Claims

[1] A deposition method, comprising:

by using a deposition apparatus including

a first electrode that includes a sputtering target,

a second electrode that faces the first electrode and is capable of supporting a substrate,

a first power supply source that includes a first high-frequency power source and a first matching circuit, the first high-frequency power source outputting first high-frequency power, the first matching circuit being connected between the first high-frequency power source and the first electrode,

a second power supply source that includes a second high-frequency power source and a second matching circuit, the second high-frequency power source outputting second high-frequency power that has the same period as the first high-frequency power and is lower than the first high-frequency power, the second matching circuit being connected between the second high-frequency power source and the second electrode and the second matching circuit including an input terminal, an output terminal, a first variable capacitor, and a second variable capacitor, the input terminal being connected to the second high-frequency power source, the output terminal being connected to

the second electrode, the first variable capacitor being connected between the input terminal and a ground potential, the second variable capacitor being connected between the input terminal and the output terminal in series, and

a phase adjuster that adjusts a phase of the first high-frequency power that is output from the first high-frequency power source and input to the first matching circuit and a phase of the second high-frequency power that is output from the second high-frequency power source and input to the second matching circuit,

causing the first high-frequency power source to output the first high-frequency power to form discharge plasma between the first electrode and the second electrode;

causing the second high-frequency power source to output the second high-frequency power and causing the phase adjuster to operate to provide a phase difference θ between the phase of the first high-frequency power and the phase of the second high-frequency power;

detecting a voltage value Vpp of the second high-frequency power and a capacitance value C1 of the first variable capacitor that correspond to the phase difference θ in a state where output impedance of the second high-frequency power source and load-side

impedance connected to the second high-frequency power source match;

forming the phase difference θ by delaying the phase of the second high-frequency power with respect to the phase of the first high-frequency power;

obtaining a profile curve of the voltage value Vpp and a profile curve of the capacitance value C1 that correspond to the phase difference θ by changing the phase difference θ; and

forming a sputtering film on the substrate in a state where the output impedance and the load-side impedance match by setting the phase difference θ in a first range of the profile curve of the voltage value Vpp or a second range and selecting the voltage value Vpp and the capacitance value C1 in combination , the first range being a range of +30 degrees to +50 degrees from a phase difference θ1 of the profile curve of the voltage value Vpp where the voltage value Vpp is the lowest, the second range being a range of +10 degrees to -10 degrees from a phase difference θ2 where the voltage value Vpp is the largest.

[2] The deposition method according to claim 1, further comprising

forming the sputtering film on the substrate by changing the phase difference θ in a stepwise manner in the first range or the second range.

[3] The deposition method according to claim 1, further comprising

forming the sputtering film on the substrate in a third range in which the phase difference θ is smaller than the second range and larger than the first range after forming the sputtering film on the substrate in the first range or the second range.

[4] The deposition method according to claim 3, wherein

the third range is a range of -50 degrees to -30 degrees from the phase difference θ2.

[5] A deposition apparatus, comprising:

a first electrode that includes a sputtering target;

a second electrode that faces the first electrode and is capable of supporting a substrate;

a first power supply source that includes a first high-frequency power source and a first matching circuit, the first high-frequency power source outputting first high-frequency power, the first matching circuit being connected between the first high-frequency power source and the first electrode;

a second power supply source that includes a second high-frequency power source and a second matching circuit, the second high-frequency power source outputting second high-frequency power that has

the same period as the first high-frequency power and is lower than the first high-frequency power, the second matching circuit being connected between the second high-frequency power source and the second electrode and the second matching circuit including an input terminal, an output terminal, a first variable capacitor, and a second variable capacitor, the input terminal being connected to the second high-frequency power source, the output terminal being connected to the second electrode, the first variable capacitor being connected between the input terminal and a ground potential, the second variable capacitor being connected between the input terminal and the output terminal in series;

a phase adjuster that adjusts a phase of the first high-frequency power that is output from the first high-frequency power source and input to the first matching circuit and a phase of the second high-frequency power that is output from the second high-frequency power source and input to the second matching circuit; and

a controller that controls the first power supply source, the second power supply source, and the phase adjuster,

the controller storing data obtained by

causing the first high-frequency power source

to output the first high-frequency power to form discharge plasma between the first electrode and the second electrode,

causing the second high-frequency power source to output the second high-frequency power and causing the phase adjuster to operate to provide a phase difference θ between the phase of the first high-frequency power and the phase of the second high-frequency power, and

detecting a voltage value Vpp of the second high-frequency power and a capacitance value C1 of the first variable capacitor that correspond to the phase difference θ in a state where output impedance of the second high-frequency power source and load-side impedance connected to the second high-frequency power source match,

the controller storing a profile curve of the voltage value Vpp and a profile curve of the capacitance value C1 that correspond to the phase difference θ obtained by forming the phase difference θ by delaying the phase of the second high-frequency power with respect to the phase of the first high-frequency power and changing the phase difference θ,

the controller setting the phase difference θ in a first range or a second range and selecting the voltage value Vpp and the capacitance value C1 in combination,

the first range being a range of +30 degrees to +50 degrees from a phase difference θ1 of the profile curve of the voltage value Vpp where the voltage value Vpp is the lowest, the second range being a range of +10 degrees to -10 degrees from a phase difference θ2 where the voltage value Vpp is the largest to form a sputtering film on the substrate in a state where the output impedance and the load-side impedance match.

[6] The deposition apparatus according to claim 5, further comprising

forming the sputtering film on the substrate by changing the phase difference θ in a stepwise manner in the first range or the second range.

[7] The deposition apparatus according to claim 5, further comprising

forming the sputtering film on the substrate in a third range in which the phase difference θ is smaller than the second range and larger than the first range after forming the sputtering film on the substrate in the first range or the second range.

[8] The deposition apparatus according to claim 7, wherein

the third range is a range of -50 degrees to -30 degrees from the phase difference θ2.