uniformity of a substrate process, when performing the substrate process by plasma-exciting a processing gas.

[0007] According to one embodiment of the present disclosure, there is provided a substrate processing apparatus which includes: a substrate process chamber having a plasma generation space in which a processing gas is plasma-excited and a substrate processing space communicating with the plasma generation space; a substrate mounting table installed inside the substrate processing space and configured to mount a substrate thereon; an inductive coupling structure provided with a coil installed so as to be wound around an outer periphery of the plasma generation space, and configured so that an electrical length of the coil is an integral multiple of a wavelength of a high-frequency power supplied to the coil and a diameter of the coil is larger than a diameter of the substrate; a substrate mounting table elevating part configured to raise or lower the substrate mounting table; a gas supply part configured to supply the processing gas to the plasma generation space; and a controller configured to control the substrate mounting table elevating part so that, when processing the substrate, the substrate mounted on the substrate mounting table is positioned at a height lower than a lower end of the coil.

BRIEF DESCRIPTION OF DRAWINGS

[0008] FIG. 1 is a schematic sectional view of a substrate processing apparatus according to an embodiment of the present disclosure.

FIG. 2 is an explanatory view for explaining a plasma generation principle of a substrate processing apparatus according to an embodiment of the present disclosure.

FIG. 3 is a view showing a configuration of a control part (control means) of a substrate processing apparatus according to an embodiment of the present disclosure.

FIG. 4 is a flowchart showing a substrate process according to an embodiment of the present disclosure.

FIG. 5 is an explanatory view of a substrate on which a groove (trench) to be processed

in a substrate process according to an embodiment of the present disclosure is formed.

FIG. 6 is a view showing height positions of probes installed inside a plasma generation space and a substrate process space in a verification example.

FIG. 7 is a view showing installation positions of probes at respective height positions in the verification example.

FIG. 8 is a view showing the measurement values of plasma density distributions at the height positions in the verification example.

FIG. 9 is a view showing the measurement results of plasma density distributions at the height positions in the verification example.

DETAILED DESCRIPTION

<First Embodiment of the Present Disclosure>

(1) Configuration of Substrate processing apparatus

[0009] A substrate processing apparatus according to a first embodiment of the present disclosure will be described below with reference to FIGS. 1 and 2. The substrate processing apparatus according to the present embodiment is configured to mainly perform an oxidizing process on a film formed on a surface of a substrate.

(Process Chamber)

[0010] A processing device 100 includes a process furnace 202 for plasma-processing a wafer 200. A process container 203 constituting a process chamber 201 is installed in the process furnace 202. The process container 203 includes a dome-shaped upper container 210 which is a first container and a bowl-shaped lower container 211 which is a second container. The lower container 211 is covered with the upper container 210 so that the process chamber 201 is formed. The upper container 210 is made of, for example, a nonmetallic material such as aluminum oxide (Al_2O_3) or quartz (SiO_2), and the lower container 211 is made of, for example, aluminum (Al).

[0011] In addition, a gate valve 244 is installed in a lower side wall of the lower container 211.

When the gate valve 244 is opened, the wafer 200 can be loaded into or unloaded from the process chamber 201 via a loading/unloading port 245 using a transfer mechanism (not shown). The gate valve 244, when being closed, serves as a partitioning valve for securing airtightness inside the process chamber 201.

[0012] The process chamber 201 includes a plasma generation space 201a around which a resonance coil 212 is installed, and a substrate process space 201b which is in communication with the plasma generation space 201a and which processes the wafer 200 received therein. The plasma generation space 201a is a space in which plasma is generated. The plasma generation space 201a refers to a space defined above a lower end of the resonance coil 212 and below an upper end of the resonance coil 212 inside the process chamber 201. On the other hand, the substrate process space 201b is a space in which the substrate is processed using plasma. The substrate process space 201b refers to a space defined below the lower end of the resonance coil 212. In the present embodiment, the diameters of the plasma generation space 201a and the substrate process space 201b in the horizontal direction are set to be substantially equal to each other.

(Susceptor)

[0013] A susceptor (substrate mounting table) 217 serving as a substrate mounting part for mounting the wafer 200 thereon is disposed at the bottom center of the process chamber 201. The susceptor 217 is made of, for example, a nonmetallic material such as aluminum nitride (AlN), ceramics, quartz or the like, and is configured to reduce metal contamination on a film or the like formed on the wafer 200.

[0014] A heater 217b as a heating mechanism is integrally embedded in the susceptor 217. The heater 217b is configured to, when supplied with electric power, heat the surface of the wafer 200, for example, from 25 degrees C to 750 degrees C.

[0015] The susceptor 217 is electrically insulated from the lower container 211. An impedance adjustment electrode 217c is installed inside the susceptor 217 in order to further improve the uniformity of the density of the plasma generated on the wafer 200 which is mounted on the susceptor 217. The impedance adjustment electrode 217c is grounded via an impedance

varying mechanism 275 as an impedance adjustment part. The impedance varying mechanism 275 is composed of a coil and a variable capacitor. The impedance varying mechanism 275 is configured to vary the impedance within a range from about 0 Ω to a parasitic impedance value of the process chamber 201 by controlling inductance and resistance of the coil and a capacitance value of the variable capacitor. As a result, the potential (bias voltage) of the wafer 200 can be controlled via the impedance adjustment electrode 217c and the susceptor 217. In the present embodiment, the uniformity of the density of the plasma generated on the wafer 200 can be improved as will be described later. Therefore, if the uniformity of the density of the plasma falls within a desired range, the bias voltage control using the impedance adjustment electrode 217c is not performed. Further, when the bias voltage control is not performed, the impedance adjustment electrode 217c may not be installed in the susceptor 217. However, the bias voltage control may be performed for the purpose of further improving the uniformity.

[0016] A susceptor elevating mechanism 268 equipped with a driving mechanism for raising and lowering the susceptor 217 is installed in the susceptor 217. In addition, through-holes 217a are formed in the susceptor 217, and wafer lifting pins 266 are installed on the bottom surface of the lower container 211. The through-holes 217a and the wafer lifting pins 266 are provided at at least three locations at respective positions facing each other. When the susceptor 217 is lowered by the susceptor elevating mechanism 268, the wafer lifting pins 266 are configured to penetrate the through-holes 217a in a state in which the wafer lifting pins 266 do not make contact with the susceptor 217. A substrate mounting part according to the present embodiment is mainly configured by the susceptor 217, the heater 217b and the electrode 217c.

(Gas Supply Part)

[0017] A gas supply head 236 is installed above the process chamber 201, namely above the upper portion of the upper container 210. The gas supply head 236 includes a cap-like lid 233, a gas inlet port 234, a buffer chamber 237, an opening 238, an additional shielding plate 240 and a gas outlet port 239. The gas supply head 236 is configured to supply a reaction gas into the process

chamber 201. The buffer chamber 237 functions as a dispersion space for dispersing the reaction gas introduced from the gas inlet port 234.

[0018] A downstream end of an oxygen-containing gas supply pipe 232a for supplying an oxygen (O_2) gas as an oxygen-containing gas, a downstream end of a hydrogen-containing gas supply pipe 232b for supplying a hydrogen (H_2) gas as a hydrogen-containing gas and a downstream end of an inert gas supply pipe 232c for supplying an argon (Ar) gas as an inert gas are connected to the gas inlet port 234 while being joined with each other. In the oxygen-containing gas supply pipe 232a, an O_2 gas supply source 250a, a mass flow controller (MFC) 252a as a flow rate control device and a valve 253a as an opening/closing valve are installed sequentially from the upstream side. In the hydrogen-containing gas supply pipe 232b, an H_2 gas supply source 250b, an MFC 252b and a valve 253b are installed sequentially from the upstream side. In the inert gas supply pipe 232c, an Ar gas supply source 250c, an MFC 252c and a valve 253c are installed sequentially from the upstream side. A valve 243a is installed at the downstream side of the joint point of the oxygen-containing gas supply pipe 232a, the hydrogen-containing gas supply pipe 232b and the inert gas supply pipe 232c. The valve 243a is connected to an upstream end of the gas inlet port 234. By opening and closing the valves 253a, 253b, 253c and 243a, a processing gas such as the oxygen-containing gas, the hydrogen-containing gas, the inert gas or the like can be supplied into the process chamber 201 via the gas supply pipes 232a, 232b and 232c while controlling the flow rates of the respective gases by the MFCs 252a, 252b and 252c.

[0019] A gas supply part (gas supply system) according to the present embodiment is mainly constituted by the gas supply head 236 (the lid 233, the gas inlet port 234, the buffer chamber 237, the opening 238, the additional shielding plate 240 and the gas outlet port 239), the oxygen-containing gas supply pipe 232a, the hydrogen-containing gas supply pipe 232b, the inert gas supply pipe 232c, the MFCs 252a, 252b and 252c, and the valves 253a, 253b, 253c and 243a.

[0020] Further, an oxygen-containing gas supply system according to the present embodiment is constituted by the gas supply head 236, the oxygen-containing gas supply pipe 232a, the MFC 252a, and the valves 253a and 243a. Moreover, a hydrogen gas supply system according to the

[0037] With such a configuration, in the resonance coil 212 according to the present embodiment, as shown in FIG. 2, the high frequency power according to the actual resonance frequency of the resonance coil including plasma is supplied (or, the high-frequency power is supplied so as to match the impedance of the resonance coil including plasma). This forms a standing wave in a state where the phase voltage and the antiphase voltage are always canceled out. When the electrical length of the resonance coil 212 is equal to the wavelength of the high-frequency power, the highest phase current is generated at the electrical midpoint of the coil, an electrical upper end of the coil, and an electrical lower end of the coil (at a node where the voltage is zero). Therefore, a donut-like induction plasma, which has almost no capacitive coupling with the wall of the process chamber or the susceptor 217 and which has extremely low electric potential, is formed in the vicinity of the electrical midpoint, the electrical upper end, and the electrical lower end of the coil.

(Control Part)

[0038] A controller 221 as the control part is configured to control the APC 242, the valve 243b and the vacuum pump 246 through a signal line A, control the susceptor elevating mechanism 268 through a signal line B, control the heater power adjustment mechanism 276 and the impedance varying mechanism 275 through a signal line C, control the gate valve 244 through a signal line D, control the RF sensor 272, the high-frequency power supply 273 and the matcher 274 through a signal line E, and control the MFCs 252a to 252c and the valves 253a to 253c and 243a through a signal line F.

[0039] As shown in FIG. 3, the controller 221 used as the control part (control means) is configured as a computer including a CPU (Central Processing Unit) 221a, a RAM (Random Access Memory) 221b, a memory device 221c and an I/O port 221d. The RAM 221b, the memory device 221c and the I/O port 221d are configured to exchange data with the CPU 221a via an internal bus 221e. An input/output device 222 composed of, for example, a touch panel, a display or the like is connected to the controller 221.

[0040] The memory device 221c is composed of, for example, a flash memory, an HDD (Hard

Disk Drive) or the like. In the memory device 221c, a control program for controlling the operation of the substrate processing apparatus, a process recipe in which sequences and conditions of the substrate process to be described later are written, and the like are stored in a readable manner. The process recipe functions as a program to cause the controller 221 to execute respective sequences in the substrate process to be described later so as to obtain a predetermined result. Hereinafter, the process recipe and the control program will be generally and simply referred to as a "program." When the term "program" is used herein, it may indicate a case of including only the process recipe, a case of including only the control program, or a case of including both the process recipe and the control program. The RAM 221b is configured as a memory area (work area) in which a program or data read by the CPU 221a is temporarily stored.

[0041] The I/O port 221d is connected to the MFCs 252a to 252c, the valves 253a to 253c, 243a and 243b, the gate valve 244, the APC 242, the vacuum pump 246, the RF sensor 272, the high-frequency power supply 273, the matcher 274, the susceptor elevating mechanism 268, the impedance varying mechanism 275, the heater power adjustment mechanism 276, and the like.

[0042] The CPU 221a is configured to read the control program from the memory device 221c and execute the same. The CPU 221a is also configured to read the process recipe from the memory device 221c according to an operation command inputted from the input/output device 222. The CPU 221a is configured to, according to the contents of the process recipe thus read, control the operation of adjusting the opening degree of the APC 242, the opening/closing operation of the valve 243b and the startup/stoppage of the vacuum pump 246 through the I/O port 221d and the signal line A, control the elevating operation of the susceptor elevating mechanism 268 through the signal line B, control the power supply amount adjustment operation (temperature adjustment operation) of the heater 217b performed by the heater power adjustment mechanism 276 and the impedance value adjustment operation performed by the impedance varying mechanism 275 through the signal line C, control the opening/closing operation of the gate valve 244 through the signal line D, control the operations of the RF sensor 272, the

matcher 274 and the high-frequency power supply 273 through the signal line E, and control the flow rate adjustment operation of various gases performed by the MFCs 252a to 252c and the opening/closing operation of the valves 253a to 253c and 243a through the signal line F.

[0043] The controller 221 may be configured by installing, on a computer, the aforementioned program stored in an external memory device 224 (for example, a magnetic tape, a magnetic disk such as a flexible disk, a hard disk or the like, an optical disk such as a CD, a DVD or the like, a magneto-optical disk such as an MO or the like, or a semiconductor memory such as a USB memory, a memory card or the like). The memory device 221c or the external memory device 224 is configured as a non-transitory computer-readable recording medium. Hereinafter, the memory device 221c and the external memory device 224 will be generally and simply referred to as a "recording medium." When the term "recording medium" is used herein, it may indicate a case of including only the memory device 221c, a case of including only the external memory device 224, or a case of including both the memory device 221c and the external memory device 224. The provision of the program to the computer may be performed using a communication means such as the Internet or a dedicated line without using the external memory device 224.

(2) Substrate Process

[0044] Next, the substrate process according to the present embodiment will be described mainly with reference to FIG. 4. FIG. 4 is a flowchart showing the substrate process according to the present embodiment. As one of various processes of manufacturing a semiconductor device such as a flash memory or the like, the substrate process according to the present embodiment is executed by the above-described processing device 100. In the following description, the operations of the respective parts constituting the processing device 100 are controlled by the controller 221.

[0045] For example, as shown in FIG. 5, a trench 301 having at least a silicon layer formed thereon and having an uneven portion with a high aspect ratio is formed in advance on the surface of the wafer 200 processed in the substrate process according to the present embodiment.

In the present embodiment, the silicon layer exposed on an inner wall of the trench 301 is subjected to an oxidizing process as a plasma-based process. The trench 301 is formed by, for example, forming a mask layer 302 having a predetermined pattern on the wafer 200 and subsequently etching the surface of the wafer 200 to a predetermined depth.

(Substrate Loading Step S110)

[0046] First, the wafer 200 is loaded into the process chamber 201. More specifically, the susceptor elevating mechanism 268 lowers the susceptor 217 to a wafer transfer position at which the wafer 200 is transferred, thereby allowing the wafer lifting pins 266 to pass through the respective through-holes 217a of the susceptor 217. As a result, the wafer lifting pins 266 remains protruded by a predetermined height from the surface of the susceptor 217.

[0047] Subsequently, the gate valve 244 is opened, and the wafer 200 is loaded into the process chamber 201 from a vacuum transfer chamber adjacent to the process chamber 201 by using a wafer transfer mechanism (not shown). The loaded wafer 200 is supported on the wafer lifting pins 266 protruding from the surface of the susceptor 217 in a horizontal posture. After loading the wafer 200 into the process chamber 201, the wafer transfer mechanism is withdrawn outward of the process chamber 201. The gate valve 244 is closed to hermetically seal the interior of the process chamber 201. Then, the susceptor elevating mechanism 268 raises the susceptor 217 so that the wafer 200 is supported on the upper surface of the susceptor 217.

(Temperature Increasing/Vacuum Exhaust Step S120)

[0048] Subsequently, the temperature of the wafer 200 loaded into the process chamber 201 is increased. The heater 217b is heated in advance. By holding the wafer 200 on the susceptor 217 in which the heater 217b is embedded, the wafer 200 is heated to a predetermined temperature falling within a range of, for example, 150 to 750 degrees C. In the present embodiment, the wafer W is heated at a temperature of 600 degrees C. While increasing the temperature of the wafer 200, the interior of the process chamber 201 is evacuated by the vacuum pump 246 via the

within a range of, for example, 100 to 5,000 W, specifically 100 to 3,500 W, and more specifically about 3,500 W. When the electric power is lower than 100 W, it is difficult to stably generate the plasma discharge.

[0051] As a result, a high-frequency electric field is formed inside the plasma generation space 201a to which the O_2 gas and the H_2 gas are supplied. By virtue of this electric field, donut-like induction plasma having a highest plasma density is excited at a height position corresponding to the electrical midpoint of the resonance coil 212 inside the plasma generation space. Each of the plasmarized O_2 gas and the plasmarized H_2 gas is dissociated, whereby reactive species such as oxygen radicals containing oxygen (oxygen active species) or oxygen ions, hydrogen radicals containing hydrogen (hydrogen active species) or hydrogen ions, and the like are generated.

[0052] As described above, when the electrical length of the resonance coil 212 is equal to the wavelength of the high-frequency power, donut-like induction plasma having an extremely low electrical potential is excited inside the plasma generation space 201a in the vicinity of the electrical midpoint of the resonance coil 212 while making almost no capacitive coupling with the wall of the process chamber and the substrate mounting table. Since the plasma having an extremely low electrical potential is generated, it is possible to prevent a sheath from being generated on the wall of the plasma generation space 201a or on the susceptor 217. Therefore, in the present embodiment, ions in the plasma are not accelerated.

[0053] Radicals generated by induction plasma and ions kept in a non-accelerated state are uniformly supplied into the trench 301 of the wafer 200 held on the susceptor 217 inside the substrate process space 201b. The supplied radicals and ions uniformly react with side walls 301a and 301b to modify the silicon layer formed on the surface into a silicon oxide layer having good step coverage.

[0054] Furthermore, since the acceleration of ions is prevented, it is possible to suppress damage of the wafer 200 due to accelerated ions. Furthermore, the sputtering action on the peripheral wall of the plasma generation space can be suppressed so that peripheral wall of the plasma generation space 201a does not undergo damage.

generation space 201a and the substrate process space 201b. In this verification, five probes were installed in each of the height positions (a) to (d) in the horizontal direction. That is to say, in this verification, the probes were installed at 20 locations in total and the distribution of the plasma density was measured.

[0065] The height position (b) is a lower end position of the resonance coil 212. Hereinafter, the height positions (a), (c) and (d) will be described using the height position (b) as a reference position (0 mm). The height position (a) is an intermediate position between the upper end and the lower end of the resonance coil 212, which is spaced apart by a distance of 100 mm upward from the lower end of the resonance coil 212. The height position (a) is a position near the electrical midpoint of the resonance coil 212 and at which the donut-like induction plasma having a highest plasma density is excited. The height position (c) is a position spaced apart by a distance of 38 mm downward from the lower end of the resonance coil 212. The height position (d) is a position spaced apart by a distance of 88 mm downward from the lower end of the resonance coil 212. In addition, the bare silicon wafer is mounted on a position spaced further apart by a distance of 50 mm downward from the height position (d).

[0066] FIG. 7 is a view showing the installation positions of the probes at each of the height positions (a) to (d). The installation positions of the probes at the respective height positions are all the same. M, L1, L2, R1 and R2 in FIG. 7 indicate tip positions of the probes (measurement positions of the plasma density), respectively. M is a position corresponding to the center position of the wafer to be mounted. L1 is a position defined by moving the probe by 30 degrees to the left side from M. L2 is a position defined by moving the probe by 60 degrees to the left side from M, which corresponds to one outer edge portion of the wafer. R1 is a position defined by moving the probe by 30 degrees to the right side from M. R2 is a position defined by moving the probe by 60 degrees to the right side from M, which corresponds to another outer edge portion of the wafer. That is to say, the plasma density distribution in a wafer plane direction (horizontal direction) was measured by measuring the plasma density at M, L1, L2, R1 and R2.

apart by a distance of 38 mm or more downward from the lower end of the resonance coil 212.

[0071] As described above, when the position of the wafer in the plasma processing step is too far downward from the lower end of the resonance coil 212, radicals and ions generated by the plasma excitation may be deactivated. Because of this, the processing rate may be lower than a practical value. Therefore, the vertical position of the wafer 200 in the plasma processing step needs to be at least such a position that radicals and ions generated by the plasma-excitation are not deactivated. According to another verification using the substrate processing apparatus according to the present embodiment, it can be noted that, similar to the height positions (c) and (d), a good plasma density distribution enough to realize a practical processing rate is obtained even at the height position of the bare wafer mounted on the susceptor 217, namely the height position spaced apart by a distance of 138 mm downward from the lower end of the resonance coil 212. Accordingly, in the substrate processing apparatus according to the present embodiment, by processing the wafer at least at a position spaced apart by a distance ranging 38 to 138 mm downward from the lower end of the resonance coil 212, it is possible to realize a practical processing rate while maintaining the wafer in-plane uniformity in the plasma process.

[0072] As another verification, the present inventors also verified a case where the power value of the supplied RF power is changed in a practical range (for example, 3,000 W or 2,500 W) with respect to the conditions under which the aforementioned verification has been performed. In this case, as the power value increases, the plasma density may increase over the entire plane direction of the wafer 200, and a deviation in the plasma density in the plane direction of the wafer may also be changed. On the other hand, it was confirmed that, in the height range described above, there is no significant change in the tendency of deviation of the plasma density in the plane direction of the wafer. That is to say, in the above-described height range, it is presumed that even in the case of changing the power value of the supplied RF power, it is possible to secure the wafer in-plane uniformity in the plasma process.

[0073] Similarly, as a further verification, the present inventors have confirmed that when the internal pressure of the process chamber is changed (for example, 50 Pa) in a practical range

with respect to the conditions under which the above-described verification has been performed, there is no significant change in the tendency of deviation of the plasma density in the plane direction of the wafer, while the plasma density is changed over the entire plane direction of the wafer (for example, the plasma density increases when the internal pressure is 50 Pa rather than 150 Pa). That is to say, in the above-described height range, it is presumed that the wafer in-plane uniformity in the plasma process can be secured even when the power value of the supplied RF power and the internal pressure of the process chamber are changed.

[0074] The aforementioned verification is directed to an embodiment in which the supplied gas is a mixed gas of the O_2 gas and the H_2 gas. However, according to another verification conducted by present the inventors, it was confirmed that even when a mixed gas of an N_2 gas and an H_2 gas is used, the wafer in-plane uniformity in the plasma process can be secured in the aforementioned height range.

[0075] According to another verification conducted by the present inventors, it is presumed that even if parameters such as the gas flow rate, the height width of the resonance coil, the winding pitch, the number of turns, the frequency of the supplied high-frequency power, and the like are changed in a practical range with respect to the conditions under which the above-described verification has been performed, similar verification results can be obtained with regard to the relationship between the uniformity of the plasma density and the height positions. In addition, it is considered that the relationship between the uniformity of the plasma density and the height positions depends mainly on the configuration of the plasma generation part. In the above-described embodiment, the processing gas is supplied from the gas supply head 236 installed in the upper portion of the process chamber 201. However, it is presumed that the similar verification result can be obtained even when a shape or position of the inlet port for introducing the processing gas into the process chamber is different from that in the above embodiment.

[0076] Furthermore, according to the plasma density distributions at the height positions (a) and (b) shown in FIG. 9, it can be noted that in the case of the present embodiment, in the plane

direction of the wafer, no large deviation in the plasma density is generated in the range of 30 degrees to the left and right sides from the center of the wafer. That is to say, by mounting the wafer in a predetermined region sufficiently away from the resonance coil 212 to the center direction, it is also possible to secure the wafer in-plane uniformity in the plasma process. In other words, it can be achieved by setting the winding diameter of the resonance coil 212 to a predetermined size sufficiently larger than the diameter of the wafer. Alternatively, it can be also achieved by using a wafer having a predetermined diameter sufficiently smaller than the winding diameter of the resonance coil 212. For example, in the present embodiment, with respect to the resonance coil 212 having a winding diameter of 500 mm, a wafer having a diameter falling within a range of 30 degrees to the left and right sides from the center, namely a wafer having a diameter of about 127 mm or less, may be used.

[0077] However, there is a limit in increasing the winding diameter of the resonance coil 212 from the viewpoint of cost, space and the like. Furthermore, in a case where a resonance coil having a winding number smaller than a predetermined magnitude is used, it is impossible to process a larger wafer. Therefore, in order to process a wafer having a larger diameter without increasing the winding diameter of the resonance coil 212, the wafer may be processed at positions spaced apart by a predetermined distance (falling within a range of 38 to 138 mm in the present embodiment) downward from the lower end of the resonance coil 212. For example, when the resonance coil 212 having a winding diameter of 500 mm is used to process a wafer having a diameter larger than about 127 mm, the wafer may be processed at positions spaced apart by a distance of a predetermined range downward from the lower end of the resonance coil 212.

[0078] In the present embodiment, there has been described the example in which the wafer is processed at a position spaced apart by a distance falling with a range of 38 to 138 mm downward from the lower end of the resonance coil 212. However, the present disclosure is not limited to this range. The height of the susceptor 217 (substrate mounting part) may be controlled to position the wafer 200 at such a height position spaced apart downward from the lower end of the resonance coil 212 that the deviation (in-plane deviation) of the plasma density

WHAT IS CLAIMED IS:

1. A substrate processing apparatus, comprising:

a substrate process chamber having a plasma generation space in which a processing gas is plasma-excited and a substrate processing space communicating with the plasma generation space;

a substrate mounting table installed inside the substrate processing space and configured to mount a substrate thereon;

an inductive coupling structure provided with a coil installed so as to be wound around an outer periphery of the plasma generation space, and configured so that an electrical length of the coil is an integral multiple of a wavelength of a high-frequency power supplied to the coil and a diameter of the coil is larger than a diameter of the substrate;

a substrate mounting table elevating part configured to raise or lower the substrate mounting table;

a gas supply part configured to supply the processing gas to the plasma generation space; and

a controller configured to control the substrate mounting table elevating part so that, when processing the substrate, the substrate mounted on the substrate mounting table is positioned at a height lower than a lower end of the coil.

2. The apparatus of Claim 1, wherein the controller is configured to control the substrate mounting table elevating part so that, when processing the substrate, the substrate mounted on the substrate mounting table is positioned at a height spaced apart by a distance of 38 mm or more downward from the lower end of the coil.

3. The apparatus of Claim 2, wherein the controller is configured to control the substrate mounting table elevating part so that, when processing the substrate, the substrate mounted on the substrate mounting table is positioned at a height spaced apart by a distance of 138 mm or less downward from the lower end of the coil.

4. The apparatus of Claim 3, wherein the diameter of the substrate is about 300 mm,

and the diameter of the coil is 500 mm or more.

5. The apparatus of Claim 4, wherein the coil has an electrical length which is one time the wavelength of the high-frequency power.

6. The apparatus of Claim 1, wherein the controller is configured to, when processing the substrate, control the substrate mounting table elevating part based on a power value of the high-frequency power supplied to the coil.

7. The apparatus of Claim 6, wherein the controller is configured to, when processing the substrate, control the substrate mounting table elevating part based on an allowable range of an in-plane deviation of a plasma density in a plane direction of the substrate, which is set for each plasma process on the substrate mounted on the substrate mounting table.

8. The apparatus of Claim 5, wherein the controller is configured to, when processing the substrate, control the substrate mounting table elevating part based on an allowable range of an in-plane deviation of a plasma density in a plane direction of the substrate, which is set for each plasma process on the substrate mounted on the substrate mounting table.

9. A method of manufacturing a semiconductor device, comprising:

loading a substrate into a substrate process chamber having a plasma generation space in which a processing gas is plasma-excited and a substrate process space communicating with the plasma generation space;

mounting the substrate on a substrate mounting table installed inside the substrate process space;

adjusting a height of the substrate mounting table so that the substrate mounted on the substrate mounting table is located at a height lower than a lower end of a coil, the coil configured to wind around an outer periphery of the plasma generation space so as to have a diameter larger than a diameter of the substrate;

supplying the processing gas to the plasma generation space;

plasma-exciting the processing gas supplied to the plasma generation space by supplying a high-frequency power to the coil to resonate the coil; and

processing the substrate mounted on the substrate mounting table by the plasma-excitation.

10. The method of Claim 9, wherein in the act of plasma-exciting the processing gas, the highest phase current is generated at the lower end of the coil.

11. The method of Claim 9, wherein in the act of adjusting a height of the substrate mounting table, the substrate mounting table is raised or lowered so that the height of the substrate is spaced apart by a distance of 38 mm or more downward from the lower end of the coil.

12. The method of Claim 11, wherein in the act of adjusting a height of the substrate mounting table, the substrate mounting table is raised or lowered so that the height of the substrate is spaced apart by a distance of 138 mm or less downward from the lower end of the coil.

13. The method of Claim 12, wherein the diameter of the substrate is about 300 mm, and the diameter of the coil is 500 mm or more.

14. The method of Claim 9, wherein in the act of adjusting a height of the substrate mounting table, the substrate mounting table is raised or lowered based on a power value of the high-frequency power supplied to the coil.

15. The apparatus of Claim 14, wherein in the act of adjusting a height of the substrate mounting table, the substrate mounting table is raised or lowered according to an allowable range of an in-plane deviation of a plasma density in a plane direction of the substrate, which is set for each plasma process on the substrate mounted on the substrate mounting table.

16. The apparatus of Claim 9, wherein in the act of adjusting a height of the substrate

mounting table, the substrate mounting table is raised or lowered according to an allowable range of an in-plane deviation of a plasma density in a plane direction of the substrate, which is set for each plasma process on the substrate mounted on the substrate mounting table.

17. A computer-readable recording medium storing a program for causing a computer to control a substrate processing apparatus so as to perform:

loading a substrate into a substrate process chamber having a plasma generation space in which a processing gas is plasma-excited and a substrate process space communicating with the plasma generation space;

mounting the substrate on a substrate mounting table installed inside the substrate process space;

adjusting a height of the substrate mounting table so that the substrate mounted on the substrate mounting table is located at a height lower than a lower end of a coil, the coil configured to wind around an outer periphery of the plasma generation space so as to have a diameter larger than a diameter of the substrate;

supplying the processing gas to the plasma generation space;

plasma-exciting the processing gas supplied to the plasma generation space by supplying a high-frequency power to the coil to resonate the coil; and

processing the substrate mounted on the substrate mounting table by the plasma-excitation.