

DESCRIPTION

Title of Invention: SUBSTRATE PROCESSING APPARATUS AND TRAY

Technical Field

[0001]

The present disclosure relates to a substrate processing apparatus and a tray for holding a substrate.

Background Art

[0002]

PTL 1 discloses a substrate processing system for processing a substrate, in which a wafer to be subjected to substrate processing and an edge ring disposed in a manner of surrounding the wafer are electrostatically attracted to a tray having a disk shape, and are transferred to a process module in this state. Further, in the substrate processing system disclosed in PTL 1, the wafer and the edge ring are placed on a susceptor in the process module via the tray, and plasma processing such as etching is performed in this state.

Citation List

Patent Documents

[0003]

PTL 1: JP2021-34390A

Summary of Invention

Technical Problem

[0004]

The technology according to the present disclosure appropriately performs sheath control of a substrate outer peripheral portion in a substrate processing apparatus, and appropriately controls a consumption amount of an annular portion of a tray.

Solution to Problem

[0005]

According to an aspect of the present disclosure, there is provided a substrate processing apparatus for processing a substrate, includes: a processing chamber; and a support member disposed within the processing chamber and having a tray support surface for supporting a tray on an upper surface thereof. The tray includes a base portion and a peripheral edge that forms a recess configured to accommodate the substrate on an upper surface of the

base portion, and the base portion and the peripheral edge are configured separately from each other.

Advantageous Effects of Invention

[0006]

In a substrate processing apparatus, sheath control of a substrate outer peripheral portion is appropriately performed, and a consumption amount of an annular portion of a tray is appropriately controlled.

Brief Description of Drawings

[0007]

[FIG.1] FIG.1 is a plan view schematically illustrating a configuration example of a wafer processing system.

[FIG.2] FIG.2 is a cross-sectional view schematically illustrating an example of a configuration of a wafer processing module.

[FIG.3] FIG.3 is a diagram illustrating a flow of wafer processing in the wafer processing system.

[FIG.4] FIG.4 is a cross-sectional view schematically illustrating a configuration example of a tray according to the present embodiment.

[FIG.5] FIG.5 is a cross-sectional view schematically illustrating a spacer provided in the tray.

[FIG.6] FIG.6 is a cross-sectional view schematically illustrating another method of placing a wafer on the tray.

[FIG.7] FIG.7 is a cross-sectional view schematically illustrating another configuration example of the tray.

[FIG.8] FIG.8 is a cross-sectional view schematically illustrating another configuration example of the tray.

[FIG.9] FIG.9 is a cross-sectional view schematically illustrating another configuration example of the tray.

[FIG.10] FIG.10 is a cross-sectional view schematically illustrating another configuration example of the tray.

[FIG.11] FIG.11 is a cross-sectional view schematically illustrating an example of a structure in the vicinity of an annular portion.

[FIG.12] FIG.12 is a cross-sectional view schematically illustrating an example of the structure in the vicinity of the annular portion.

[FIG.13] FIG.13 is a cross-sectional view schematically illustrating an example of the

structure in the vicinity of the annular portion.

[FIG.14] FIG.14 is a cross-sectional view schematically illustrating an example of the structure in the vicinity of the annular portion.

[FIG.15] FIG.15 is a cross-sectional view schematically illustrating an example of the structure in the vicinity of the annular portion.

[FIG.16] FIG.16 is a cross-sectional view schematically illustrating an example of the structure in the vicinity of the annular portion.

[FIG.17] FIG.17 is a cross-sectional view schematically illustrating an example of the structure in the vicinity of the annular portion.

[FIG.18] FIG.18 is a diagram illustrating an example of a method of placing/separating the wafer on/from the tray.

[FIG.19] FIG.19 is a diagram illustrating an example of a method of separating the wafer from the tray.

[FIG.20] FIG.20 is a diagram illustrating an example of a method of separating the wafer from the tray.

[FIG.21] FIG.21 is a diagram illustrating an example of a method of separating the wafer from the tray.

[FIG.22] FIG.22 is a cross-sectional view schematically illustrating another configuration example of the tray.

[FIG.23] FIG.23 is a cross-sectional view schematically illustrating another configuration example of the tray.

[FIG.24] FIG.24 is a cross-sectional view schematically illustrating another configuration example of the tray.

[FIG.25] FIG.25 is a diagram illustrating an example of a transfer method of the tray.

[FIG.26] FIG.26 is a cross-sectional view schematically illustrating an example of a method of fixing the tray to a support member.

[FIG.27] FIG.27 is a cross-sectional view schematically illustrating an example of a method of fixing the tray to the support member.

[FIG.28] FIG.28 is a cross-sectional view schematically illustrating an example of a method of fixing the tray to the support member.

[FIG.29] FIG.29 is a perspective view illustrating a configuration example of a lock mechanism for fixing the tray to the support member.

[FIG.30] FIG.30 is a cross-sectional view schematically illustrating an example of a method of fixing the tray to the support member.

[FIG.31] FIG.31 is a cross-sectional view schematically illustrating an example of a method of fixing the tray to the support member.

[FIG.32] FIG.32 is a cross-sectional view schematically illustrating an example of a method of separating the tray from the support member.

Description of Embodiments

[0008]

In a process of manufacturing a semiconductor device, various kinds of plasma processing such as etching processing, film formation processing, and diffusion processing are performed on a semiconductor substrate (hereinafter, referred to as a "wafer"). In these kinds of plasma processing, it is important to ensure temperature uniformity and electric field uniformity, including an outer peripheral portion of the wafer, during processing, in order to obtain uniform in-plane processing results on the wafer.

[0009]

In a substrate processing system, when a wafer to be subjected to substrate processing and an edge ring are attracted and held by a disk-shaped tray and are transferred to a process module, and plasma processing is performed in this state, it is necessary to improve the temperature uniformity and electric field uniformity, including the outer peripheral portion of the wafer that does not directly contact a susceptor. Furthermore, when the wafer processing is etching processing as plasma processing, it is desirable to control tilting of the outermost peripheral portion of a wafer W.

[0010]

The disk-shaped tray includes a central portion (a disk portion to be described later) for holding the wafer and an outer peripheral portion (an annular portion to be described later). When the outer peripheral portion is used as an edge ring in the plasma processing, the outer peripheral portion has the same function as that of an edge ring in the related art. That is, in order to control the product quality of a wafer outer peripheral portion, it is important to grasp a consumption amount of the annular portion and to perform sheath control at a wafer end portion.

[0011]

The technique according to the present disclosure has been made in view of the above circumstances, and is implemented to appropriately perform the sheath control of a substrate outer peripheral portion in the substrate processing apparatus, and appropriately control the consumption amount of the annular portion. Hereinafter, a wafer processing system provided with a wafer processing module according to an embodiment will be described with reference to the drawings. The same reference numerals will be given to elements having substantially the same functional configurations throughout the specification and the drawings, and redundant description thereof will be omitted.

[0012]

Configuration of Wafer Processing System

FIG. 1 is a plan view schematically illustrating an outline of a configuration of a wafer processing system 1.

In the wafer processing system 1, various kinds of processing are performed on a wafer W that is a substrate. The wafer W is an example of a substrate. The wafer W is, for example, a semiconductor wafer such as a semiconductor substrate, and in one embodiment, a device layer (not illustrated) that includes a plurality of devices is formed on a surface of the wafer W. In the wafer processing system 1 according to the present embodiment, the wafer W to be processed is transferred and processed in a state of being placed on a tray T to be described later (see FIG. 2). The wafer W is placed on the tray T in a state where the surface on which the device layer is formed faces upward. Hereinafter, for the sake of simplicity of description, the tray T in a state of holding the wafer W to be transferred and processed in the wafer processing system 1 may be referred to as a "tray Tw". A detailed configuration of the tray T will be described later.

[0013]

In the following embodiment, a case where the device layer is formed on the surface of the wafer W as described above will be described as an example. However, the wafer W does not necessarily need to be a device wafer on which the device layer is formed.

[0014]

As illustrated in FIG. 1, the wafer processing system 1 has a configuration in which an atmospheric transfer module 2 and a vacuum transfer module 3 are integrally connected to each other through a load-lock module 4. The atmospheric transfer module 2 transfers the tray Tw in an atmospheric environment. The vacuum transfer module 3 transfers the tray Tw in a vacuum (decompressed) atmosphere.

[0015]

The load-lock module 4 includes one or more load-lock chambers 4a, for example, two load-lock chambers 4a in the present embodiment. The load-lock chamber 4a is provided to enable communication between an interior space of the atmospheric transfer module 2 and an interior space of the vacuum transfer module 3 through a transfer port. The transfer port is configured to be openable and closable by a gate valve 4b.

[0016]

The load-lock module 4 is configured to temporarily hold the tray Tw. The load-lock module 4 is configured such that an interior space thereof can be switched between an atmospheric environment and a vacuum environment. That is, the load-lock module 4 is configured to appropriately transfer the tray Tw between the atmospheric transfer module 2 in

an atmospheric environment and the vacuum transfer module 3 in a vacuum environment.

[0017]

The atmospheric transfer module 2 includes a rectangular housing therein, and an interior of the housing is maintained in the atmospheric environment. A plurality of, for example, three load ports 5 are connected side by side on one side surface for forming a long side of the atmospheric transfer module 2 on a Y-axis negative direction side. The two load-lock chambers 4a described above are connected side by side on the other side surface for forming a long side of the atmospheric transfer module 2 on a Y-axis positive direction side. Furthermore, the atmospheric transfer module 2 may be further connected to an orienter module (not illustrated) for adjusting a horizontal orientation of the tray Tw, or a storage module (not illustrated) for storing a plurality of trays Tw.

[0018]

A hoop F capable of storing the plurality of trays Tw is placed on the load port 5. A ceiling transfer mechanism (OHT: not illustrated) movable along a rail disposed on a ceiling surface of a clean room where the wafer processing system 1 is disposed is provided above the wafer processing system 1, and the hoop F accesses the wafer processing system 1 via the ceiling transfer mechanism and is delivered to the load port 5.

[0019]

Further, a first transfer mechanism 6 that transfers the tray Tw is provided in the atmospheric transfer module 2. The first transfer mechanism 6 is configured to transfer the tray Tw between the hoop F of the load port 5 and the load-lock chamber 4a of the load-lock module 4. A configuration of the first transfer mechanism 6 is not particularly limited.

[0020]

The vacuum transfer module 3 is implemented by a planar rectangular housing, and an interior of the housing can be maintained in a vacuum (decompressed) atmosphere. A plurality of, for example, four wafer processing modules 7 are connected to side surfaces of the vacuum transfer module 3. An interior space of each of the wafer processing modules 7 communicates with an interior space of the vacuum transfer module 3 through a transfer port. The transfer port is configured to be openable and closable by a gate valve 7a. The number and disposition of the wafer processing modules 7 are not limited to those in the present embodiment, and may be freely set.

[0021]

Further, a second transfer mechanism 8 that transfers the tray Tw is provided in the vacuum transfer module 3. The second transfer mechanism 8 is configured to transfer the tray Tw between the load-lock chamber 4a of the load-lock module 4 and one or more wafer processing modules 7. A configuration of the second transfer mechanism 8 is not particularly

limited.

[0022]

In the wafer processing module 7 serving as a substrate processing apparatus, in an example, plasma processing such as etching processing is performed on the wafer W placed on the tray T. FIG. 2 is a view illustrating an example in which the wafer processing module 7 is a capacitively-coupled plasma processing apparatus.

[0023]

The wafer processing module 7, which is a capacitively-coupled plasma processing apparatus, includes a plasma processing chamber 10, a gas supply 20, a power source 30, and an exhaust system 40. Further, the wafer processing module 7 includes a support member 11 and a gas introduction unit. The gas introduction unit is configured to introduce at least one processing gas into the plasma processing chamber 10. The gas introduction unit includes a shower head 15. The support member 11 is disposed in the plasma processing chamber 10. The shower head 15 is disposed above the support member 11. In one embodiment, the shower head 15 constitutes at least a portion of a ceiling portion of the plasma processing chamber 10. The plasma processing chamber 10 has a plasma processing space 10s defined by the shower head 15, a sidewall 10a of the plasma processing chamber 10, and the support member 11. The plasma processing chamber 10 is grounded. The shower head 15 and the support member 11 are electrically insulated from a housing of the plasma processing chamber 10.

[0024]

The support member 11 includes a base 12, an electrostatic chuck 13, and a lifter 14. The base 12 includes a conductive member. The conductive member of the base 12 may function as a lower electrode. The electrostatic chuck 13 is disposed on the base 12. The electrostatic chuck 13 includes a ceramic member 13a and an electrostatic electrode 13b disposed in the ceramic member 13a. The ceramic member 13a is made of a dielectric and has a tray support surface for supporting the tray Tw. The electrostatic chuck 13, including this ceramic member 13a, is configured as a tray support. In one embodiment, the tray support surface of the ceramic member 13a has a larger diameter than the wafer W placed on the tray T, and a smaller diameter than the tray T or substantially the same size as the tray T.

[0025]

At least one RF/DC electrode coupled to an RF power source 31 and/or a DC power source 32, which will be described later, may be disposed in the ceramic member 13a. In this case, at least one RF/DC electrode functions as the lower electrode. When a bias RF signal and/or DC signal, which will be described later, is supplied to at least one RF/DC electrode, the RF/DC electrode is also referred to as a bias electrode. The conductive member of the base 12 and the at least one RF/DC electrode may function as a plurality of lower electrodes. The

electrostatic electrode 13b may also function as the lower electrode. Accordingly, the support member 11 includes at least one lower electrode.

[0026]

The lifter 14 includes a plurality of lift pins 14a, three lift pins 14a in the present embodiment, and an actuator 14b which is a driving mechanism that moves the lift pins 14a in a vertical direction. A plurality of through-holes 12h and 13h penetrating in a thickness direction are formed in the base 12 and the electrostatic chuck 13, and in the present embodiment, three through-holes 12h and 13h are formed, and the lift pins 14a of the lifter 14 are inserted into the through-holes 12h and 13h. Examples of the actuator 14b include an electric actuator, an air cylinder, and a motor.

[0027]

Then, the lifter 14 causes the lift pins 14a to be moved along an axial direction (vertical direction) by the actuator 14b to lift and lower the tray Tw on the electrostatic chuck 13. Accordingly, the tray Tw is moved between a transfer height at which the transfer between the electrostatic chuck 13 and the second transfer mechanism 8 is performed and a processing height at which wafer processing is performed on the electrostatic chuck 13.

[0028]

The support member 11 may include a temperature control module configured to adjust a temperature of at least one of the electrostatic chuck 13, the tray T, and the wafer W to a target temperature. The temperature control module may include a heater, a heat transfer medium, a flow path 12a, or a combination thereof. A heat transfer fluid, such as brine or gas, flows through the flow path 12a. In one embodiment, the flow path 12a is formed in the base 12, and one or a plurality of heaters are disposed in the ceramic member 13a of the electrostatic chuck 13. Further, the support member 11 may include a gas supply configured to supply a gas (for example, nitrogen (N₂) gas) to a gap between a back surface of the tray T and the tray support surface of the electrostatic chuck 13. This gas supply may be shared with the gas supply 20 to be described later.

[0029]

The shower head 15 is configured to introduce at least one processing gas from the gas supply 20 into the plasma processing space 10s. The shower head 15 includes at least one gas supply port 15a, at least one gas diffusion chamber 15b, and a plurality of gas introduction ports 15c. A processing gas supplied to the gas supply port 15a passes through the gas diffusion chamber 15b and is introduced into the plasma processing space 10s from the plurality of gas introduction ports 15c. The shower head 15 includes at least one upper electrode. The gas introduction unit may include one or more side gas injectors (SGI) that are attached to one or more openings formed in the sidewall 10a, in addition to the shower head 15.

[0030]

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 processing gas from each corresponding gas source 21 to the shower head 15 via each corresponding flow rate controller 22. The flow rate controller 22 may include, for example, a mass flow controller or a pressure-controlled flow rate controller. Further, the gas supply 20 may include at least one flow rate modulation device that modulates or pulses a flow rate of at least one processing gas.

[0031]

The power source 30 includes the RF power source 31 coupled to the plasma processing chamber 10 via at least one impedance matching circuit. The RF power 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. Accordingly, the plasma is formed from at least one processing gas supplied into the plasma processing space 10s. Accordingly, the RF power source 31 may function as at least a part of the plasma generator. Supplying a bias RF signal to at least one lower electrode can generate a bias potential in the wafer W to attract an ionic component in the formed plasma to the wafer W.

[0032]

In one embodiment, the RF power source 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 via 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 from 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.

[0033]

The second RF generator 31b is configured to be coupled to at least one lower electrode via at least one impedance matching circuit to generate the bias RF signal (bias RF power). A frequency of the bias RF signal may be the same as or different from a 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 from 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. Further, in various embodiments, at least one of the source RF signal and the bias RF signal may be pulsed.

[0034]

Further, the power source 30 may include the DC power source 32 coupled to the plasma processing chamber 10. The DC power source 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 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 configured to generate a second DC signal. The generated second DC signal is applied to at least one upper electrode.

[0035]

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 pulses may each have a rectangular, trapezoidal, or triangular pulse waveform or a combination thereof. In one embodiment, a waveform generator that generates the sequence of the voltage pulses from a DC signal is connected between the first DC generator 32a and at least one lower electrode. Accordingly, the first DC generator 32a and the waveform generator form a voltage pulse generator. When the second DC generator 32b and the waveform generator form a voltage pulse generator, the voltage pulse generator is connected to at least one upper electrode. The voltage pulse may have a positive polarity or a negative polarity. Further, the sequence of the voltage pulses may include one or more positive voltage pulses and one or more negative voltage pulses in one cycle. The first and second DC generators 32a and 32b may be provided in addition to the RF power source 31, and the first DC generator 32a may be provided instead of the second RF generator 31b.

[0036]

The exhaust system 40 may be connected to, for example, a gas exhaust port 10e disposed at a bottom portion of the plasma processing chamber 10. The exhaust system 40 may include a pressure adjusting valve and a vacuum pump. The pressure adjusting valve adjusts a pressure in the plasma processing space 10s. The vacuum pump may include a turbo molecular pump, a dry pump, or a combination thereof.

[0037]

The wafer processing module 7 is configured as described above by way of example, but the configuration of the wafer processing module 7 is not limited thereto.

[0038]

For example, in the example illustrated in FIG. 2, a case where a plasma generator of the wafer processing module 7 generates capacitively coupled plasma (CCP) has been described as an example. However, the plasma generated by the plasma generator may be inductively-coupled plasma (ICP), electron-cyclotron-resonance plasma (ECR plasma), helicon wave

plasma (HWP), surface wave plasma (SWP), or the like. Further, various types of plasma generators, including an alternating current (AC) plasma generator and a direct current (DC) plasma generator, may be used. In one embodiment, an AC signal (AC power) used by the AC plasma generator has a frequency in a range of 100 kHz to 10 GHz. Accordingly, the AC signal includes a radio frequency (RF) signal and a microwave signal. In one embodiment, the RF signal has a frequency in a range of 100 kHz to 150 MHz.

[0039]

Reference will be made again to FIG. 1.

The wafer processing system 1 described above is provided with a controller 9 as illustrated in FIG. 1. The controller 9 processes computer-executable instructions for causing the wafer processing system 1 to execute various steps described in the present disclosure. The controller 9 may be configured to control elements of the wafer processing system 1 to execute various steps described herein. In one embodiment, a part or all of the controller 9 may be provided in the wafer processing system 1. The controller 9 may include a processor 9a1, a storage 9a2, and a communication interface 9a3. The controller 9 is implemented by, for example, a computer 9a. The processor 9a1 may read a program from the storage 9a2 and execute various control operations by executing the read program. The program may be stored in advance in the storage 9a2, or may be acquired via a medium when necessary. The acquired program is stored in the storage 9a2, read from the storage 9a2 by the processor 9a1, and is executed. The medium may be various recording media readable by the computer 9a, or may be a communication line connected to the communication interface 9a3. The processor 9a1 may be a central processing unit (CPU). The storage 9a2 may include a random access memory (RAM), a read only memory (ROM), a hard disk drive (HDD), a solid state drive (SSD), or a combination thereof. The communication interface 9a3 may communicate with the wafer processing system 1 via a communication line such as a local area network (LAN). Further, the storage medium may be temporary or non-temporary medium.

[0040]

<Processing Flow in Wafer Processing System>

Next, the wafer processing performed using the wafer processing system 1 configured as described above will be described in accordance with the flow of the transfer of the tray Tw. FIG. 3 is a diagram illustrating main steps in the wafer processing. As described above, in the following description, a case where the wafer W is a device wafer in which a device layer is formed on a front surface side will be described as an example, but the device layer may not be formed on the wafer W.

[0041]

First, prior to transferring the hoop F to the wafer processing system 1, the wafer W to

be processed is placed on the tray T by a placing device (not illustrated) provided outside the wafer processing system 1, and the tray Tw on which the wafer W is placed is prepared (step S1 in FIG. 3). At this time, the wafer W is placed on the tray T in a state where a front surface side on which the device layer is formed faces upward. The tray Tw on which the wafer W is placed is accommodated in the hoop F (step S2 in FIG. 3). In the hoop F, the tray Tw is accommodated with a wafer support surface side, on which the wafer W is placed, facing upwards.

[0042]

Next, the hoop F accommodating the plurality of trays Tw is transferred by the ceiling transfer mechanism (OHT) (not illustrated) and placed on the load port 5 of the wafer processing system 1 (step S3 in FIG. 3). Next, the tray Tw is removed from the hoop F by the first transfer mechanism 6 and transferred to the wafer processing module 7 via the load lock chamber 4a of the load-lock module 4 and the second transfer mechanism 8. In the wafer processing module 7, a back surface side of the tray Tw on which the wafer W is placed (a side surface opposite to the wafer support surface on which the wafer W is placed) is attracted and held by the electrostatic chuck 13 of the support member 11 (step S4 in FIG. 3). Furthermore, as will be described later, if, for example, the weight of the tray Tw is sufficient to bring the wafer W into contact with the support member 11 and cool the wafer W sufficiently, then electrostatic attraction by the electrostatic chuck 13 is not necessarily required.

[0043]

In the wafer processing module 7, any processing according to the purpose of wafer processing, such as plasma processing including etching, is performed (step S5 in FIG. 3).

Specifically, for example, after the wafer W is loaded, the inside of the plasma processing chamber 10 is decompressed to a desired vacuum level, and then a desired processing gas is supplied into the plasma processing space 10s. Thereafter, at least one RF signal (RF power) is supplied to at least one lower electrode and/or at least one upper electrode by the RF power source 31, and the processing gas is excited to generate plasma. Then, the wafer W is subjected to plasma processing by the action of the plasma generated in this manner. At this time, the plasma processing of the wafer W is performed in a state where the wafer W is placed on the tray T.

[0044]

Once the wafer W has undergone the desired wafer processing, the tray Tw is then unloaded from the wafer processing module 7 by the second transfer mechanism 8. The tray Tw, which has been unloaded from the wafer processing module 7, is retrieved in the hoop F via the load lock chamber 4a of the load-lock module 4 and the first transfer mechanism 6 (step S6 in FIG. 3).

[0045]

The hoop F accommodating the processed wafer W is then unloaded from the wafer processing system 1 by the ceiling transfer mechanism (OHT) (not illustrated) (step S7 in FIG. 3).

Subsequently, the tray T and the wafer W are separated by a separation device (not illustrated) provided outside the wafer processing system 1 (step S8 in FIG. 3). Thus, the series of wafer processing operations using the wafer processing system 1 ends.

[0046]

According to the present embodiment, as described above, in the state where the wafer W to be processed is placed on the tray T, the transfer in the wafer processing system 1 and the wafer processing in the wafer processing module 7 are performed sequentially.

[0047]

In the above description, as illustrated in FIG. 3, the case where the wafer W is placed on the tray T in advance outside the wafer processing system 1, that is, the case where the tray Tw is loaded into the wafer processing system 1 has been described as an example. However, the placing of the wafer W on the tray T is not necessarily performed outside the wafer processing system 1, and may be performed inside the wafer processing system 1. In this case, a hoop F accommodating a plurality of trays T and a hoop F containing a plurality of wafers W are respectively loaded to the wafer processing system 1, and the wafers W are placed on/separated from the trays T in a placing device (not illustrated)/separation device (not illustrated) which is connected to and disposed on, for example, the atmospheric transfer module 2. Furthermore, at this time, the placing device and the separation device may be disposed independently, and the wafers W may be placed on/separated from the trays T in different devices, or the placing device and the separation device may be configured as a single unit, and the wafers W are placed on/separated from the trays T in the same device.

[0048]

Detailed Structure of Tray

Next, a detailed structure of the tray T on which the wafer W is placed will be described. FIG. 4 is a cross-sectional view schematically illustrating a configuration example of the tray T, and illustrates a state where the tray T is disposed above the support member 11 of the wafer processing module 7. In FIG. 4, the through-holes 12h and 13h are omitted for the sake of simplicity of illustration.

[0049]

As illustrated in FIG. 4, the tray T has a substantially disk shape, and has a cross-sectional recess shape in which a thickness of a central portion is smaller than a thickness of an outer peripheral portion in a cross-sectional view. Hereinafter, the central portion of the tray T

having a small thickness in a cross-sectional view will be referred to as a [disk portion 101], and the outer peripheral portion of the tray T having a large thickness in a cross-sectional view will be referred to as an [annular portion 102]. Further, a cross-sectional recess shape formed by the disk portion 101 and the annular portion 102 may be referred to as a "recess 103". Further, the tray T has a first heat transfer material 104 disposed between the wafer W and an upper surface of the disk portion 101 when the wafer W is accommodated, and a second heat transfer material 105 disposed between a tray placing surface and a lower surface of the disk portion 101 when the tray T is placed on the tray placing surface of the electrostatic chuck 13.

[0050]

The disk portion 101 is made of, for example, at least one material selected from Si, SiC, SiN, C, SiO₂, Al₂O₃, Y₂O₃, YOF, W, Ti, TiN, ZeO₂, and a green sheet. Accordingly, the disk portion 101 may be made of a conductive material or may be made of an insulating material. Further, the relative permittivity of the disk portion 101 may be 8.0 or less. A volume resistivity of the disk portion 101 may be, for example, 1×10^{12} [$\Omega \cdot \text{cm}$] or less when the electrostatic chuck 13 is a Johnson-Rahbek (JR) type electrostatic chuck, or may be 1×10^{13} [$\Omega \cdot \text{cm}$] or more when the electrostatic chuck 13 is a Coulomb type electrostatic chuck.

[0051]

A diameter r1 of the disk portion 101 is formed to be slightly larger than a diameter r3 of the wafer W, and the wafer W can be accommodated in the disk portion 101. Accordingly, the disk portion 101 of the tray T has a wafer placing surface for supporting the wafer W, and the tray T has the recess 103 for accommodating the wafer W. When the wafer W is placed on the wafer placing surface, a gap G (a difference between the diameter r1 and the diameter r3) generated between an outer end portion of the wafer W and an inner peripheral surface of the annular portion 102 is preferably 0.1 mm or less. In order to efficiently cool the wafer W to be described later, it is desirable that the diameter r1 of the disk portion 101 is equal to or less than a diameter r4 of the support member 11 (the electrostatic chuck 13) that holds the tray Tw in the wafer processing module 7.

A thickness t1 of the disk portion 101 is not particularly limited, and it is desirable to set the thickness to a thickness that can efficiently cool the wafer W to be described later and can ensure a mechanical strength of the tray T.

[0052]

The annular portion 102 is made of, for example, at least one material selected from Si, SiC, SiN, C, SiO₂, Al₂O₃, Y₂O₃, YOF, W, Ti, TiN, ZeO₂, and a green sheet, and may be made of the same material as the disk portion 101, or may be made of a different material. Accordingly, the annular portion 102 may be made of a conductive material or may be made of an insulating material. However, in a case where the annular portion 102 is used as an edge ring

in plasma processing to be described later, the annular portion 102 may be made of a material equivalent to an edge ring in the related art. Further, it is desirable that the relative permittivity and the volume resistivity of the annular portion 102 are the same as those of the wafer W.

[0053]

A thickness t_2 of the annular portion 102 can be appropriately changed according to the purpose of wafer processing. Accordingly, an upper surface height of the annular portion 102 may be larger, smaller, or the same as an upper surface height of the wafer W. The thickness t_2 of the annular portion 102 is, for example, 3 mm to 5 mm. During the plasma processing in the wafer processing module 7, the annular portion 102 is disposed in a manner of surrounding the periphery of the wafer W held on the disk portion 101, and also functions as an edge ring (also referred to as a focus ring) for reducing non-uniformity of the plasma processing. Accordingly, the thickness t_2 and a width r_2 of the annular portion 102 may be substantially the same as a thickness and a width of an edge ring (not illustrated) used in plasma processing in the related art.

[0054]

A diameter of the entire tray T (for example, an outer diameter of the annular portion 102, diameter $r_1 + \text{width } r_2$) may be equal to or larger than the diameter r_4 of the support member 11 (the electrostatic chuck 13) that holds the tray Tw in the wafer processing module 7 (diameter $r_1 + \text{width } r_2 \geq \text{diameter } r_4$). In this case, it is possible to prevent a surface of the support member 11 (the electrostatic chuck 13) from being exposed to plasma during the plasma processing in the wafer processing module 7 by making the tray T larger than the support member 11. Accordingly, it is possible to reduce consumption of the support member 11 and reduce a time and a frequency required for maintenance of the wafer processing module 7.

[0055]

As described above, the gap G is formed between an outer end portion of the wafer W and an inner peripheral surface of the annular portion 102. In a portion where the gap G is formed, corners of the recess 103 may be exposed to plasma during the plasma processing in the wafer processing module 7. In this case, the corners are easily consumed depending on a material of the tray T, which may cause deterioration in life of the tray T or generation of particles. It is known that consumption of a corner easily occurs when a shape of the corner is a right angle.

[0056]

Therefore, in order to prevent consumption of the corners of the recess 103, the corners may not be formed at a right angle, and a space between the wafer W and the tray T may be filled. Specifically, for example, as illustrated in FIG. 5, it is desirable to provide a round-shaped spacer 106 at a corner 103a of the recess 103. Although it is not illustrated, a spacer configured

to match a shape of an outer end portion of the wafer W may be provided instead of the round-shaped spacer. In this case, the spacer 106 is formed of a member having at least plasma resistance. By providing the spacer 106 at the corner 103a in this manner, it is possible to prevent the corner 103a from being exposed to plasma during the plasma processing in the wafer processing module 7, and prevent deterioration of life of the tray T and generation of particles.

[0057]

The spacer 106 disposed in the corner 103a may be integrally formed with at least one of the disk portion 101 and the annular portion 102, which is not illustrated, instead of being formed as a separate body from the tray T (the disk portion 101 and the annular portion 102) as illustrated in FIG. 5.

[0058]

In the examples illustrated in FIGS. 4 and 5, the wafer W is held on the disk portion 101 of the tray T, but as illustrated in FIG. 6, a stepped portion 107 for holding an outer peripheral portion of the wafer W may be provided at the annular portion 102 to hold the wafer W on the stepped portion 107. Instead of the stepped portion 107, the wafer W may be held on the spacer 106 illustrated in FIG. 5. In other words, the spacer 106 may have a rectangular cross-sectional shape, and may have the stepped portion 107 for holding the outer peripheral portion of the wafer W.

In this case, a gap is formed between the back surface of the wafer W and the disk portion 101 of the tray T. However, the wafer W can be properly cooled as will be described later by filling the gap with the first heat transfer material 104 to be described later.

[0059]

In FIG. 4, the disk portion 101 and the annular portion 102 of the tray T are integrally formed using the same material. However, the configuration of the tray T is not limited thereto. In one embodiment, as illustrated in FIG. 7, the tray T may be implemented such that the diameter r_1 of the disk portion 101 and an outer diameter of the annular portion 102 are the same, and the annular portion 102 is disposed on an upper surface of the disk portion 101. In this case, the disk portion 101 is implemented as a base portion for placing the wafer W in the center thereof, and has a placing surface (ring placing surface) of the annular portion 102 as an edge ring on the upper surface. In this case, the annular portion 102 as the peripheral edge is placed on the upper surface of the disk portion 101 as the base portion, and the recess 103 for accommodating the wafer W is formed. That is, the disk portion 101 as the base portion and the annular portion 102 as the peripheral edge may be implemented separately. In this case, the disk portion 101 and the annular portion 102 may be made of different materials. Further, in this case, an edge ring in the related art may be used as the annular portion 102.

[0060]

In FIGS. 4 and 7, the disk portion 101 and the annular portion 102 are each formed by a single member. However, at least one of the disk portion 101 and the annular portion 102 may be formed by stacking two or more members as illustrated in FIG. 8. In this case, each of a plurality of members to be stacked may be made of a different material as illustrated in FIG. 8, or the members may be made of the same material, which is not illustrated.

[0061]

Further, in FIG. 4, 7 and 8, the recess 103 is formed on an upper surface side (wafer placing surface) of the tray T. However, instead of or in addition to this, as illustrated in FIGS. 9 and 10, a recess 108 may be further formed on a lower surface side of the tray T. In this case, it is desirable that the recess 108 formed on the lower surface side of the tray T have a shape that engages with a tray support surface of the electrostatic chuck 13, as illustrated in FIG. 10.

[0062]

The first heat transfer material 104 is disposed between the wafer W and the wafer placing surface of the tray T as illustrated in FIG. 4. Accordingly, the first heat transfer material 104 is disposed in the recess 103 of the tray T. The first heat transfer material 104 may adopt a liquid heat transfer material or a heat transfer sheet as will be described later. The wafer W placed on the tray T is in full thermal contact with the tray T via the first heat transfer material 104, so that cooling efficiency of the wafer W by the heat transfer fluid flowing through the flow path 12a formed in the base 12 can be improved.

[0063]

More specifically, in a plasma processing apparatus in the related art, in order to prevent a surface of an electrostatic chuck from being exposed to plasma and from being consumed, a wafer placing surface of the electrostatic chuck is generally smaller than a wafer to be held (a diameter of the wafer > an outer diameter of the electrostatic chuck). However, in this case, an outer peripheral portion of the wafer is not directly held by the electrostatic chuck, and as a result, cooling of the outer peripheral portion may be insufficient as compared with a central portion of the wafer.

For example, in a case where the wafer W is deformed due to warpage, it becomes difficult to make the electrostatic chuck and the entire surface of the wafer in solid contact uniformly, and as a result, a pressing force on the electrostatic chuck is weakened in a part (a portion warped and deformed upward) of the surface of the wafer, and thus, cooling may be insufficient in a part of the surface of the wafer.

[0064]

In this respect, as in the technique according to the present embodiment, by accommodating the wafer W in the recess 103 of the tray T, and further providing the first heat

transfer material 104 between the wafer W and the disk portion 101 of the tray T, the wafer W and the tray T can be easily brought into full contact with each other via the first heat transfer material 104, so that the entire surface of the wafer W can be uniformly cooled.

[0065]

For example, a liquid heat transfer material or a sheet heat transfer material can be selected as the first heat transfer material 104. However, as long as heat transfer efficiency between the wafer W and the tray T can be improved by appropriately bringing the wafer W and the tray T into full contact with each other, a gas may be used as the first heat transfer material 104.

[0066]

The second heat transfer material 105 is disposed between the tray T and the tray placing surface of the electrostatic chuck 13 as illustrated in FIG. 4. The second heat transfer material 105 may adopt a liquid heat transfer material or a heat transfer sheet as will be described later. The second heat transfer material 105 may use the same material as the first heat transfer material 104, or may use a different material. The tray T held by the electrostatic chuck 13 is in full thermal contact with the electrostatic chuck 13 via the second heat transfer material 105, so that the cooling efficiency of the tray T by a heat transfer fluid flowing through the flow path 12a formed in the base 12 can be improved, and thus the cooling efficiency of the wafer W placed on the tray T can be improved.

[0067]

More specifically, in a plasma processing apparatus in the related art, in order to sufficiently cool a wafer on an electrostatic chuck, for example, it is necessary to increase a pressing force of the wafer against a wafer placing surface of the electrostatic chuck by an electrostatic force or the like, and properly maintain a solid contact between the electrostatic chuck and the wafer.

[0068]

In this respect, as in the technique according to the present embodiment, by providing the second heat transfer material 105 between the tray T and the tray support surface of the electrostatic chuck 13, the tray T and the electrostatic chuck 13 are easily brought into thermal contact with each other via the second heat transfer material 105, and a sufficient cooling effect of the wafer W can be expected by the weight of the tray Tw without applying a stress such as electrostatic attraction.

The wafer W can be cooled by the weight of the tray Tw by interposing the second heat transfer material 105 in this manner. However, the tray T may be naturally held on the electrostatic chuck 13 by electrostatic attraction or the like. In this case, a pressing force of the tray T against the electrostatic chuck 13 can be improved, and the cooling efficiency of the

wafer W can be further improved.

[0069]

The tray T according to the present embodiment is configured as described above by way of example. According to the present embodiment, the annular portion 102 functioning as an edge ring in the related art is transferred together with the wafer W as described above. In other words, the edge ring (annular portion 102) and the wafer W are integrally unloaded from the wafer processing module 7 in one processing of the wafer processing module 7. Accordingly, when the edge ring (the annular portion 102) is consumed by the plasma processing, it is not necessary to stop the operation of the wafer processing module 7 for replacing the edge ring as in the related art, and the annular portion 102 unloaded from the wafer processing module 7 in one processing may be replaced directly outside the wafer processing module 7. Accordingly, it is possible to maximize an operating time of the wafer processing module 7.

[0070]

Further, since the edge ring (annular portion 102) is replaced in one processing in this manner, consumption of the edge ring due to continuous wafer processing in the wafer processing module 7 is prevented, and as a result, an influence on a process result due to the consumption of the edge ring is prevented.

[0071]

In this manner, the tray T consumed by the plasma processing may be reconditioned and regenerated only for the consumed portion after the tray T is unloaded from the wafer processing module 7, then the tray T may be placed with the wafer W again and transferred to the wafer processing module 7. For example, the consumed portion may be reconditioned and regenerated by thermal spraying, or may be reconditioned and regenerated by CVD, PVD, sol-gel, or stacking molding technique (3D printing technique).

Alternatively, after the tray T is subjected to coarse separation and surface layer blasting and separated for each constituent material, the tray T may be reused as a new processed product different from the tray T. Si powder obtained through the separation may be used for the reconditioning and regeneration of the consumed portion of the tray T described above after the powder is formed.

[0072]

<Example of Structure in Vicinity of Annular Portion>

For example, when the wafer processing in the wafer processing module 7 is etching processing as the plasma processing, it is desirable to control tilting of the outermost peripheral portion of the wafer W. When the annular portion 102 of the tray T is consumed by the plasma processing and an upper surface height of the annular portion 102 changes, a plasma sheath

position formed on an outer peripheral portion of the wafer W is lowered below a plasma sheath position formed on a central portion of the wafer W, so that an incidence angle of ions on the wafer W is tilted, and an etched groove formed at the outermost peripheral portion of the wafer W is tilted (tilting).

[0073]

In view of the above, in order to appropriately control the tilting of the outermost peripheral portion of the wafer W, it is required to effectively drive the annular portion 102 and set the upper surface height thereof to a desired height. Accordingly, in one embodiment, as illustrated in FIG. 7, the disk portion 101 as the base portion and the annular portion 102 as the peripheral edge may be implemented separately, and only the annular portion 102 as the peripheral edge may be implemented to be capable of being lifted and lowered. Specifically, as illustrated in FIG. 11, a lift pin 202 may be provided which is inserted through a through-hole 200 formed to penetrate through the base 12, the electrostatic chuck 13, and the disk portion 101 as the base portion.

[0074]

The lift pin 202 may include a distal end 202a which can be inserted through a through-hole 200a formed in the disk portion 101 as a base portion, and a root portion 202b which is inserted through a through-hole 200b formed in the base 12 and the electrostatic chuck 13. In one embodiment, a diameter A1 of the distal end 202a may be smaller than a diameter A2 of the root portion 202b. In this case, a diameter of the through-hole 200a may be smaller than a diameter of the through-hole 200b. That is, in the through-hole 200, a step 203 is formed at a boundary between the through-holes 200a and 200b, and the disk portion 101 as the base portion is lifted and lowered by the root portion 202b coming into contact with the step 203 as the root portion 202b is lifted and lowered. In one embodiment, the distal end 202a and the root portion 202b can be independently lifted and lowered. By lifting and lowering the distal end 202a, only the annular portion 102 as the peripheral edge can be lifted and lowered as illustrated in FIG. 12, and by lifting and lowering the root portion 202b, both the annular portion 102 as the peripheral edge and the disk portion 101 as the base portion can be lifted and lowered as illustrated in FIG. 13.

[0075]

As illustrated in FIG. 12, only the annular portion 102 as the peripheral edge is lifted and lowered, for example, when tilting at the outermost peripheral portion is controlled when etching processing as plasma processing is performed on the wafer W. Specifically, when the upper surface height of the annular portion 102 is lower than the upper surface height at the central portion of the wafer W, a plasma sheath position formed above the outer peripheral portion of the wafer W is lowered, and the incidence angle of ions is inclined inward in a radial

direction of the wafer W. In this case, if only the annular portion 102 is lifted, the upper surface height of the annular portion 102 can be matched with the upper surface height at the central portion of the wafer W, and the plasma sheath position can be corrected. By making the upper surface height of the annular portion 102 higher than the upper surface height at the central portion of the wafer W, the position of the plasma sheath formed above the outer peripheral portion of the wafer W can be made higher, and the incidence angle of ions can be intentionally inclined to the radially outer side of the wafer W in accordance with the etching processing.

As illustrated in FIG. 13, both the annular portion 102 as the peripheral edge and the disk portion 101 as the base portion are lifted and lowered, for example, when the second transfer mechanism 8 is inserted on a back surface side of the tray Tw on which the wafer W is mounted, and the tray Tw is transferred. That is, by lifting both the annular portion 102 as the peripheral edge and the disk portion 101 as the base portion, the second transfer mechanism 8 can be inserted on the back surface side of the tray Tw, and the tray Tw can be easily transferred.

[0076]

The method of controlling the lift pins 202 is not limited, and for example, a control operation by the controller 9 may be used.

[0077]

In order to appropriately control the tilting of the outermost peripheral portion of the wafer W and control the product quality of the outer peripheral portion of the wafer W, it is required to grasp the consumption amount of the annular portion 102. Accordingly, in one embodiment, the consumption amount of the annular portion 102 as the peripheral edge may be measured by irradiating the annular portion 102 with light and measuring the thickness of the annular portion 102.

[0078]

For example, as illustrated in FIG. 14, a transmission path 210 may be provided to penetrate the base 12, the electrostatic chuck 13, and the disk portion 101 as the base portion, and light L may be emitted from a light source 212 to the annular portion 102 as the peripheral edge. The transmission path 210 may be provided by making a part of materials of the base 12, the electrostatic chuck 13, and the disk portion 101 as the base portion different materials, as illustrated in FIG. 14. A material constituting the transmission path 210 is not limited as long as the material transmits the light L having a wavelength emitted from the light source 212, and may be, for example, sapphire or quartz. The number and arrangement of the transmission paths 210 are freely set. The transmission paths 210 may be provided at one location or at a plurality of locations in the circumferential direction.

[0079]

When the transmission path 210 is provided, a part or all of the base 12, the electrostatic

chuck 13, and the disk portion 101 as the base portion may be made of a material that transmits the light L of a wavelength emitted from the light source 212. For example, as illustrated in FIG. 15, the electrostatic chuck 13 and the disk portion 101 serving as the base portion may be made of a material that transmits the light L, and the transmission path 210 may be provided only in the base 12. The material that transmits the light L is freely set, and may be, for example, sapphire and quartz.

[0080]

The light source 212 is not particularly limited, and may be an optical system sensor that receives and detects reflected light reflected on the upper surface of the annular portion 102 as the peripheral edge and reflected light reflected on the lower surface thereof, and measures the thickness of the annular portion 102 by the phase difference between the reflected light. The wavelength of the light used as the light L may be 1.5 μm to 2.7 μm , and in this case, the material constituting the transmission path 210 may be Si or SiO_2 .

[0081]

In order to appropriately control tilting of the outermost peripheral portion of the wafer W, a DC signal may be applied to the annular portion 102 as the peripheral edge. In one embodiment, as illustrated in FIGS. 16 and 17, the lift pins 202 for lifting and lowering only the annular portion 102 as the peripheral edge may be formed of a conductive material, and the lift pins 202 may be electrically connected to the DC power source 32. That is, the configuration may be such that the DC power is supplied from the DC power source 32 to the annular portion 102 as the peripheral edge via the lift pins 202.

[0082]

As described above, the base 12 includes a conductive member, and the conductive member of the base 12 can function as a lower electrode. That is, an RF signal may be applied to the base 12. In this case, it is preferable that an insulating material is provided between the base 12 and the lift pins 202. For example, although not illustrated, when the lift pin 202 is formed of a conductive material, an insulating sleeve may be provided around the lift pin 202. Although not illustrated, the lift pin 202 may be electrically connected to the RF power source 31 instead of the DC power source 32. In this case, an RF signal is applied to the annular portion 102 as the peripheral edge.

[0083]

Method of Placing/Separating Wafer on/from Tray

Next, an example of a method of placing the wafer W on the tray T in the above placing device (not illustrated), and an example of a method of separating the wafer W from the tray T in the separation device (not illustrated) will be described.

[0084]

(1) Use of Lift Pin

When placing/separating the wafer W on/from the tray T, a through-hole 101h formed in the disk portion 101 can be used.

That is, as illustrated in FIG. 18, in the placing device/separation device, in the state where the tray T is placed on a stage, the lift pin is configured to be able to protrude and retract from the upper surface of the disk portion 101 of the tray T through the through-hole 101h formed in the disk portion 101 of the tray T. This allows the lower surface of the wafer W mounted on the tray T to be supported by the lift pins and moved in the vertical direction (lifted up), thereby enabling the placing/separating of the wafer W on/from the tray T.

Further, the transfer of the wafer W between the placing device/separation device and the outside of the placing device/separation device is carried out, for example, by holding the wafer W in a transfer mechanism provided outside the placing device/separation device. At this time, the transfer mechanism holds the back surface side of the wafer W opposite to the surface where the device layer is formed, or an outer end portion of the wafer W, in order to prevent damage to the device layer formed on the front surface side of the wafer W. For example, when the transfer mechanism holds the back surface of the wafer W, as illustrated in FIG. 18, the transfer mechanism is configured to be insertable between the wafer W and the stage while the wafer W is lifted up by the lift pins.

[0085]

(2) Use of Fluid

When separating the wafer W from the tray T, instead of, or in addition to, the lift pin and insertion member In described above, a configuration may be made to allow a fluid to be introduced between the wafer W and the tray T, that is, into the recess 103.

[0086]

Specifically, as illustrated in FIG. 19 in the separation device, the fluid is supplied between the wafer W and the tray T through through-holes formed in the stage and the through-hole 101h formed in the disk portion 101 of the tray T, thereby causing the wafer W to float above the tray T. By using the lift pins illustrated in FIG. 18 in such a state, the tray T and the wafer W can be easily separated from each other. Alternatively, the wafer W can be unloaded from the separation device by holding the outer end portion of the wafer W with the transfer mechanism in this state.

Furthermore, an inert gas (for example, N₂ gas) or an ionic liquid can be used as the fluid supplied to the recess 103.

[0087]

(3) Division of Tray

When the wafer W is loaded/unloaded onto/from the tray T, the wafer W may be

transferred in/out from the annular portion 102 of the tray T to/from the recess 103 of the tray T.

[0088]

Specifically, as illustrated in FIG. 20(a), for example, the annular portion 102 of the tray T may be divided to be movable (lifted up) in the vertical direction with respect to the disk portion 101.

Then, by lifting up the annular portion 102 and sliding the wafer W against the recess 103 in this state, as illustrated in FIG. 20(b), the wafer W can be placed/separated on/from the tray T.

[0089]

(4) Other Methods for Dividing Tray

In the example of (3) above, the annular portion 102 of the tray T is divided, but instead of the annular portion 102, at least a portion of the disk portion 101 may be divided.

[0090]

Specifically, as illustrated in FIG. 21, for example, a portion or all of the disk portion 101 of the tray T may be divided to be capable of being buffer-driven (lifted up) in the vertical direction. In other words, a portion of the tray T (in particular, the disk portion 101) may be divided.

Then, this divided portion 101p is lifted up with a lift pin, and in this state, a transfer arm of the transfer mechanism provided outside the placing device/separation device is inserted into the back surface side of the wafer W, so that the wafer W can be placed on/separated from the tray T.

[0091]

When a portion of the disk portion 101 of the tray T is divided and formed in this manner, it is desirable to select a sheet heat transfer material rather than the liquid heat transfer material for the first heat transfer material 104 and the second heat transfer material 105 in order to prevent leakage when the divided portion 101p is lifted up. When the sheet heat transfer material is selected as the first heat transfer material 104 and the second heat transfer material 105, the first heat transfer material 104 and the second heat transfer material 105 may be divided to match the shape of the divided portion 101p of the disk portion 101, as illustrated in FIG. 21. Alternatively, the first heat transfer material 104 and the second heat transfer material 105 can be expanded and contracted in the vertical direction in accordance with the lift-up of the divided portion 101p, as illustrated in FIG. 22, by selecting a stretchable sheet heat transfer material without dividing the first heat transfer material 104 and the second heat transfer material 105. Further, as illustrated in FIG. 23, for example, only one of the first heat transfer material 104 and the second heat transfer material 105 may be divided to match the shape of the divided

portion 101p (in the illustrated example, the second heat transfer material 105).

[0092]

For example, in the examples illustrated in FIGS. 21 to 23, a portion of the disk portion 101 is divided and configured as the divided portion 101p that can be lifted up. However, as illustrated in FIG. 24, the through-hole 101h through which the lift pin is inserted may be formed in part or all of the disk portion 101, and the wafer W may be lifted up by the lift pin via the first heat transfer material 104 or the second heat transfer material 105 (the second heat transfer material 105 in the illustrated example). Therefore, the through-hole 101h formed in the disk portion 101 of the tray T may be provided with a buffer-driven divided portion 101p, or the divided portion 101p may be omitted.

[0093]

In the examples illustrated in FIGS. 21 to 24, the through-hole 101h (divided portion 101p) for placing/separating the wafer W on/from the tray T is disposed only at one location in the center of the disk portion 101. However, the number of through-holes 101h (divided portion 101p) is not limited thereto, and the through-holes 101h may be disposed at a plurality of locations (preferably three locations or more) within a surface of the disk portion 101.

A shape of the through-hole 101h (divided portion 101p) is not particularly limited, and the through-hole 101h may have any shape such as a circular shape or a rectangular shape in a plan view.

[0094]

<Method of Transferring and Placing Tray on Electrostatic Chuck>

Next, a method of transferring and placing the tray Tw configured as described above on the electrostatic chuck 13 in the wafer processing module 7 will be described.

[0095]

(1) Use of Lift Pin

When the tray Tw is placed on the tray support surface of the electrostatic chuck 13, the lift pin 14a inserted into the through-holes 12h and 13h described above can be used.

That is, for example, in a state where the tray Tw is disposed above the electrostatic chuck 13 by the second transfer mechanism 8 (see also FIG. 3), the lift pin 14a protrudes from an upper surface of the electrostatic chuck 13 through the through-holes 12h and 13h, so that the tray Tw is transferred from the second transfer mechanism 8 to an upper end portion of the lift pin 14a. After the second transfer mechanism 8 is retracted, the lift pin 14a is lowered to transfer the tray Tw from the lift pin 14a to the tray support surface of the electrostatic chuck 13.

[0096]

In this manner, the transfer is performed in a manner that a lower surface side of the

tray Tw is supported by the second transfer mechanism 8 and the lift pin 14a, so that the tray Tw can be transferred to the electrostatic chuck 13 without damaging the device layer formed on a surface of the wafer W placed on the tray T.

[0097]

(2) Hold Tray from Upper or Side Surface

When the wafer W is transferred to the electrostatic chuck 13, it is necessary to prevent the damage to the device layer formed on the surface of the wafer W in this manner, and in the wafer processing in the related art without using the tray T, in principle, it is necessary to hold the back surface side of the wafer W and perform the transfer.

In this respect, in the wafer processing according to the present embodiment, the wafer W is transferred in a state where the wafer W is placed on the tray T as described above. Further, in the present embodiment, the tray T has the annular portion 102 disposed outside the wafer W in the radial direction.

[0098]

Therefore, in the wafer processing according to the present embodiment, instead of supporting the lower surface side of the tray Tw by the second transfer mechanism 8 and the lift pin 14a as described above, the tray T may be held from an upper side or a side surface side and transferred between the second transfer mechanism 8 and the electrostatic chuck 13.

[0099]

Specifically, for example, as illustrated in FIG. 25, the annular portion 102 of the tray T on which the wafer W is placed may be held from the upper side and transferred by the second transfer mechanism 8. At this time, since the damage to the device layer formed on the surface of the wafer W is prevented by holding the annular portion 102 of the tray T, the second transfer mechanism 8 may physically hold the annular portion 102 of the tray T and transfer the tray T. A method of holding the tray T by the second transfer mechanism 8 is not particularly limited, and any method such as a magnet, vacuum attraction, or electrostatic attraction can be selected.

[0100]

In this manner, in the wafer processing according to the present embodiment in which the wafer W to be processed is placed on the tray T and transferred, since it is not necessary to bring the wafer W and the second transfer mechanism 8 into direct contact with each other by holding the tray T by the second transfer mechanism 8, holding and transfer can be performed by accessing, from above, the tray Tw on which the wafer W is placed.

Further, since the tray Tw can be held from above in this manner, it is not necessary to transfer the tray Tw to the electrostatic chuck 13 via the lift pin 14a as in the related art when the tray Tw is transferred to the electrostatic chuck 13, and the tray Tw can be directly transferred from the second transfer mechanism 8 to the electrostatic chuck 13. Therefore, when

the tray Tw is held from the upper side or a side in this manner, the lifter 14 for transferring the tray Tw to the electrostatic chuck 13 can be omitted, and the configuration of the wafer processing module 7 can be simplified.

[0101]

Method of Fixing Tray to Support Member

Next, an example of a method of fixing the tray Tw transferred as described above to the support member 11 (the electrostatic chuck 13) in the wafer processing module 7 will be described.

As described above, the tray Tw is held on the tray support surface of the support member 11. In order to efficiently cool the wafer W by the heat transfer fluid flowing through the flow path 12a formed in the base 12, it is necessary to increase a pressing force (surface pressure) of the tray Tw against the electrostatic chuck 13. Therefore, in the following description, in order to improve the cooling efficiency of the wafer W, a method of holding the tray Tw on the electrostatic chuck 13 by a pressing force equal to or larger than the weight of the tray Tw will be described.

[0102]

(1) Electrostatic Attraction

As illustrated in FIG. 2, the electrostatic chuck 13 of the support member 11 includes the electrostatic electrode 13b for supporting the tray Tw on the tray support surface. The tray Tw can be attracted and held on the support member 11 by using the electrostatic electrode 13b.

[0103]

First, a case where the disk portion 101 of the tray T is made of a conductive material will be described.

When the tray T is attracted and held, first, as illustrated in FIG. 26(a), a voltage (positive (+) charges in the illustrated example) is applied to the electrostatic electrode 13b. Then, the electrostatic electrode 13b is positively (+) charged.

When the electrostatic electrode 13b is positively (+) charged, as illustrated in FIG. 26(b), charges of an opposite polarity (that is, negative (-) charges) to the charges accumulated in the electrostatic electrode 13b are accumulated in the disk portion 101 of the tray T or the wafer W, while the positive charges and the negative charges are separated by the ceramic member 13a that is a dielectric. Then, a Coulomb force is generated with the tray T (the wafer W) and the electrostatic electrode 13b serving as both electrodes, and thus the tray Tw is attracted and held onto the tray support surface of the electrostatic chuck 13.

[0104]

In a case where the tray Tw is attracted and held onto the electrostatic chuck 13 by the Coulomb force in this manner, the Coulomb force can be increased to increase an attraction and

holding force of the electrostatic chuck 13 by generating plasma in the wafer processing module 7. Specifically, as illustrated in FIG. 26(c), charges of an opposite polarity (that is, negative (-) charges) to the charges accumulated in the electrostatic electrode 13b are moved from the plasma to the disk portion 101 of the tray T or the wafer W by generating plasma in the plasma processing space 10s. That is, the Coulomb force can be increased by compensating charges from the plasma, and the tray Tw can be more firmly attracted and held.

[0105]

Next, a case where the disk portion 101 of the tray T is made of an insulating material will be described. When the disk portion 101 of the tray T is made of an insulating material, a charging electrode 101b is disposed in the disk portion 101.

When the tray T is attracted and held, first, as illustrated in FIG. 27(a), a voltage (positive (+) charges in the illustrated example) is applied to the electrostatic electrode 13b. Then, the electrostatic electrode 13b is positively (+) charged.

When the electrostatic electrode 13b is positively (+) charged, as illustrated in FIG. 27(b), charges of an opposite polarity (that is, negative (-) charges) to the charges accumulated in the electrostatic electrode 13b are accumulated in the charging electrode 101b disposed in the disk portion 101 and the wafer W, while the positive charges and the negative charges are separated by the ceramic member 13a that is a dielectric and the disk portion 101 that is an insulating member. Then, a Coulomb force is generated with the charging electrode 101b (the wafer W) and the electrostatic electrode 13b serving as both electrodes, and thus the tray Tw is attracted and held onto the tray support surface of the electrostatic chuck 13.

[0106]

When the disk portion 101 of the tray T is made of an insulating material, the Coulomb force can be increased to increase the attraction and holding force of the electrostatic chuck 13 by generating plasma in the wafer processing module 7. Specifically, as illustrated in FIG. 27(c), charges of an opposite polarity (that is, negative (-) charges) to the charges accumulated in the electrostatic electrode 13b are moved from the plasma to the charging electrode 101b and the wafer W by generating plasma in the plasma processing space 10s. That is, the Coulomb force can be increased by compensating charges from the plasma, and the tray Tw can be more firmly attracted and held.

[0107]

In this manner, regardless of whether the disk portion of the tray T is made of a conductive member or an insulating member, the tray Tw can be appropriately attracted and held on the tray support surface by applying a voltage to the electrostatic electrode 13b of the electrostatic chuck 13. In this case, the Coulomb force between the tray Tw and the electrostatic chuck 13 can be increased and the tray Tw can be more firmly attracted and held by generating

plasma in the plasma processing space 10s.

[0108]

By using the Coulomb force in this manner, the attraction and holding of the tray Tw can be controlled simply by controlling the voltage applied to the electrostatic electrode 13b. Therefore, the tray Tw can be attracted and held without complicating the structure of the support member 11. Further, since the attraction and holding can be performed by a simple voltage control in this manner, controllability is improved, and the attraction force in a surface of the tray Tw can be uniformly controlled, that is, a surface pressure of the tray Tw against the electrostatic chuck 13 is uniformly controlled, so that the cooling efficiency of the wafer W can be improved, and the reproducibility of the attraction force can be improved.

[0109]

(2) Clamp Holding

In the examples illustrated in FIGS. 26 and 27 described above, a case in which the tray Tw is electrostatically attracted by the electrostatic chuck 13 of the support member 11 is described by way of example. However, a method of holding the tray Tw on the support member 11 is not limited thereto. Therefore, the support member 11 does not need to include the electrostatic chuck 13 in the wafer processing module 7.

[0110]

Specifically, for example, as illustrated in FIG. 28, a plurality of, for example, two or more pin members 130 may be provided on a lower surface side of the tray T, and after the pin members 130 are inserted into fixing holes formed in the support member 11, the tray T and the support member 11 may be mechanically held and fixed by a lock mechanism 131. It is desirable that the pin member 130 and the lock mechanism 131 have a configuration in which the pin member 130 is pulled into the fixing hole (the support member 11) when the tray T is fixed (locked) to the support member 11, and the pin member 130 is pushed upward from the fixing hole (the support member 11) when the pin member 130 is separated (unlocked). In this manner, by locking the pin member 130 provided in the tray T to the support member 11, adhesiveness (surface pressure) between the tray T and the support member 11 (the electrostatic chuck 13) can be improved, and heat transfer performance can be improved, so that the cooling efficiency of the wafer W can be improved.

[0111]

A structure of the lock mechanism 131 is not particularly limited as long as the lock mechanism 131 can improve adhesiveness between the support member 11 (the electrostatic chuck 13) and the tray T when the tray T is fixed (locked).

For example, the lock mechanism 131 may be a clamp chuck mechanism. As illustrated in FIG. 28, a pull-in member 131a having a tapered shape for pulling in the pin member 130

and a push-out member 131b having a tapered shape for pushing out the pin member 130 may be moved in a horizontal direction by a slide mechanism 131c.

[0112]

Alternatively, for example, the lock mechanism 131 may be a ring rotation mechanism. As illustrated in FIG. 29, the lock mechanism 131 may be implemented to be rotatable in a circumferential direction relative to the pin member 130 after the pin member 130 is inserted into the fixing hole. In this case, the rotation mechanism that rotates the tray T and the support member 11 relative to each other may be a motor. In this case, the ring rotation mechanism may rotate only the lock mechanism 131 relative to the pin member 130, or may rotate the entire support member 11 relative to the pin member 130.

When only the lock mechanism 131 is configured to be rotatable, the structure of the lock mechanism 131 can be miniaturized. When the entire support member 11 is implemented to be rotatable, the structure of the lock mechanism 131 is enlarged. On the other hand, when the liquid heat transfer material is supplied through the through-holes 12h and 13h, the through-holes 12h and 13h can be moved in the circumferential direction by the rotation at the time of transferring the tray T and at the time of supplying the liquid heat transfer material. In other words, both the transfer of the tray T and the supply of the liquid heat transfer material can be achieved without shifting a position of the through-hole 101h formed in the tray T with respect to formation positions of the through-holes 12h and 13h in the circumferential direction and/or the radial direction.

[0113]

(3) Magnetic Force Holding

For example, the tray Tw may be attracted and held by a magnetic force onto the support member 11.

[0114]

Specifically, as illustrated in FIG. 30, magnets 102m and 11m are disposed inside the annular portion 102 of the tray T and an outer peripheral portion inside the support member 11 corresponding to the annular portion 102 (position facing the annular portion 102). An electromagnet or a permanent magnet can be selected as the magnets 102m and 11m disposed inside the annular portion 102 and the support member 11.

Then, by placing the tray Tw above the support member 11 where the magnet 11m is disposed such that the magnet 11m and the magnet 102m face each other, a magnetic force with the magnet 11m and the magnet 102m serving as two poles is generated, and the tray Tw can be attracted and held on the support member 11.

[0115]

In this case, for example, as illustrated in FIG. 30, a demagnetizer 140 is configured to

allow free insertion and removal between the annular portion 102 of the tray Tw and the outer peripheral portion of the support member 11. Accordingly, when the demagnetizer 140 is disposed between the annular portion 102 and the support member 11, the magnetic force generated between the magnet 11m and the magnet 102m is canceled out, and the tray Tw can be transferred from the tray support surface of the support member 11.

[0116]

In this manner, in the wafer processing module 7 according to the present embodiment, the tray T may be configured to be attracted and held onto the support member 11 by disposing magnets inside the tray T and the support member 11.

[0117]

(4) Vacuum Attraction

The support member 11 of the wafer processing module 7 may include a vacuum chuck instead of the electrostatic chuck 13. In this case, it is desirable to select an elastic sheet heat transfer material as the second heat transfer material 105 disposed at least on the lower surface side of the tray T.

[0118]

Specifically, for example, as illustrated in FIG. 31(a), through-holes 105h are formed in the second heat transfer material 105 (sheet heat transfer material) disposed on the lower surface side of the tray T at positions corresponding to vacuum lines 11v formed in the support member 11 in a plan view. Then, as illustrated in FIG. 31(b), a vacuum pump connected to the vacuum line 11v is activated to attract and hold the tray Tw on the tray support surface of the support member 11 by a vacuum force.

[0119]

In this case, the second heat transfer material 105 is compressed in a thickness direction along with pressing of the tray T onto the tray support surface by the vacuum force by selecting an elastic sheet heat transfer material as the second heat transfer material 105. In this manner, the through-hole 105h is closed by plastic deformation of the second heat transfer material 105, and the entire surface of the tray T and the support member 11 come into contact with each other via the second heat transfer material 105, so that the tray T can be appropriately vacuum attracted and the cooling efficiency of the wafer W placed on the tray T can be improved.

[0120]

<Method of Separating Tray from Electrostatic Chuck>

Next, an example of a method of separating the tray Tw fixed to the support member 11 (the electrostatic chuck 13) as described above from the support member 11 will be described.

[0121]

As described above, the support member 11 according to the present embodiment is provided with the lifter 14, and the tray Tw is supported from below by the lift pin 14a and is configured to be separable from the tray support surface of the support member 11 (the electrostatic chuck 13).

However, when the tray Tw is separated from the support member 11 using the lift pin 14a, there is a concern that the tray Tw may not be easily separated from the tray support surface due to, for example, the influence of residual attraction or vacuum attraction. Then, when the tray Tw is lifted by the lift pin 14a in a state where there is residual attraction or the like, there is a concern that the tray T or the wafer W may be damaged due to overload.

[0122]

Therefore, in the wafer processing module 7 according to the present embodiment, an inert gas (for example, a N₂ gas) is supplied to an interface between the tray Tw and the support member 11 in order to prevent the damage caused by the overload related to the lift-up described above.

More specifically, as illustrated in FIG. 32, an inert gas supply flow path 151 connected to a gas supply 150 provided with a gas source is added to the through-holes 12h and 13h through which the lift pins 14a for lifting and lowering the tray Tw are inserted. Then, when the tray Tw is to be separated, the supply of the inert gas is started before the tray Tw is lifted by the lift pins 14a, and thus the separation of the tray Tw from the support member 11 is assisted by pressurizing the interface between the tray Tw and the support member 11. The gas supply 150 may be shared with the gas supply 20 illustrated in FIG. 2.

[0123]

According to the present embodiment, the tray Tw can be easily removed by supplying the inert gas when the tray Tw is separated from the support member 11 as described above.

[0124]

As described above, the support member 11 is formed with the plurality of through-holes 12h and 13h, for example, the three through-holes 12h and 13h in the present embodiment, through which the three lift pins 14a are inserted. However, the inert gas for separating the tray Tw may be supplied to at least one of the through-holes 12h and 13h.

In the embodiment described above, the inert gas (N₂ gas) is supplied to the interface between the tray Tw and the support member 11. However, the supply is not limited to the inert gas as long as the interface between the tray Tw and the support member 11 can be appropriately pressurized in vacuum. Specifically, for example, the above-described ionic liquid may be supplied to the interface between the tray Tw and the support member 11 when the tray Tw is separated.

[0125]

< Operations and Effects of Technique of Present Disclosure >

In the wafer processing system 1 according to the technique of the present disclosure, the wafer W to be processed is placed on the tray T, and the tray T and the wafer W are transferred and processed together. As an example of the configuration of the tray T, as illustrated in FIG. 7, the disk portion 101 as the base portion and the annular portion 102 as the peripheral edge are provided separately. As illustrated in FIG. 12, the configuration is such that only the annular portion 102 as the peripheral edge can be lifted and lowered. Accordingly, the wafer W can be transferred and the annular portion 102 can be driven (lifted and lowered) by a small number of driving mechanisms. In the edge ring in the related art used in the plasma processing, there are cases in which it is necessary to separately provide the pin for transferring the wafer W and the pin for driving the edge ring, and there are problems of an increase in the number of temperature-specific points and an increase in cost. These problems are resolved by the present configuration.

[0126]

In the configurations of FIGS. 12 and 13, the lift pins 202 are disposed not directly under the wafer W but at the outer peripheral portion of the wafer W. Accordingly, it is possible to prevent the temperature-specific point from occurring directly under the wafer W, and to improve the temperature uniformity and the electric field uniformity.

[0127]

In the configurations of FIGS. 14 and 15, the light L is emitted from the light source 212 to the annular portion 102 as the peripheral edge, and the thickness of the annular portion 102 can be measured. Accordingly, the consumption amount of the annular portion 102 can be grasped. In particular, even when the annular portion 102 is thin, the fine consumption management can be performed, and a management criterion can be clearly set. The fine consumption management of the annular portion 102 makes it possible to appropriately control the product quality of a wafer outer peripheral portion.

[0128]

In the configurations of FIGS. 16 and 17, the tray T and the wafer W are transferred integrally by the lift pins 202, and the DC power is supplied from the DC power source 32 to the annular portion 102 as the peripheral edge via the lift pins 202. Accordingly, the sheath control at an end portion of the wafer W can be appropriately performed, and the product quality of the outer peripheral portion of the wafer can be appropriately controlled.

[0129]

In the wafer processing module 7 according to the technique of the present disclosure, the pressing force (surface pressure) of the tray T against the tray support surface of the support member 11 is improved by electrostatic attraction or clamp holding as described above.

Accordingly, the heat transfer performance from the wafer W to the support member 11 can be further improved, and the cooling efficiency of the wafer W can be further appropriately improved.

[0130]

In the above description, a plasma processing module that performs plasma processing such as etching on the wafer W has been described as an example of the wafer processing module 7. However, the wafer processing performed in the wafer processing module 7 is not limited to the plasma processing. For example, the technology described in the present disclosure can be applied to any processing that requires ensuring the temperature uniformity and electric field uniformity, including the outer peripheral portion of the wafer W to be processed.

[0131]

It shall be understood that the embodiments disclosed herein are illustrative and are not restrictive in all aspects. The embodiment described above may be omitted, replaced, or modified in various forms without departing from the scope and spirit of the appended claims. For example, the components of the embodiments described above may be combined as desired. From the desired combination, functions and effects of each component related to the combination can be obtained as a matter of course, and other functions and effects apparent to those skilled in the art can be obtained from the description herein.

[0132]

The effects described herein are merely illustrative or exemplary, and are not limited. In other words, the technique according to the present disclosure may have other effects apparent to those skilled in the art from the description herein, in addition to or in place of the effects described above.

Reference Signs List

[0133]

- 1 wafer processing system
- 10 plasma processing chamber
- 11 support member
- 101 disk portion (base portion)
- 102 annular portion (peripheral edge)
- 103 recess
- T tray
- Tw tray (on which wafer is mounted)
- W wafer

CLAIMS

[Claim 1]

A substrate processing apparatus for processing a substrate, comprising:
a processing chamber; and
a support member disposed within the processing chamber and having a tray support surface for supporting a tray on an upper surface thereof, wherein
the tray includes a base portion and a peripheral edge that forms a recess configured to accommodate the substrate on an upper surface of the base portion, and
the base portion and the peripheral edge are configured separately from each other.

[Claim 2]

The substrate processing apparatus according to claim 1, further comprising:
a controller; and
a lift pin configured to lift and lower the tray at an upper portion of the support member, wherein
the controller lifts and lowers the base portion and/or the peripheral edge by the lift pin.

[Claim 3]

The substrate processing apparatus according to claim 2, wherein
the lift pin is formed of a conductive material, and
a power source configured to supply DC power to the peripheral edge is electrically connected to the lift pin.

[Claim 4]

The substrate processing apparatus according to any one of claims 1 to 3, wherein
the base portion and the peripheral edge are formed of different materials.

[Claim 5]

The substrate processing apparatus according to claim 1, further comprising:
a light source configured to irradiate the peripheral edge with light, wherein
the support member and the base portion are provided with a transmission path through which the light emitted from the light source is transmitted.

[Claim 6]

The substrate processing apparatus according to claim 5, wherein
the light source is an optical system sensor that receives and detects reflected light reflected on an upper surface of the peripheral edge and reflected light reflected on a lower surface of the peripheral edge, and measures a thickness of the peripheral edge based on a phase difference between the reflected light.

[Claim 7]

A tray supported by a support member disposed in a processing chamber for processing a substrate, the tray comprising:

a base portion; and

a peripheral edge that forms a recess configured to accommodate the substrate on an upper surface of the base portion, wherein

the base portion and the peripheral edge are configured separately from each other.

[Claim 8]

The tray according to claim 7, wherein

the base portion and the peripheral edge are formed of different materials.

[Claim 9]

The tray according to claim 7 or 8, wherein

the base portion is provided with a transmission path through which light emitted from a light source is transmitted.