another exemplary embodiment. FIG. 8(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to another exemplary embodiment. FIG. 8(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to another exemplary embodiment. In another embodiment, as shown in FIG. 8(a), in a cross-section orthogonal to the radial direction D1, the inner surface 80 is curved at a bottom portion 82 that is farthest from the opening 8a. In one embodiment, the inner surface 80 from the opening 8a to the bottom portion 82 may be a tapered surface 81. In the cross-section orthogonal to the radial direction D1, the radius of curvature of the bottom portion

82 is smaller than the radius of curvature of the tip 71a of each of the plurality of lifter pins 71. In the plurality of recesses 8A, a gap is defined between the bottom portion 82 of the inner surface 80 and the tip 71a of each of the plurality of lifter pins 71. In the plurality of recesses 8A, the tip 71a of each of the plurality of lifter pins 71 faces the tapered surface 81.

[0053] Reference is now made to FIG. 9(a) and FIG. 9(b) to describe a plurality of recesses 8B according to yet another exemplary embodiment. FIG. 9(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to yet another exemplary embodiment. FIG. 9(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to yet another exemplary embodiment. In yet another embodiment, as shown in FIG. 9(a), in a cross-section orthogonal to the radial direction D1, the inner surface 80 includes a tapered surface 81 and a flat surface 83. As described above, the tapered surface 81 widens as it approaches the opening 8a of each of the plurality of recesses 8. The flat surface 83 faces the tip 71a of each of the plurality of lifter pins 71. The tapered surface 81 and the flat surface 83 are continuous. In the plurality of recesses 8B, the tip 71a of each of the plurality of lifter pins 71 faces the flat surface 83 of the inner surface 80. The tip 71a of each of the plurality of lifter pins 71 may be along the flat surface 83 of the inner surface 80.

[0054] Reference is now made to FIG. 10(a) and FIG. 10(b) to describe a plurality of recesses 8C according to yet another exemplary embodiment. FIG. 10(a) is an enlarged cross-sectional view orthogonal to the radial direction of one recess according to yet another exemplary

embodiment. FIG. 10(b) is an enlarged cross-sectional view orthogonal to the circumferential direction of one recess according to yet another exemplary embodiment. In yet another embodiment, as shown in FIG. 10(a), in a cross-section orthogonal to the radial direction D1, the inner surface 80 includes a tapered surface 81, a flat surface 84, and an inner wall surface 85. As described above, the tapered surface 81 widens as it approaches the opening 8a of each of the plurality of recesses 8. The flat surface 84 faces the tip 71a of each of the plurality of lifter pins 71. The tip 71a of each of the plurality of lifter pins 71 may be along the flat surface 84 of the inner surface 80. The inner wall surface 85 connects the tapered surface 81 and the flat surface 84. The inner wall surface 85 extends along the direction in which the plurality of lifter pins 71 move. In the example shown in FIG. 10(a), the inner wall surface 85 extends along the vertical direction.

[0055] FIG. 11 is a flowchart of a teaching method for a transfer robot according to one exemplary embodiment. The teaching method for a transfer robot is performed using the substrate processing system PS. An example of the teaching method for a transfer robot (hereinafter referred to as "method MT") will now be described with reference to FIG. 11. The controller MC is configured to perform the method MT. Note that the method MT may be performed using a substrate processing system other than the substrate processing system PS. In the method MT, teaching of the transfer robot TR of the transfer module VTM is performed. In the teaching, a path along which the transfer robot TR transfers the substrate W in substrate processing is taught. In the method MT, a dummy substrate may be used in place of the substrate W. In the

method MT described below, an edge ring ER is used as an example of the ring member R.

5 [0056] The method MT is started after the edge ring ER is disposed on the ring support surface 51d. The edge ring ER may be disposed on the ring support surface 51d by an operator. In one embodiment, the method MT may include step ST1. If the method MT includes step ST1, the method MT starts from step ST1. In step ST1, the processing space 10s is depressurized. The controller MC may control the exhaust system 40 to depressurize the processing space 10s. Since the method MT starts from step ST1, deviation of the edge ring ER and/or the substrate W due to depressurization of the processing space 10s is resolved by subsequent steps.

15 [0057] After step ST1, step ST2 is performed. In step ST2, the plurality of lifter pins 71 are moved upward in order to cause the edge ring ER to self-guide so that the tips of the plurality of lifter pins 71 are respectively positioned within the plurality of recesses 8 by lifting the edge ring ER disposed on the ring support surface 51d from the ring support surface 51d by the plurality of lifter pins 71. The controller MC may control the drive unit 72 to move the plurality of lifter pins 71 upward. By step ST2, the deviation of the edge ring ER disposed on the ring support surface 51d is corrected to a position defined by the plurality of lifter pins 71 and the plurality of recesses 8 of the edge ring ER.

20 [0058] After step ST2, step ST3 is performed. In step ST3, the plurality of lifter pins 71 are moved downward in order to lower the edge ring ER lifted by the plurality of lifter pins 71 onto the ring support surface 51d. The controller MC may control the drive unit 72 to move the plurality of

25

lifter pins 71 downward.

[0059] In one embodiment, each of step ST2 and step ST3 may be performed a plurality of times. The controller MC may control the drive unit 72 to alternately repeat each of the operation of lifting the edge ring ER from the ring support surface 51d and the operation of lowering the edge ring ER onto the ring support surface 51d. The deviation of the edge ring ER on the ring support surface 51d that cannot be resolved by a single execution of step ST2 and step ST3 can be resolved.

[0060] After step ST3, step ST4 is performed. In step ST4, the position of the edge ring ER disposed on the ring support surface 51d is detected by the position detector PD. In one embodiment, step ST4 may include step ST41. In step ST41, the center position of the edge ring ER is estimated from the position of the edge ring ER detected by the position detector PD. In one example, the center position of the edge ring ER may be estimated based on two or more edges of the edge ring ER detected by the pair of distance sensors FS1 and FS2 and the diameter of the edge ring ER stored in advance. The center position of the edge ring ER may be estimated from the circumcenter of a triangle based on three or more edges of the edge ring ER detected by the pair of distance sensors FS1 and FS2. The edge of the edge ring ER may be the inner edge of the edge ring ER or the outer edge of the edge ring ER.

[0061] In one embodiment, the method MT may include step ST42 and step ST43. In step ST42, the center position of the substrate support surface 51c is estimated from the position of the edge of the substrate support surface 51c detected by the position detector PD. In one example, the center position of the substrate support surface 51c may be

estimated based on two or more edges of the substrate support surface 51c detected by the pair of distance sensors FS1 and FS2 and the diameter of the substrate support surface 51c stored in advance. The center position of the substrate support surface 51c may be estimated from the circumcenter of a triangle based on three or more edges of the substrate support surface 51c detected by the pair of distance sensors FS1 and FS2. In step ST43, the deviation between the center position of the edge ring ER estimated in step ST41 and the center position of the substrate support surface 51c estimated in step ST42 is acquired.

[0062] In one embodiment, in step ST43, when the deviation is greater than a threshold value, step ST2, step ST3, step ST41, step ST42, and step ST43 may be repeated at least once. In the example shown in FIG. 11, when the determination in step ST43 is "NO" and the number of times the determination in step ST43 has been "NO" until the method MT ends is three or fewer ($n \leq 3$), step ST2, step ST3, step ST41, step ST42, and step ST43 are repeated.

[0063] In one embodiment, in step ST43, when the deviation is greater than a threshold value, step ST5 of issuing a warning is performed. In the example shown in FIG. 11, when the determination in step ST43 is "NO" and the number of times the determination in step ST43 has been "NO" until the method MT ends is more than three ($n > 3$), step ST5 is performed. The method MT ends after step ST5.

[0064] In one embodiment, after step ST3, step ST6 may be performed. In step ST6, the edge ring ER on the ring support surface 51d is held by the electrostatic chuck 51. The controller MC may be configured to control the electrostatic chuck 51 to hold the edge ring ER on the ring

support surface 51d. In the example shown in FIG. 11, after step ST43, when the determination in step ST43 is "YES", step ST6 is performed.

[0065] After step ST4, step ST7 is performed. In step ST7, the substrate W supported on the end effector FK11 or FK12 is transferred to the substrate support surface 51c based on the position of the edge ring ER detected by the position detector PD. The controller MC may be configured to control the transfer module VTM to transfer the substrate W to the substrate support surface 51c. Step ST7 may include step ST71, step ST72, and step ST73. In step ST71, the substrate W is placed on the plurality of lifter pins 73 protruding above the substrate support surface 51c based on the position of the edge ring ER detected by the position detector PD. In step ST72, the plurality of lifter pins 73 are moved downward in order to lower the substrate W placed on the plurality of lifter pins 73 onto the substrate support surface 51c. In step ST73, the position of the substrate W lowered onto the substrate support surface 51c by step ST72 is detected by the position detector PD.

[0066] In one embodiment, step ST7 may include step ST7a. In step ST7a, the substrate W is transferred so that the center position of the substrate W estimated from the position of the end effector FK11 or FK12 overlaps with the center position of the edge ring ER estimated in step ST41. In one example, the center position of the substrate W is estimated from the position of the coordinates of the end effector FK11 or FK12 in the transfer module VTM. The controller MC may be configured to control the transfer module VTM so that the center position of the substrate W overlaps with the center position of the edge ring ER. In step ST73, the center position of the substrate W may be

estimated. In step ST73, the deviation between the center position of the substrate W and the center position of the edge ring ER and/or the substrate support surface 51c may be acquired. After step ST7, the method MT ends.

5 [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.

10 [0068] The position detector may be a contact sensor or a non-contact sensor. The distance sensor is an example of a non-contact sensor. The position detector may be an imaging element. The imaging element may be disposed inside the chamber 10.

15 [0069] Various exemplary embodiments included in the present disclosure will now be described in [E1] to [E18] below.

[0070] [E1]

A substrate processing system comprising:

a chamber providing a processing space therein;

a substrate support disposed in the processing space;

20 a transfer module including a transfer robot having an end effector configured to support a substrate and configured to transfer the substrate to the processing space;

a controller configured to control the substrate support and the transfer module; and

25 a position detector,

wherein the substrate support has:

a substrate support surface configured to support the substrate;

a ring support surface surrounding the substrate support surface and configured to support a ring member;

5 a plurality of lifter pins configured to protrude upward from the ring support surface; and

a drive unit configured to move the plurality of lifter pins up and down,

10 wherein the ring member provides a plurality of recesses respectively corresponding to the plurality of lifter pins,

wherein the position detector is configured to detect a position of the ring member disposed on the ring support surface, and

wherein the controller is configured to perform:

15 (a) controlling the drive unit to move the plurality of lifter pins upward in order to cause the ring member to self-guide so that tips of the plurality of lifter pins are respectively positioned within the plurality of recesses by lifting the ring member disposed on the ring support surface from the ring support surface by the plurality of lifter pins;

20 (b) controlling, after the (a), the drive unit to move the plurality of lifter pins downward in order to lower the ring member lifted by the plurality of lifter pins onto the ring support surface;

(c) detecting, after the (b), the position of the ring member that is disposed on the ring support surface, by the position detector; and

25

(d) controlling, after the (c), the transfer module to

transfer the substrate supported on the end effector to the substrate support surface based on the position of the ring member detected by the position detector.

[0071] [E2]

5 The substrate processing system according to E1, wherein the controller is configured to perform, before the (a), depressurizing the processing space.

[0072] [E3]

10 The substrate processing system according to E1 or E2, wherein the controller is configured to perform each of the (a) and the (b) a plurality of times.

[0073] [E4]

15 The substrate processing system according to any one of E1 to E3, wherein the (c) includes (c1) estimating a center position of the ring member from the position of the ring member detected by the position detector, and

 wherein the (d) includes (d1) controlling the transfer module so that a center position of the substrate estimated from a position of the end effector overlaps with the center position of the ring member estimated in the (c1).

20

[0074] [E5]

 The substrate processing system according to E4, wherein the ring support surface is positioned lower than the substrate support surface,

25 wherein the position detector is configured to detect an edge of the substrate support surface, and

wherein the controller is configured to perform:

(c2) estimating a center position of the substrate support surface from the position of the edge of the substrate support surface detected by the position detector; and

5 (c3) acquiring a deviation between the center position of the ring member estimated in the (c1) and the center position of the substrate support surface estimated in the (c2).

[0075] [E6]

10 The substrate processing system according to E5, wherein the controller is configured to, when the deviation is greater than a threshold value in the (c3), repeat the (a), the (b), the (c1), the (c2), and the (c3) at least once.

[0076] [E7]

15 The substrate processing system according to E5 or E6, wherein the controller is configured to, when the deviation is greater than a threshold value in the (c3), perform issuing a warning.

[0077] [E8]

20 The substrate processing system according to any one of E1 to E7, wherein the substrate support has an electrostatic chuck including the substrate support surface and the ring support surface and configured to hold the substrate on the substrate support surface and the ring member on the ring support surface, respectively, and

wherein the controller is configured to perform:

25 (b1) controlling the electrostatic chuck to electrostatically attract and hold the ring member on the ring support surface, between the (b) and the (c).

[0078] [E9]

The substrate processing system according to any one of E1 to E8, wherein the position detector includes a pair of distance sensors, wherein the end effector has:

5

a main body; and

a pair of tip portions protruding from the main body,

wherein a gap is defined between the pair of tip portions, and

wherein the pair of distance sensors are respectively disposed at

the pair of tip portions.

10

[0079] [E10]

The substrate processing system according to any one of E1 to E9, wherein the substrate support further has the ring member.

[0080] [E11]

15

The substrate processing system according to any one of E1 to E10, wherein the plurality of recesses include three or more recesses.

[0081] [E12]

The substrate processing system according to any one of E1 to E11, wherein each of the plurality of recesses includes:

a first width along a radial direction of the ring member;

20

and

a second width along a circumferential direction of the

ring member, and

wherein the first width is larger than the second width.

[0082] [E13]

25

The substrate processing system according to any one of E1 to E12, wherein an inner surface defining each of the plurality of recesses

includes a tapered surface that widens as it approaches an opening of each of the plurality of recesses.

[0083] [E14]

5 The substrate processing system according to any one of E1 to E13, wherein, in a cross-section orthogonal to the radial direction of the ring member, an inner surface defining each of the plurality of recesses is curved so as to widen as it approaches an opening of each of the plurality of recesses, and

10 wherein the tip of each of the plurality of lifter pins is curved along the inner surface.

[0084] [E15]

15 The substrate processing system according to any one of E1 to E14, wherein, in a cross-section orthogonal to the radial direction of the ring member, an inner surface defining each of the plurality of recesses is curved at a bottom portion farthest from an opening of each of the plurality of recesses, and

 wherein, in the cross-section, a radius of curvature of the bottom portion is smaller than a radius of curvature of the tip of each of the plurality of lifter pins.

20 [0085] [E16]

 The substrate processing system according to any one of E13 to E15, wherein an inner surface defining each of the plurality of recesses includes a flat surface facing the tip of each of the plurality of lifter pins, and

25 wherein the tapered surface and the flat surface are continuous.

[0086] [E17]

The substrate processing system according to any one of E13 to E16, wherein an inner surface defining each of the plurality of recesses includes:

5 a flat surface facing the tip of each of the plurality of lifter pins; and

an inner wall surface extending along a direction in which the plurality of lifter pins move and connecting the tapered surface and the flat surface.

[0087] [E18]

10 A teaching method for a transfer robot performed in a substrate processing system,

wherein the substrate processing system comprises:

a chamber providing a processing space therein; and

a substrate support disposed in the processing space,

15 wherein the substrate support has:

a substrate support surface configured to support a substrate;

a ring support surface surrounding the substrate support surface and configured to support a ring member; and

20 a plurality of lifter pins configured to protrude upward from the ring support surface,

wherein the ring member provides a plurality of recesses, and

wherein the teaching method for a transfer robot includes:

25 (a) moving the plurality of lifter pins upward in order to cause the ring member to self-guide so that tips of the plurality of lifter pins are respectively positioned within the plurality of recesses by lifting

the ring member disposed on the ring support surface from the ring support surface by the plurality of lifter pins;

5 (b) moving, after the (a), the plurality of lifter pins downward in order to lower the ring member lifted by the plurality of lifter pins onto the ring support surface;

(c) detecting, after the (b), the position of the ring member disposed on the ring support surface; and

(d) transferring, after the (c), the substrate to the substrate support surface based on the detected position of the ring member.

10 [0088] E18 may be performed using the substrate processing system according to any one of E1 to E17.

[0089] From the above description, it will be understood that various embodiments of the present disclosure are described herein for purposes of explanation, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, and the true scope and spirit are indicated by the appended claims.

Reference Signs List

20 [0090] 1: plasma processing apparatus, 8, 8A, 8B, 8C: recess, 8a: opening, 10: chamber, 10s: processing space, 11: substrate support, 51: electrostatic chuck, 51c: substrate support surface, 51d: ring support surface, 71, 73: lifter pin, 71a, FSa: tip, 80: inner surface, 81: tapered surface, 82: bottom portion, 83, 84: flat surface, 85: inner wall surface, 25 D1: radial direction, D2: circumferential direction, FK11, FK12, FK31: end effector, FKB: tip portion, FKM: main body, FS1, FS2: distance

sensor, MC: controller, PD: position detector, PS: substrate processing system, R: ring member, VTM: transfer module, W: substrate, W1: first width, W2: second width.

CLAIMS

[Claim 1]

A substrate processing system comprising:

a chamber providing a processing space therein;

5 a substrate support disposed in the processing space;

a transfer module including a transfer robot having an end effector configured to support a substrate and configured to transfer the substrate to the processing space;

10 a controller configured to control the substrate support and the transfer module; and

a position detector,

wherein the substrate support has:

a substrate support surface configured to support the substrate;

15 a ring support surface surrounding the substrate support surface and configured to support a ring member;

a plurality of lifter pins configured to protrude upward from the ring support surface; and

20 a drive unit configured to move the plurality of lifter pins up and down,

wherein the ring member provides a plurality of recesses respectively corresponding to the plurality of lifter pins,

wherein the position detector is configured to detect a position of the ring member disposed on the ring support surface, and

25 wherein the controller is configured to perform:

(a) controlling the drive unit to move the plurality of lifter

pins upward in order to cause the ring member to self-guide so that tips of the plurality of lifter pins are respectively positioned within the plurality of recesses by lifting the ring member disposed on the ring support surface from the ring support surface by the plurality of lifter pins;

(b) after the (a), controlling the drive unit to move the plurality of lifter pins downward in order to lower the ring member lifted by the plurality of lifter pins onto the ring support surface;

(c) after the (b), detecting the position of the ring member that is disposed on the ring support surface, by the position detector; and

(d) after the (c), controlling the transfer module to transfer the substrate supported on the end effector to the substrate support surface based on the position of the ring member detected by the position detector.

[Claim 2]

The substrate processing system according to claim 1, wherein the controller is configured to perform before the (a), depressurizing the processing space.

[Claim 3]

The substrate processing system according to claim 1, wherein the controller is configured to perform each of the (a) and the (b) a plurality of times.

[Claim 4]

The substrate processing system according to claim 1, wherein the (c) includes (c1) estimating a center position of the ring member from the position of the ring member detected by the

position detector, and

wherein the (d) includes (d1) controlling the transfer module so that a center position of the substrate estimated from a position of the end effector overlaps with the center position of the ring member estimated in the (c1).

[Claim 5]

The substrate processing system according to claim 4,

wherein the ring support surface is positioned lower than the substrate support surface,

wherein the position detector is configured to detect an edge of the substrate support surface, and

wherein the controller is configured to perform:

(c2) estimating a center position of the substrate support surface from the position of the edge of the substrate support surface detected by the position detector; and

(c3) acquiring a deviation between the center position of the ring member estimated in the (c1) and the center position of the substrate support surface estimated in the (c2).

[Claim 6]

The substrate processing system according to claim 5,

wherein the controller is configured to, when the deviation is greater than a threshold value in the (c3), repeat the (a), the (b), the (c1), the (c2), and the (c3) at least once.

[Claim 7]

The substrate processing system according to claim 5,

wherein the controller is configured to, when the deviation is

greater than a threshold value in the (c3), perform issuing a warning.

[Claim 8]

The substrate processing system according to claim 1,

5 wherein the substrate support has an electrostatic chuck including the substrate support surface and the ring support surface, the electrostatic chuck configured to hold the substrate on the substrate support surface and the ring member on the ring support surface, respectively, and

10 wherein the controller is configured to perform (b1) controlling the electrostatic chuck to electrostatically attract and hold the ring member on the ring support surface, between the (b) and the (c).

[Claim 9]

The substrate processing system according to claim 1,

15 wherein the position detector includes a pair of distance sensors, wherein the end effector has:

a main body; and

a pair of tip portions protruding from the main body,

wherein a gap is defined between the pair of tip portions, and

20 wherein the pair of distance sensors are respectively disposed at the pair of tip portions.

[Claim 10]

The substrate processing system according to any one of claims 1 to 9,

wherein the substrate support further has the ring member.

25

[Claim 11]

The substrate processing system according to claim 10,
wherein the plurality of recesses include three or more recesses.

[Claim 12]

The substrate processing system according to claim 10,
wherein each of the plurality of recesses includes:

a first width along a radial direction of the ring member;

and

a second width along a circumferential direction of the
ring member, and

wherein the first width is larger than the second width.

[Claim 13]

The substrate processing system according to claim 10,

wherein an inner surface defining each of the plurality of recesses
includes a tapered surface that widens as it approaches an opening of
each of the plurality of recesses.

[Claim 14]

The substrate processing system according to claim 10,

wherein, in a cross-section orthogonal to the radial direction of
the ring member, an inner surface defining each of the plurality of
recesses is curved to widen as it approaches an opening of each of the
plurality of recesses, and

wherein the tip of each of the plurality of lifter pins is curved
along the inner surface.

[Claim 15]

The substrate processing system according to claim 10,

wherein, in a cross-section orthogonal to the radial direction of

the ring member, an inner surface defining each of the plurality of recesses is curved at a bottom portion farthest from an opening of each of the plurality of recesses, and

5 wherein, in the cross-section, a radius of curvature of the bottom portion is smaller than a radius of curvature of the tip of each of the plurality of lifter pins.

[Claim 16]

The substrate processing system according to claim 13,
10 wherein an inner surface defining each of the plurality of recesses includes a flat surface facing the tip of each of the plurality of lifter pins, and

wherein the tapered surface and the flat surface are continuous.

[Claim 17]

The substrate processing system according to claim 13,
15 wherein an inner surface defining each of the plurality of recesses includes:

a flat surface facing the tip of each of the plurality of lifter pins; and

20 an inner wall surface extending along a direction in which the plurality of lifter pins move and connecting the tapered surface and the flat surface.

[Claim 18]

A teaching method for a transfer robot performed in a substrate processing system,

25 wherein the substrate processing system comprises:

a chamber providing a processing space therein; and

a substrate support disposed in the processing space,
wherein the substrate support has:

a substrate support surface configured to support a
substrate;

5 a ring support surface surrounding the substrate support
surface and configured to support a ring member; and

a plurality of lifter pins configured to protrude upward
from the ring support surface,

wherein the ring member provides a plurality of recesses, and

10 wherein the teaching method for a transfer robot includes:

(a) moving the plurality of lifter pins upward in order to
cause the ring member to self-guide so that tips of the plurality of lifter
pins are respectively positioned within the plurality of recesses by lifting
the ring member disposed on the ring support surface from the ring
support surface by the plurality of lifter pins;

15 (b) after the (a) moving the plurality of lifter pins
downward in order to lower the ring member lifted by the plurality of
lifter pins onto the ring support surface;

(c) after the (b) detecting the position of the ring member
disposed on the ring support surface; and

20 (d) after the (c) transferring the substrate to the substrate
support surface based on the detected position of the ring member.