Description

Title of Invention: SUBSTRATE SUPPORT, ELECTROSTATIC CHUCK, PLASMA PROCESSING APPARATUS, AND METHOD FOR MANUFACTURING ELECTROSTATIC CHUCK

Technical Field

[0001]

Exemplary embodiments of the present disclosure relate to a substrate support, an electrostatic chuck, a plasma processing apparatus, and a method for manufacturing an electrostatic chuck.

Background Art

[0002]

As a technique for providing a plasma processing apparatus having a temperature sensor placed on a stage that supports a substrate, there is a technique described in Patent Literature 1.

Citation List

Patent Literature

[0003]

Patent Literature 1: Japanese Patent Application Laid-Open No. 2018-206805

Summary of Invention

Technical Problem

[0004]

The present disclosure provides a technique capable of quickly controlling a temperature of a substrate or a substrate support.

Solution to Problem

[0005]

A substrate support in one exemplary embodiment of the present disclosure includes a base including a flow path through which a temperature-controlled medium flows; a support placed on the base, the support including a front surface that supports a substrate and a back surface; and a heat flux sensor placed on the back surface of the support.

Advantageous Effect of Invention

[0006]

According to one exemplary embodiment of the present disclosure, it is possible to provide a technique capable of quickly controlling the temperature of the substrate or the substrate support.

Brief Description of Drawings

[0007]

[Figure 1] Figure 1 is a diagram illustrating a configuration example of a plasma processing system.

[Figure 2] Figure 2 is a diagram illustrating a configuration example of a plasma processing apparatus.

[Figure 3] Figure 3 is a diagram illustrating a configuration example of a processing circuit.

[Figure 4] Figure 4 is a diagram illustrating a configuration example of a substrate support.

[Figure 5] Figure 5 is a diagram illustrating an example of a divided region of an electrostatic chuck.

[Figure 6] Figure 6 is a diagram illustrating a placement example of a heater in the electrostatic chuck.

[Figure 7] Figure 7 is a diagram illustrating a configuration example of a heat flux sensor on a back surface of a ceramic member.

[Figure 8] Figure 8 is a diagram illustrating an example of the heat flux sensor.

[Figure 9] Figure 9 is a flowchart illustrating an example of a method for manufacturing an electrostatic chuck.

Description of Embodiments

[0008]

Hereinafter each embodiment of the present disclosure will be described below.

[0009]

In one exemplary embodiment, there is provided a substrate support including: a base including a flow path through which a temperature-controlled medium flows; a support placed on the base, the support including a front surface that supports a substrate and a back surface; and a heat flux sensor placed on the back surface of the support.

[0010]

In one exemplary embodiment, an adhesive layer is placed between the base and the support.

[0011]

In one exemplary embodiment, the heat flux sensor is a magneto-thermoelectric conversion element.

[0012]

In one exemplary embodiment, the heat flux sensor is a magneto-thermoelectric conversion element using an anomalous Nernst effect.

[0013]

In one exemplary embodiment, the heat flux sensor has a thickness in a range of 0.1 μm or more and 10 μm or less.

[0014]

In one exemplary embodiment, the heat flux sensor is formed by performing machining processing on the back surface of the support.

[0015]

In one exemplary embodiment, the support includes a substrate chuck electrode.

[0016]

In one exemplary embodiment, the support includes a heater.

[0017]

In one exemplary embodiment, the support includes multiple heaters, and one or more heat flux sensors are placed for each of the heaters.

[0018]

In one exemplary embodiment, there is provided an electrostatic chuck that holds a substrate, including: a dielectric including a front surface that supports the substrate and a back surface; a substrate chuck electrode placed in the dielectric; and a heat flux sensor placed on the back surface of the dielectric.

[0019]

In one exemplary embodiment, the heat flux sensor is a magneto-thermoelectric conversion element.

[0020]

In one exemplary embodiment, the heat flux sensor is a magneto-thermoelectric conversion element using an anomalous Nernst effect.

[0021]

In one exemplary embodiment, the heat flux sensor has a thickness in a range of 0.1 μm or more and 10 μm or less.

[0022]

In one exemplary embodiment, the heat flux sensor is formed by performing machining processing on the back surface of the dielectric.

[0023]

In one exemplary embodiment, the dielectric includes a heater.

[0024]

In one exemplary embodiment, the dielectric includes multiple heaters, and one or more heat flux sensors are placed for each of the heaters.

[0025]

In one exemplary embodiment, there is provided a plasma processing apparatus including: a chamber; a substrate support placed in the chamber; a gas supply configured to supply a processing gas into the chamber; and a plasma generator configured to generate plasma from the processing gas in the chamber, in which the substrate support includes: a base including a flow path through which a temperature-controlled medium flows; a support placed on the base, the support including a front surface that supports a substrate and a back surface; and a heat flux sensor placed on the back surface of the support.

[0026]

In one exemplary embodiment, the plasma processing apparatus further includes: a controller, in which the support includes a heater, and the controller is configured to control an output of the heater based on a heat flux measured by the heat flux sensor.

[0027]

In one exemplary embodiment, there is provided a method for manufacturing an electrostatic chuck, including: forming a dielectric that includes a front surface that supports a substrate and a back surface and in which a substrate chuck electrode is placed; and forming a heat flux sensor on the back surface of the dielectric.

[0028]

Each embodiment of the present disclosure will be described in detail below with reference to the drawings. Furthermore, identical or similar elements in each drawing are denoted by the same reference numeral, and redundant explanations are omitted. Unless otherwise specified, positional relationships of up, down, left, right, and the like will be explained based on positional relationships illustrated in the drawings. The dimensional ratios illustrated in the drawings do not represent actual ratios, and actual ratios are not limited to those illustrated.

[0029] <Example of Plasma Processing System>

[0030]

Figure 1 is a diagram illustrating a configuration example of a plasma processing system. In one embodiment, the plasma processing system includes a plasma processing apparatus 1 and a controller 2. The plasma

processing system is one example of a substrate processing system and the plasma processing apparatus 1 is one example of a substrate processing apparatus. The plasma processing apparatus 1 includes a plasma processing chamber 10, a substrate support 11 and a plasma generator 12. The plasma processing chamber 10 has a plasma processing space. Further, the plasma processing chamber 10 has at least one gas supply port for supplying at least one processing gas into the plasma processing space, and at least one gas exhaust port for exhausting the gas from the plasma processing space. The gas supply port is connected to the gas supply 20, which will be described below, and the gas exhaust port is connected to the exhaust system 40, which will be described below. The substrate support 11 is placed in the plasma processing space and has a substrate support surface for supporting a substrate.

[0031]

The plasma generator 12 is configured to generate plasma from at least one processing gas supplied into the plasma processing space. Plasma generated in the plasma processing space may be Capacitively Coupled Plasma (CCP), Inductively Coupled Plasma (ICP), Electron-Cyclotron-resonance (ECR) plasma, Helicon Wave Plasma (HWP), Surface Wave Plasma (SWP), or the like. Furthermore, 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 in the AC plasma generator has a frequency in the 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 the

range of 100 kHz to 150 MHz.

[0032]

The controller 2 processes computer-executable instructions that cause the plasma processing apparatus 1 to execute various steps described in the present disclosure. The controller 2 may be configured to control each element of the plasma processing apparatus 1 to execute the various steps described herein. In one embodiment, a part or all of the controller 2 may be included in the plasma processing apparatus 1. The controller 2 may include a processor 2a1, a storage 2a2, and a communication interface 2a3. The controller 2 is implemented, for example, by a computer 2a. The processor 2a1 may be configured to read a program from the storage 2a2 and perform various control operations by executing the read program. This program may be stored in the storage 2a2 in advance, or may be acquired via a medium when needed. The acquired program is stored in the storage 2a2 and read from the storage 2a2 and executed by the processor 2a1. The medium may be various storage media readable by the computer 2a, or may be a communication line connected to the communication interface 2a3. The processor 2a1 may be a Central Processing Unit (CPU). The storage 2a2 may include Random Access Memory (RAM), Read Only Memory (ROM), Hard Disk Drive (HDD), Solid State Drive (SSD), or a combination thereof. The communication interface 2a3 may communicate with the plasma processing apparatus 1 via a communication line such as a Local Area Network (LAN).

[0033]

Hereinafter, a configuration example of a capacitively coupled plasma

processing apparatus as an example of the plasma processing apparatus 1 will be described. Figure 2 is a diagram illustrating a configuration example of the capacitively coupled plasma processing apparatus.

[0034]

The capacitively coupled plasma processing apparatus 1 includes the plasma processing chamber 10, the gas supply 20, a power source 30, and the exhaust system 40. Further, the plasma processing apparatus 1 includes a substrate support 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 13. The substrate support 11 is placed in the plasma processing chamber 10. The shower head 13 is placed above the substrate support 11. In one embodiment, the shower head 13 constitutes at least a part of a ceiling of the plasma processing chamber 10. The plasma processing chamber 10 has a plasma processing space 10s defined by the shower head 13, a sidewall 10a of the plasma processing chamber 10, and the substrate support 11. The plasma processing chamber 10 is grounded. The shower head 13 and the substrate support 11 are electrically insulated from a housing of the plasma processing chamber 10.

[0035]

The substrate support 11 includes a main body 111 and a ring assembly 112. The main body 111 has a central region 111a for supporting a substrate W and an annular region 111b for supporting the ring assembly 112. The wafer is one example of the substrate W. The annular region 111b of the main body 111

surrounds the central region 111a of the main body 111 in a plan view. The substrate W is placed on the central region 111a of the main body 111 and the ring assembly 112 is placed on the annular region 111b of the main body 111 to surround the substrate W on the central region 111a of the main body 111. Accordingly, the central region 111a is also referred to as a substrate support surface for supporting the substrate W, and the annular region 111b is also referred to as a ring support surface for supporting the ring assembly 112.

[0036]

In one embodiment, the main body 111 includes a base 1110 and an electrostatic chuck 1111. The base 1110 includes a conductive member. The conductive member of the base 1110 may function as a lower electrode. The electrostatic chuck 1111 is placed on the base 1110. The electrostatic chuck 1111 includes a ceramic member 1111a and an electrostatic electrode 1111b placed in the ceramic member 1111a. The ceramic member 1111a has a central region 111a. In one embodiment, the ceramic member 1111a also has an annular region 111b. Other members that surround the electrostatic chuck 1111, such as an annular electrostatic chuck and an annular insulating member, may have the annular region 111b. In this case, the ring assembly 112 may be placed on the annular electrostatic chuck or the annular insulating member, or may be placed on both the electrostatic chuck 1111 and the annular insulating member. Further, at least one RF/DC electrode coupled to an RF power source 31 and/or a DC power source 32 described below may be placed in the ceramic member 1111a. In this case, at least one RF/DC electrode functions as the lower electrode. When the bias RF signal and/or the DC signal described

below are 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 1110 and at least one RF/DC electrode may function as multiple lower electrodes. Further, the electrostatic electrode 1111b may function as the lower electrode. Accordingly, the substrate support 11 includes at least one lower electrode.

[0037]

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

[0038]

Further, the substrate support 11 may include a temperature-controlled module configured to adjust at least one of the electrostatic chuck 1111, the ring assembly 112, and the substrate to a target temperature. The temperature-controlled module may include a heater, a heat transfer medium, a flow path 1110a, or a combination thereof. A heat transfer fluid, such as brine or gas, flows through the flow path 1110a. In one embodiment, the flow path 1110a is formed in the base 1110, and one or more heaters are placed in the ceramic member 1111a of the electrostatic chuck 1111. Further, the substrate support 11 may include a heat transfer gas supply configured to supply a heat transfer gas to a gap between a back surface of the substrate W and the central region 111a.

[0039]

The shower head 13 is configured to introduce at least one processing

gas from the gas supply 20 into the plasma processing space 10s. The shower head 13 has at least one gas supply port 13a, at least one gas diffusion chamber 13b, and multiple gas introduction ports 13c. The processing gas supplied to the gas supply port 13a passes through the gas diffusion chamber 13b and is introduced into the plasma processing space 10s from the multiple gas introduction ports 13c. Further, the shower head 13 includes at least one upper electrode. The gas introduction unit may include, in addition to the shower head 13, one or more side gas injectors (SGI) that are attached to one or more openings formed in the sidewall 10a.

[0040]

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 the respective corresponding gas sources 21 to the shower head 13 via the respective corresponding flow rate controllers 22. Each 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 the flow rate of at least one processing gas.

[0041]

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. As a result, plasma is generated 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 12. Further, by supplying the bias RF signal to at least one lower electrode, a bias potential is generated in the substrate W, and ion components in the generated plasma can be drawn into the substrate W.

[0042]

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 configured to be coupled to at least one lower electrode and/or at least one upper electrode via at least one impedance matching circuit to generate a source RF signal (source RF power) for generating plasma. In one embodiment, the source RF signal has a frequency in the range of 10 MHz to 150 MHz. In one embodiment, the first RF generator 31a may be configured to generate multiple 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.

[0043]

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 in the range of 100 kHz to 60 MHz. In one embodiment, the second RF generator 31b may be

configured to generate multiple 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.

[0044]

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 configured to be 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 configured to be connected to at least one upper electrode to generate a second DC signal. The generated second DC signal is applied to at least one upper electrode.

[0045]

In various embodiments, the first and second DC signals may be pulsed. In this case, the sequence of voltage pulses is applied to at least one lower electrode and/or at least one upper electrode. The voltage pulse may have a pulse waveform of a rectangle, a trapezoid, a triangle or a combination thereof. In one embodiment, a waveform generator for generating the sequence of voltage pulses from the DC signal is connected between the first DC generator 32a and at least one lower electrode. Therefore, the first DC generator 32a and the waveform generator constitute a voltage pulse generator. When the second DC generator 32b and the waveform generator constitute the 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.

[0046]

The exhaust system 40 may be connected to, for example, a gas exhaust port 10e placed 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 in the plasma processing space 10s is adjusted by the pressure adjusting valve. The vacuum pump may include a turbo molecular pump, a dry pump, or a combination thereof.

[0047] <Configuration Example of Controller>

Figure 3 illustrates a processing circuit 130 that controls all control processing, description, or blocks of a flowchart in the present specification on a computer. These control processes, descriptions, or blocks represent a part of a code including one or more executable instructions for implementing a specific logical function or step of a module, a segment, or processing. It will be understood by those skilled in the art that alternative embodiments are included in the scope of the exemplary embodiments of the present disclosure, and the functions thereof can be executed in an order different from the illustrated or described order, such as substantially simultaneously or in a reverse order,

depending on the functions involved. Various elements, features, and processing described in the present specification may be used independently or combined in various ways. Any conceivable combination and sub-combination are included in the scope of the present disclosure.

[0048]

In one embodiment, the processing circuit 130 may include a CPU 1200 that executes one or more control processing described above/below. The processing data and the instructions may be stored in a memory 1202. These processing data and instructions may be stored in a storage media disk 1204 such as a hard disk drive (HDD) or a portable storage medium, or may be stored remotely. Further, the present disclosure described in the claims is not limited by a form of a computer-readable medium in which the instructions of the processing according to the present disclosure are stored. For example, these instructions may be stored in a CD, a DVD, a flash memory, a RAM, a ROM, a PROM, an EPROM, an EEPROM, a hard disk, or any other information processing apparatus that communicates with the processing circuit 130, such as a server or a computer.

[0049]

Further, the present disclosure described in the claims may be provided as a utility application, a background daemon, a configuration element of an operating system, or a combination thereof, and may be executed in conjunction with the CPU 1200 and an operating system such as Microsoft Windows, UNIX, Solaris, LINUX, or Apple MAC-OS which is known to those skilled in the art.

[0050]

In one embodiment, the hardware elements that construct the processing circuit 130 may be implemented by various circuit elements. Further, each function of the above-described embodiment may be implemented by a circuit (circuitry) including one or more processing circuits. The processing circuit includes a specific programmed processing apparatus, for example, the processing apparatus (CPU) 1200. The processing circuit also includes a device such as an application specific integrated circuit (ASIC) or a conventional circuit component configured to implement the described functions.

[0051]

In one embodiment, the processing circuit 130 may include the CPU 1200 that executes the above-described processing. The processing circuit 130 may be a general-purpose computer or a dedicated specific machine. In one embodiment, when the processing apparatus 1200 is programmed to remove backscattering from a fog by spatial modulation and temporal modulation, the processing circuit 130 may function as the dedicated specific machine.

[0052]

Alternatively or additionally, the CPU 1200 may be implemented on an FPGA, an ASIC, or a PLD, or may use a discrete logic circuit, as understood by those skilled in the art. Further, the CPU 1200 may be implemented as multiple processing apparatuses that cooperate to execute the instructions of the processing of the present disclosure described above in parallel.

[0053]

The processing circuit 130 may also include a network controller 1206 for interfacing a network 1228, for example, an Intel Ethernet PRO network interface

card manufactured by Intel Corporation, or the like. The network 1228 may be a public network such as the internet, a private network such as a LAN or a WAN, or any combination thereof, and may also include a sub-network such as a PSTN or an ISDN. The network 1228 may also be wired, such as an Ethernet network, or wireless, such as a cellular network including EDGE, 3G, and 4G wireless cellular systems. The wireless network may also be Wi-Fi, Bluetooth, or any other known wireless communication form.

[0054]

The processing circuit 130 may further include a display apparatus controller 1208 such as a graphics card or a graphics adapter for interfacing a display apparatus 1210 such as a monitor. The general-purpose I/O interface 1212 may interface a keyboard and/or a mouse 1214, and a touch panel 1216 integrated with or separate from the display apparatus 1210. The general-purpose I/O interface may also be connected to various peripheral apparatuses 1218 such as a printer and a scanner.

[0055]

A general-purpose storage apparatus controller 1224 is connected to the storage media disk 1204 via a communication bus 1226 such as ISA, EISA, VESA, or PCI, and all the configuration elements of the processing circuit 130 may be connected to each other. General features and functions of the display apparatus 1210, the keyboard and/or the mouse 1214, the display apparatus controller 1208, the storage apparatus controller 1224, the network controller 1206, an audio controller, and the general-purpose I/O interface 1212 are known and will not be described in detail in the present specification for the sake of

simplicity.

[0056]

The exemplary circuit elements described in the present disclosure may be replaced with other elements and may have a structure different from the examples described in the present specification. Further, the circuit configured to implement the features described in the present specification may be implemented in multiple circuit units (for example, chips) or may be combined as a circuit of a single chip set.

[0057]

The functions and features described in the present specification may also be executed by various configuration elements distributed and placed on the system. For example, one or more processing apparatuses may execute these functions, and in this case, the processing apparatuses may be distributed and placed over multiple configuration elements communicating with each other via a network. As the distributed and placed configuration elements, in addition to various human interfaces and communication apparatuses (display monitor, smartphone, tablet, personal digital assistant (PDA), and the like), one or more client machines and server machines capable of sharing processing may be included. The network may be a private network such as a LAN or a WAN, or a public network such as the Internet. The input to the system may be received by direct input by a user or may be received remotely as real-time or batch processing. Further, some of the examples may be implemented on a module or hardware not the same as the above-described module or hardware. Therefore, other examples are also included in the scope of the claims.

[0058] <Configuration Example of Substrate Support>

Figure 4 is a diagram illustrating a configuration example of the substrate support 11. In one embodiment, the substrate support 11 includes the base 1110, the electrostatic chuck 1111, a heat flux sensor 200, and an adhesive layer 201. The substrate support 11 may be an example of a substrate support.

[0059]

The base 1110 may have a substantially cylindrical shape. The base 1110 may be made of a metal, a metal matrix composite (MMC), or ceramics.

[0060]

The base 1110 may include the flow path 1110a through which a temperature-controlled medium flows. The flow path 1110a may be placed in the base 1110. The flow path 1110a is connected to a medium supply 251 provided outside the chamber 10 via a connecting flow path 250. The medium supply 251 may be configured to supply a temperature-controlled refrigerant adjusted to a set temperature to the flow path 1110a through the connecting flow path 250 and to return the temperature-controlled refrigerant that passes through the flow path 1110a to the medium supply 251 through the connecting flow path 250. The base 1110 may be configured to discharge heat input from the electrostatic chuck 1111 by the temperature-controlled medium flowing through the flow path 1110a, thereby cooling the electrostatic chuck 1111 or the substrate W. The temperature-controlled medium may be a gas or a liquid.

[0061]

The electrostatic chuck 1111 may include the ceramic member 1111a and the electrostatic electrode 1111b placed in the ceramic member 1111a. The

ceramic member 1111a may be an example of a dielectric.

[0062]

The ceramic member 1111a may have a substantially cylindrical shape. The ceramic member 1111a may include a front surface 300 that supports the substrate W and a back surface 301 placed on a side opposite to the front surface 300. In one embodiment, the front surface 300 may include a horizontal surface 310, multiple protrusions 311, and a seal band 312. The multiple protrusions 311 and the seal band 312 may protrude upward from the horizontal surface 310. The seal band 312 may be configured in an annular shape to surround the protrusions 311. The seal band 312 may be placed on an outer periphery of the front surface 300. The protrusions 311 and the seal band 312 may be configured to come into contact with the back surface of the substrate W when the substrate W is electrostatically chucked. A gas outlet may be formed in the horizontal surface 310. The gas outlet may be connected to a heat transfer gas supply placed outside the chamber 10. The heat transfer gas supply may be configured to supply a heat transfer gas from the gas outlet to a space formed between the substrate W and the horizontal surface 310, thereby enabling the temperature control of the substrate W.

[0063]

The electrostatic electrode 1111b may be placed directly below the front surface 300 in the ceramic member 1111a. The electrostatic electrode 1111b may be electrically connected to a DC power source 350. When a DC voltage from the DC power source 350 is applied to the electrostatic electrode 1111b, an electrostatic attraction force (Coulomb force) may be generated between the

ceramic member 1111a and the substrate W. The substrate W may be attracted to the ceramic member 1111a by the electrostatic attraction force and may be adsorbed and held on the ceramic member 1111a. The ceramic member 1111a may be an example of a support.

[0064]

The electrostatic chuck 1111 may further include a heater 360 placed in the ceramic member 1111a. The heater 360 may be placed below the electrostatic electrode 1111b in the ceramic member 1111a. In one embodiment, as illustrated in Figure 5, the ceramic member 1111a may be divided into multiple divided regions 370 in a plan view, and the heater 360 may be placed in each of the multiple divided regions 370. The multiple divided regions 370 may be divided into multiple regions in a concentric circular shape with a central axis C1 of the ceramic member 1111a as a circle center, and each region on the same circumference may be further divided into multiple regions in a circumferential direction. That is, the divided region 370 may be divided into multiple regions in a radial direction and the circumferential direction. In addition, the multiple divided regions 370 may be formed by dividing the ceramic member 1111a in a vertical and horizontal lattice shape in a plan view.

[0065]

As illustrated in Figure 6, the front surface 300 of the ceramic member 1111a may be further divided into multiple finely divided regions 370. The multiple divided regions 370 may include a central zone 370a including the central axis C1 of the ceramic member 1111a and multiple zones 370b arranged in the circumferential direction in multiple regions arranged in the radial direction

with respect to the central axis C1. The multiple divided regions 370 may be formed by finely dividing the ceramic member 1111a in a vertical and horizontal lattice shape. The number of the divided regions 370 may be 50 or more, 100 or more, or 150 or more. The heater 360 may be placed one by one in each divided region 370, or multiple heaters 360 may be placed in each divided region 370. In addition, the divided regions 370 or the heaters 360 may be placed in multiple stages in the vertical direction. The number and the placement of the divided regions 370 or the heaters 360 in each stage may be different from each other. The number of the divided regions 370 or the heaters 360 can be optionally selected. The ceramic member 1111a may not be divided into multiple regions and may be one region.

[0066]

As illustrated in Figure 4, the heater 360 may be electrically connected to a power source 380. The power source 380 may be configured to supply power to the heater 360 to cause the heater 360 to generate heat. The power source 380 may be configured to supply a given power to each of multiple heaters 360 to cause each heater 360 to generate heat with a given heat generation amount.

[0067]

The heat flux sensor 200 may be placed on the back surface 301 of the ceramic member 1111a. The heat flux sensor 200 may be able to detect a heat flux passing through the back surface 301 of the ceramic member 1111a in the vertical direction. As illustrated in Figures 4 and 7, multiple heat flux sensors 200 may be placed on the back surface 301.

[0068]

The heat flux sensor 200 may be a magneto-thermoelectric conversion element. In one embodiment, as illustrated in Figure 8, the heat flux sensor 200 may be a magneto-thermoelectric conversion element using an anomalous Nernst effect. The heat flux sensor 200 is a device in which a generated voltage Vq varies according to a heat flux Fq, and may be a device in which the voltage Vq is generated in a direction perpendicular to a direction of the heat flux Fq. The heat flux sensor 200 may have a thickness in the vertical direction in a range of 0.1 μm or more and 10 μm or less.

[0069]

The heat flux sensor 200 illustrated in Figures 4 and 7 may be formed by performing machining processing on the back surface 301 of the ceramic member 1111a. The machining processing includes machining processing of the back surface itself and machining processing of the back surface as a base. In one embodiment, the heat flux sensor 200 may be formed by forming a film of a topological material on the back surface of the ceramic member 1111a using a film formation technique and forming the film of the topological material into a given pattern using an etching technique. The film formation technique may be a sputtering technique. The heat flux sensor 200 may be manufactured at a separate location and attached to the back surface 301 of the ceramic member 1111a.

[0070]

As illustrated in Figure 4, the heat flux sensor 200 may be electrically connected to a sensor controller 390 placed outside the ceramic member 1111a.

The sensor controller 390 may be included in the controller 2 or may be controlled by the controller 2. In one embodiment, as illustrated in Figure 7, a wiring 400 connected to the heat flux sensor 200 may be formed on the back surface 301 of the ceramic member 1111a. The wiring 400 may extend from the heat flux sensor 200 to an outer edge of the back surface 301 of the ceramic member 1111a and may have a terminal 400a on a side surface of the ceramic member 1111a. The terminal 400a of the wiring 400 may be electrically connected to the sensor controller 390 by a lead wire 401. The wiring 400 may be formed by performing machining processing on the back surface 301 of the ceramic member 1111a together with the heat flux sensor 200. In one embodiment, the wiring 400 may be formed by forming a film of a wiring material on the back surface of the ceramic member 1111a using a film formation technique and forming the film into a given pattern using an etching technique. The film formation technique may be a sputtering technique. The wiring 400 may be manufactured at a separate location and attached to the back surface 301 of the ceramic member 1111a.

[0071]

In one embodiment, the heat flux sensor 200 may be placed at a position corresponding to each divided region 370 of the ceramic member 1111a in a plan view. The heat flux sensor 200 may be placed one by one in each divided region 370, or multiple heat flux sensors 200 may be placed in each divided region 370. The heat flux sensor 200 may be placed to correspond to each heater 360. The heat flux sensor 200 may be placed one by one for one heater 360, or multiple heat flux sensors 200 may be placed for one heater 360.

[0072]

As illustrated in Figure 4, the adhesive layer 201 may be interposed between the base 1110 and the electrostatic chuck 1111. The adhesive layer 201 may have a thickness larger than a thickness of the heat flux sensor 200 in the vertical direction, and may be configured to cover the heat flux sensor 200 without a gap. The heat flux sensor 200 may be placed in the adhesive layer 201 and may be in non-contact with the base 1110. The adhesive layer 201 may be made of a material having electrical insulation properties and high thermal conductivity. In an example, the adhesive layer 201 may be made of silicone as a main component or may be made of acrylic as a main component. The adhesive layer 201 may have, for example, a film such as polyimide as a core material. The adhesive layer 201 may be formed by mixing at least one of alumina particles, aluminum nitride particles, and other substances as a filler into silicone or acrylic for the purpose of improving thermal conductivity.

[0073] <Example of Method for Manufacturing Electrostatic Chuck>

Figure 9 is a flowchart illustrating an example of a method for manufacturing an electrostatic chuck. In one embodiment, the method for manufacturing the electrostatic chuck 1111 may include a step ST1 of forming the ceramic member 1111a and a step ST2 of forming the heat flux sensor 200 on the back surface of the ceramic member 1111a.

[0074]

In the step ST1, the protrusions 311 or the seal band 312 may be formed on the front surface 300 of the ceramic member 1111a. The electrostatic electrode 1111b or the heater 360 may be formed in the ceramic member 1111a.

[0075]

In the step ST2, first, the topological material which is a material for generating the anomalous Nernst effect may be formed into a film on the back surface of the ceramic member 1111a. The film formation may be performed by sputtering. Next, the film of the topological material may be formed into a given pattern using an etching technique. In one embodiment, a mask having an opening may be formed on the film of the topological material, and the film of the topological material may be formed into a given pattern (a dot pattern, a line and space pattern, or the like) by plasma etching or wet etching. The step ST1 and the step ST2 may be performed in this order or in the reverse order. The step ST2 may include a step of forming a conductive wiring that connects the deposited and patterned topological material. After the step ST2, a step of processing the ceramic member 1111a may be provided.

[0076] <Example of Plasma Processing Method>

A plasma processing method performed by the plasma processing apparatus 1 includes etching processing of etching a film on the substrate W using plasma. In one embodiment, the plasma processing method is executed by the controller 2 in the plasma processing apparatus 1.

[0077]

First, as illustrated in Figure 2, the substrate W is carried into the chamber 10 and placed on the substrate support 11. The substrate W is adsorbed and held by the electrostatic chuck 1111 as illustrated in Figure 4. At this time, the substrate W is placed on the ceramic member 1111a, and the back surface of the substrate W comes into contact with the protrusion 311 and the seal band 312.

The DC voltage is applied to the electrostatic electrode 1111b, the electrostatic attraction force is generated between the electrostatic chuck 1111 and the substrate W, and the substrate W is adsorbed to the electrostatic chuck 1111.

[0078]

Next, plasma is generated in the plasma processing space 10s by the plasma generator 12 illustrated in Figure 2. The processing gas is supplied to the shower head 13 by the gas supply 20, and supplied from the shower head 13 to the plasma processing space 10s. The processing gas supplied at this time includes a gas that generates active species necessary for the etching processing of the substrate W.

[0079]

One or more RF signals are supplied from the RF power source 31 to the upper electrode and/or the lower electrode. The atmosphere in the plasma processing space 10s is exhausted from the gas exhaust port 10e, and the inside of the plasma processing space 10s is depressurized. Plasma is generated from the processing gas on the substrate support 11 in the plasma processing space 10s, and the substrate W is etched.

[0080]

In the above-described plasma processing, a large amount of heat is generated by the generation of plasma. In the plasma processing, the heat generated by plasma is also transferred to the substrate W on the substrate support 11. In the base 1110 of the substrate support 11 illustrated in Figure 4, the temperature-controlled medium having a constant temperature flows through the flow path 1110a, and heat Q transferred from the substrate W to the

electrostatic chuck 1111, the adhesive layer 201, and the base 1110 in this order is discharged by the temperature-controlled medium. As a result, the substrate W and the substrate support 11 are cooled.

[0081]

In the plasma processing, the temperature of the substrate W or the electrostatic chuck 1111 is controlled to a given target temperature. In one embodiment, power is supplied from the power source 380 to the heater 360, and the heater 360 generates heat to adjust the temperature of the substrate W or the electrostatic chuck 1111.

[0082]

In one embodiment, the controller 2 adjusts the supply power (voltage and current) from the power source 380 to the heater 360 based on the heat flux measured by the heat flux sensor 200, and controls an output (heat generation amount) of the heater 360. In one embodiment, the heat flux sensor 200 measures the heat flux Fq of the heat Q flowing from the substrate W to the base 1110 through the electrostatic chuck 1111. The controller 2 estimates the temperature of the substrate W or the electrostatic chuck 1111 in a thermal equilibrium state based on the value of the heat flux Fq, and calculates the heat generation amount of the heater 360 necessary for the substrate W or the electrostatic chuck 1111 to reach the target temperature. The controller 2 adjusts the supply power to the heater 360 to control (feedforward control) the heat generation amount of the heater 360.

[0083]

The control of the heat generation amount of the heater 360 may be

performed for each divided region 370 of the ceramic member 1111a and for each heater 360. The heat flux may be measured by the heat flux sensor 200 corresponding to each divided region 370, and the heat generation amount of the heater 360 corresponding to each divided region 370 may be controlled based on the heat flux of each divided region 370. In addition, the controller 2 may estimate the temperature of the substrate W or the electrostatic chuck 1111 based on the heat flux measured by the heat flux sensor 200. The controller 2 may estimate the amount of heat diffusion in the lateral direction (horizontal direction) from a difference in the heat flux between the adjacent divided regions 370, and control the heat generation amount of the heater 360 corresponding to each divided region 370.

[0084]

According to the present exemplary embodiment, the substrate support 11 includes the base 1110 having the flow path 1110a through which the temperature-controlled medium flows, the ceramic member 1111a placed on the base 1110, and the heat flux sensor 200 placed on the back surface 301 of the ceramic member 1111a. By measuring the heat flux on the back surface 301 of the ceramic member 1111a with the heat flux sensor 200, the temperature (heat amount) of the substrate W or the electrostatic chuck 1111 in the thermal equilibrium state can be quickly grasped. As a result, the substrate W or the electrostatic chuck 1111 can be quickly temperature-controlled as compared with a temperature feedback control system.

[0085]

When a variation in heat occurs, a time difference occurs between the

heat variation and the temperature variation of the substrate or the electrostatic chuck 1111 according to the thermal capacity of the substrate, the electrostatic chuck 1111, or the like. Therefore, when the output of the heater 360 is feedback-controlled based on the temperature measured by the temperature sensor, an excess or deficiency occurs in the output of the heater 360, and it takes time for the temperature of the substrate or the electrostatic chuck 1111 to converge. Therefore, by using the heat flux sensor 200, the temperature control can be quickly performed as compared with a case where the temperature sensor is used.

[0086]

By measuring the heat flux with the heat flux sensor 200, the temperature of the substrate W or the electrostatic chuck 1111 can be calculated using the known thermal capacity of the substrate W or the electrostatic chuck 1111, so that a condition of the etching processing can be accurately set. In the present exemplary embodiment, the heat flux sensor 200 is used for controlling the heater 360, but may be simply used for calculating the temperature of the substrate W or the electrostatic chuck 1111.

[0087]

According to the present exemplary embodiment, since the heat flux sensor 200 is a magneto-thermoelectric conversion element using the anomalous Nernst effect, the heat flux can be detected even when the thickness of the heat flux sensor 200 is reduced. Therefore, the heat flux sensor 200 can be made thin. As a result, the heat flux sensor 200 itself is less likely to disturb the heat flux, it is difficult to form a thermal anomaly spot due to the structure of

the sensor, and the in-plane uniformity of the substrate temperature can be maintained.

[0088]

According to the present exemplary embodiment, since the heat flux sensor 200 is formed by performing the machining processing on the back surface 301 of the ceramic member 1111a, for example, a large number of fine heat flux sensors 200 may be placed. As a result, even when the ceramic member 1111a has a large number of divided regions 370 having the heater 360, the heat flux sensor can be placed in each divided region 370.

[0089]

According to the present exemplary embodiment, since the adhesive layer 201 is placed between the base 1110 and the ceramic member 1111a, the heat is appropriately transferred from the ceramic member 1111a to the base 1110 even when the heat flux sensor 200 is placed on the back surface 301 of the ceramic member 1111a.

[0090]

According to the present exemplary embodiment, the ceramic member 1111a includes the heater 360, and the controller 2 is configured to control the output of the heater 360 based on the heat flux measured by the heat flux sensor 200. As a result, the substrate W or the electrostatic chuck 1111 can be quickly temperature-controlled.

[0091]

In the above-described embodiment, the example in which the electrostatic chuck 1111 is used in a capacitively coupled plasma apparatus is

described, but the present disclosure is not limited to this, and the electrostatic chuck 1111 may be used in another type of the plasma apparatus. In addition, the electrostatic chuck 1111 is not limited to the plasma processing apparatus, and may be used in another substrate processing apparatus. The substrate support 11 may have a support that does not have a substrate chuck electrode, instead of the electrostatic chuck 1111. The heat flux sensor 200 may be a thermoelectric conversion element using a Seebeck effect.

[0092]

Embodiments of the present disclosure further include the following aspects.

[0093] (Aspect 1)

A substrate support including:

a base including a flow path through which a temperature-controlled medium flows;

a support placed on the base, the support including a front surface that supports a substrate and a back surface; and

a heat flux sensor placed on the back surface of the support.

[0094] (Aspect 2)

The substrate support according to Aspect 1, in which an adhesive layer is placed between the base and the support.

[0095] (Aspect 3)

The substrate support according to Aspect 1 or 2, in which the heat flux sensor is a magneto-thermoelectric conversion element.

[0096] (Aspect 4)

The substrate support according to any one of Aspects 1 to 3, in which the heat flux sensor is a magneto-thermoelectric conversion element using an anomalous Nernst effect.

[0097] (Aspect 5)

The substrate support according to any one of Aspects 1 to 4, in which the heat flux sensor has a thickness in a range of 0.1 μm or more and 10 μm or less.

[0098] (Aspect 6)

The substrate support according to any one of Aspects 1 to 5, in which the heat flux sensor is formed by performing machining processing on the back surface of the support.

[0099] (Aspect 7)

The substrate support according to any one of Aspects 1 to 6, in which the support includes a substrate chuck electrode.

[0100] (Aspect 8)

The substrate support according to any one of Aspects 1 to 7, in which the support includes a heater.

[0101] (Aspect 9)

The substrate support according to any one of Aspects 1 to 8, in which the support includes multiple heaters, and

one or more heat flux sensors are placed for each of the heaters.

[0102] (Aspect 10)

An electrostatic chuck that holds a substrate, including:

a dielectric including a front surface that supports the substrate and a back surface;

a substrate chuck electrode placed in the dielectric; and

a heat flux sensor placed on the back surface of the dielectric.

[0103] (Aspect 11)

The electrostatic chuck according to Aspect 10, in which the heat flux sensor is a magneto-thermoelectric conversion element.

[0104] (Aspect 12)

The electrostatic chuck according to Aspect 10 or 11, in which the heat flux sensor is a magneto-thermoelectric conversion element using an anomalous Nernst effect.

[0105] (Aspect 13)

The electrostatic chuck according to any one of Aspects 10 to 12, in which the heat flux sensor has a thickness in a range of 0.1 μm or more and 10 μm or less.

[0106] (Aspect 14)

The electrostatic chuck according to any one of Aspects 10 to 13, in which the heat flux sensor is formed by performing machining processing on the back surface of the dielectric.

[0107] (Aspect 15)

The electrostatic chuck according to any one of Aspects 10 to 14, in which the dielectric includes a heater.

[0108] (Aspect 16)

The electrostatic chuck according to any one of Aspects 10 to 15, in which the dielectric includes multiple heaters, and

one or more heat flux sensors are placed for each of the heaters.

[0109] (Aspect 17)

A plasma processing apparatus including:

a chamber;

a substrate support placed in the chamber;

a gas supply configured to supply a processing gas into the chamber; and

a plasma generator configured to generate plasma from the processing gas in the chamber,

in which the substrate support includes:

a base including a flow path through which a temperature-controlled medium flows;

a support placed on the base, the support including a front surface that supports a substrate and a back surface; and

a heat flux sensor placed on the back surface of the support.

[0110] (Aspect 18)

The plasma processing apparatus according to Aspect 17, further including:

a controller,

in which the support includes a heater, and

the controller is configured to control an output of the heater based on a heat flux measured by the heat flux sensor.

[0111] (Aspect 19)

A method for manufacturing an electrostatic chuck, including:

forming a dielectric that includes a front surface that supports a substrate and a back surface and in which a substrate chuck electrode is placed; and

forming a heat flux sensor on the back surface of the dielectric.

[0112]

Each of the embodiments described above is for illustrative purposes only and is not intended to limit the scope of the present disclosure. Each of the embodiments described above may be modified in various ways without departing from the scope and spirit of the present disclosure. For example, a part of configuration elements in one embodiment may be added to other embodiments. Furthermore, a part of configuration elements in one embodiment can be replaced with corresponding configuration elements in other embodiments.

Reference Signs List

[0113]

1 ... plasma processing apparatus

2 ... controller

10 ... chamber

11 ... substrate support

1110 ... base

1110a ... flow path

1111 ... electrostatic chuck

1111a ... ceramic member

1111b ... electrostatic electrode

200 ... heat flux sensor

201 ... adhesive layer

360 ... heater

W ... substrate

Claims

1. A substrate support comprising:

a base including a flow path through which a temperature-controlled medium flows;

a support placed on the base, the support including a front surface that supports a substrate and a back surface; and

a heat flux sensor placed on the back surface of the support.

2. The substrate support according to Claim 1, wherein an adhesive layer is placed between the base and the support.

3. The substrate support according to Claim 1, wherein the heat flux sensor is a magneto-thermoelectric conversion element.

4. The substrate support according to Claim 1, wherein the heat flux sensor is a magneto-thermoelectric conversion element using an anomalous Nernst effect.

5. The substrate support according to Claim 1, wherein the heat flux sensor has a thickness in a range of 0.1 μm or more and 10 μm or less.

6. The substrate support according to Claim 1, wherein the heat flux sensor is formed by performing machining processing on the back surface of the support.

7. The substrate support according to Claim 1, wherein the support includes a substrate chuck electrode.

8. The substrate support according to Claim 1, wherein the support includes a heater.

9. The substrate support according to Claim 1, wherein the support includes multiple heaters, and

one or more heat flux sensors are placed for each of the heaters.

10. An electrostatic chuck that holds a substrate, comprising:

a dielectric including a front surface that supports the substrate and a back surface;

a substrate chuck electrode placed in the dielectric; and

a heat flux sensor placed on the back surface of the dielectric.

11. The electrostatic chuck according to Claim 10, wherein the heat flux sensor is a magneto-thermoelectric conversion element.

12. The electrostatic chuck according to Claim 10, wherein the heat flux sensor is a magneto-thermoelectric conversion element using an anomalous Nernst effect.

13. The electrostatic chuck according to Claim 10, wherein the heat flux sensor has a thickness in a range of 0.1 μm or more and 10 μm or less.

14. The electrostatic chuck according to Claim 10, wherein the heat flux sensor is formed by performing machining processing on the back surface of the dielectric.

15. The electrostatic chuck according to Claim 10, wherein the dielectric includes a heater.

16. The electrostatic chuck according to Claim 10, wherein the dielectric includes multiple heaters, and

one or more heat flux sensors are placed for each of the heaters.

17. A plasma processing apparatus comprising:

a chamber;

a substrate support placed in the chamber;

a gas supply configured to supply a processing gas into the chamber; and

a plasma generator configured to generate plasma from the processing gas in the chamber,

wherein the substrate support includes:

a base including a flow path through which a temperature-controlled medium flows;

a support placed on the base, the support including a front surface that

supports a substrate and a back surface; and

a heat flux sensor placed on the back surface of the support.

18. The plasma processing apparatus according to Claim 17, further comprising:

a controller,

wherein the support includes a heater, and

the controller is configured to control an output of the heater based on a heat flux measured by the heat flux sensor.

19. A method for manufacturing an electrostatic chuck, comprising:

forming a dielectric that includes a front surface that supports a substrate and a back surface and in which a substrate chuck electrode is placed; and

forming a heat flux sensor on the back surface of the dielectric.