PLASMA PROCESSING APPARATUS, POWER SUPPLY SYSTEM, CONTROL METHOD, PROGRAM, AND STORAGE MEDIUM

FIELD

[0001] Exemplary embodiments of the disclosure relate to a plasma processing apparatus, a power supply system, a control method, a program, and a storage medium.

BACKGROUND

[0002] A plasma processing apparatus is used to perform plasma processing on substrates. The plasma processing apparatus uses bias radio-frequency power to draw ions in plasma generated in a chamber to a substrate. Patent Literature 1 below describes a plasma processing apparatus that modulates the power level and the frequency of bias radio-frequency 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 aspects of the disclosure are directed to a technique for reducing the power level of a reflected wave of source radio-frequency power.

SOLUTION TO PROBLEM

[0005] According to a first aspect, there is provided a plasma processing apparatus that includes a chamber, a substrate support, a bias power supply, and a radio-frequency power supply. The substrate support is in the chamber. The bias power supply is electrically coupled to the substrate support to generate electrical bias energy. The electrical bias energy has a bias frequency. The electrical bias energy has waveform cycles each having a duration being an inverse of the bias frequency. The radio-frequency power supply is electrically coupled to a radio-frequency electrode to generate source radio-frequency power to generate plasma from a gas in the chamber. The radio-frequency power supply selects an initial frequency group corresponding to a specified process. The radio-frequency power supply uses, in a first period, a plurality of frequencies included in the initial frequency group as a plurality of source frequencies of the source radio-frequency power for a respective plurality of phase periods in a waveform cycle of the electrical bias energy. The radio-frequency power supply adjusts, in a second period subsequent to the first period, the plurality of source frequencies of the source radio-frequency power for the respective plurality of phase periods in a waveform cycle of the electrical bias energy to decrease a power level of a reflected wave of the source radio-frequency power from a load.

[0005a] According to a second aspect, there is provided a power supply system, including: a bias power supply configured to generate electrical bias energy to be provided to a substrate support in a chamber in a plasma processing apparatus, the electrical bias energy having a bias frequency, the electrical bias energy having waveform cycles each having a duration being an inverse of the bias frequency; and a radio-frequency power supply configured to generate source radio-frequency power to be provided to a radio-frequency electrode to generate plasma

from a gas in the chamber, wherein the radio-frequency power supply selects an initial frequency group corresponding to a specified process, uses, in a first period, a plurality of frequencies included in the initial frequency group as a plurality of source frequencies of the source radio-frequency power for a respective plurality of phase periods in a waveform cycle of the electrical bias energy, and adjusts, in a second period subsequent to the first period, the plurality of source frequencies of the source radio-frequency power for the respective plurality of phase periods in a waveform cycle of the electrical bias energy to decrease a power level of a reflected wave of the source radio-frequency power from a load.

[0005b] According to a third aspect, there is provided a control method, including: (a) providing electrical bias energy having a bias frequency from a bias power supply to a substrate support in a chamber in a plasma processing apparatus, the electrical bias energy having a bias frequency, the electrical bias energy having waveform cycles each having a duration being an inverse of the bias frequency; and (b) providing source radio-frequency power from a radio-frequency power supply to a radio-frequency electrode to generate plasma from a gas in the chamber, (b) including selecting an initial frequency group corresponding to a specified process, using, in a first period, a plurality of frequencies included in the initial frequency group as a plurality of source frequencies of the source radio-frequency power for a respective plurality of phase periods in a waveform cycle of the electrical bias energy, and adjusting, in a second period subsequent to the first period, the plurality of source frequencies of the source radio-frequency power for the respective plurality of phase periods in a waveform cycle of the electrical bias energy to decrease a power level of a reflected wave of the source radio-frequency power from a load.

[0005c] According to a fourth aspect, there is provided a program executable by a computer in a plasma processing apparatus to implement the above control method with the above plasma processing apparatus.

[0005d] According to a fifth aspect, there is provided a storage medium storing the above program.

ADVANTAGEOUS EFFECTS

[0006] The technique according to the above exemplary aspects reduces the power level of the reflected wave of the source radio-frequency power.

BRIEF DESCRIPTION OF DRAWINGS

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

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

FIG. 3 is a schematic diagram of a plasma processing apparatus according to one exemplary embodiment.

FIG. 4 is an example timing chart of electrical bias energy, showing its waveforms.

FIGs. 5A and 5B are each a timing chart of source radio-frequency power and electrical bias energy in the plasma processing apparatus according to one exemplary embodiment.

FIG. 6 is a waveform chart of electrical bias energy in the plasma processing apparatus according to one exemplary embodiment.

FIGs. 7A and 7B are each a table of a database usable for the plasma processing apparatus according to one exemplary embodiment.

FIG. 8 is a waveform chart of electrical bias energy in the plasma processing apparatus