PLASMA PROCESSING APPARATUS, POWER SUPPLY SYSTEM, AND METHOD FOR CONTROLLING SOURCE FREQUENCY

FIELD

[0001] Exemplary embodiments of the disclosure relate to a plasma processing apparatus, a power supply system, and a method for controlling a frequency.

BACKGROUND

[0002] A plasma processing apparatus performs plasma processing of substrates. The plasma processing apparatus provides source radio-frequency (RF) power to generate plasma from a gas in a chamber. The plasma processing apparatus uses bias RF power to draw ions from plasma generated in the chamber into a substrate. Patent Literature 1 below describes a plasma processing apparatus that modulates the power level and the frequency of bias RF power.

CITATION LIST

PATENT LITERATURE

[0003] Patent Literature 1: Japanese Unexamined Patent Application Publication No. 2009-246091

BRIEF SUMMARY

TECHNICAL PROBLEM

[0004] One or more examples of the disclosure are directed to a technique for reducing the degree of reflection of source radio-frequency power.

SOLUTION TO PROBLEM

[0005] According to a first aspect of the present invention, there is provided a plasma processing apparatus comprising a chamber, a substrate support, a radio-frequency power supply, and a bias power supply. The substrate support is in the chamber. The radio-frequency power supply generates source radio-frequency power having a source frequency to generate plasma from a gas in the chamber. The bias power supply provides an electrical bias to the substrate support to draw ions from

plasma in the chamber. The electrical bias has a waveform cycle. The radio-frequency power supply sets a time series of source frequencies of the source radio-frequency power in a frequency adjustment cycle having a same duration as the waveform cycle to include a maximum frequency in a first specific phase, a minimum frequency in a second specific phase, and an interpolated frequency in a phase other than least two specific phases including the first specific phase and the second specific phase. The radio-frequency power supply and the bias power supply set a phase difference between the frequency adjustment cycle and the waveform cycle to reduce a degree of reflection of the source radio-frequency power, and the frequency adjustment cycle has the source frequency changed based on a set of initial frequencies specifying initial source frequencies in the at least two specific phases. The radio-frequency power supply identifies, after setting the phase difference, the source frequency in the first specific phase and the source frequency in the second specific phase to reduce the degree of reflection of the source radio-frequency power while changing the maximum frequency in the first specific phase and the minimum frequency in the second specific phase in the time series of the source frequencies in the frequency adjustment cycle in a direction opposite to each other.

[0005A] According to a second aspect of the present invention, there is provided a power supply system, comprising:

a radio-frequency power supply configured to generate source radio-frequency power having a source frequency to generate plasma from a gas in a chamber in a plasma processing apparatus; and

a bias power supply configured to provide an electrical bias having a waveform cycle to a substrate support in the chamber to draw ions from plasma in the chamber,

wherein the radio-frequency power supply sets a time series of source frequencies of the source radio-frequency power in a frequency adjustment cycle having a same duration as the waveform cycle to include a maximum frequency in a first specific phase, a minimum frequency in a second specific phase, and an interpolated frequency in a phase other than at least two specific phases including the first specific phase and the second specific phase,

the radio-frequency power supply and the bias power supply set a phase difference between the frequency adjustment cycle and the waveform cycle to reduce a degree of

reflection of the source radio-frequency power, and the frequency adjustment cycle has the source frequency changed based on a set of initial frequencies specifying initial source frequencies in the at least two specific phases, and

the radio-frequency power supply identifies, after setting the phase difference, the source frequency in the first specific phase and the source frequency in the second specific phase to reduce the degree of reflection of the source radio-frequency power while changing the maximum frequency in the first specific phase and the minimum frequency in the second specific phase in the time series of source frequencies in the frequency adjustment cycle in a direction opposite to each other.

[0005B] According to a third aspect of the present invention, there is provided a method for controlling a source frequency, the method comprising:

(a) providing source radio-frequency power having a source frequency from a radio-frequency power supply to generate plasma from a gas in a chamber in a plasma processing apparatus;

(b) providing an electrical bias having a waveform cycle from a bias power supply to a substrate support in the chamber to draw ions from plasma in the chamber,

(a) including setting, with the radio-frequency power supply, a time series of source frequencies of the source radio-frequency power in a frequency adjustment cycle having a same duration as the waveform cycle to include a maximum frequency in a first specific phase, a minimum frequency in a second specific phase, and an interpolated frequency in a phase other than at least two specific phases including the first specific phase and the second specific phase;

(c) setting a phase difference between the frequency adjustment cycle and the waveform cycle to reduce a degree of reflection of the source radio-frequency power, the frequency adjustment cycle having the source frequency changed based on a set of initial frequencies specifying initial source frequencies in the at least two specific phases; and

(d) identifying, after setting the phase difference, the source frequency in the first specific phase and the source frequency in the second specific phase to reduce the degree of reflection of the source radio-frequency power while changing the maximum frequency in the first

specific phase and the minimum frequency in the second specific phase in the time series of the source frequencies in the frequency adjustment cycle in a direction opposite to each other.

ADVANTAGEOUS EFFECTS

[0006] The technique according to one exemplary embodiment reduces the degree of reflection of the source radio-frequency power.

BRIEF DESCRIPTION OF DRAWINGS

[0007] FIG. 1 is a diagram of a plasma processing system, describing an example structure.

FIG. 2 is a diagram of a capacitively coupled plasma processing apparatus, describing an example structure.

FIG. 3 is a diagram of a power supply system in the plasma processing apparatus according to one exemplary embodiment, showing an example structure.

FIGs. 4A and 4B are graphs each showing an example waveform of an electrical bias.

FIGs. 5A to 5C are graphs each showing an example time series of source frequencies in the plasma processing apparatus according to the exemplary embodiment.