

Summary

[0006] Embodiments of the disclosure provide apparatus, methods and computer programs for chamber matching using a voltage control mode. It should be appreciated that the present embodiments can be implemented in numerous ways, e.g., a process, an apparatus, a system, a device, or a method on a computer-readable medium. Several embodiments are described below.

[0007] In some embodiments, a voltage control mode is used to perform chamber-to-chamber matching and/or to perform intra-chamber matching. The voltage control mode is used to reduce variability in characteristics of one or more plasma chambers. The variability in characteristics of one or more plasma chambers creates harmonics that add a variation to a fundamental waveform. By measuring and extracting the harmonics, the variability in characteristics is accounted for. Based on the harmonics, power supplied to a plasma chamber is controlled and/or elements of a plasma system are replaced with other corresponding elements to reduce the effect of the harmonics on the one or more plasma chambers.

[0008] In several embodiments, a method for compensating for harmonics produced during plasma processing in a plasma chamber is described. The method includes retrieving a measurement of a combined waveform. The combined waveform includes a fundamental waveform and a harmonic waveform. The combined waveform defines a voltage proximate to a surface of a chuck, which is coupled to a radio frequency (RF) transmission line. The RF transmission line is coupled to an impedance matching circuit. The impedance matching circuit is coupled to an RF generator. The method further includes extracting the fundamental waveform from the combined waveform, determining a difference between a magnitude of the combined waveform and a magnitude of the fundamental waveform, and controlling the RF generator to compensate for the difference. The method is executed by one or more processors.

[0009] In a number of embodiments, a method for compensating for harmonics produced during plasma processing in a plasma chamber is described. The method includes retrieving a measurement of a combined waveform, which includes a fundamental waveform and a harmonic waveform. The combined waveform defines a variable proximate to a surface of a chuck, the chuck coupled to an RF transmission line, which is coupled to an impedance matching circuit. The impedance matching circuit is coupled to an RF generator.

of the RF strap 148. As yet another example, the ESC model 182 has the same capacitance, inductance, resistance, or a combination thereof as that of the ESC 127.

[00111] The processor 184 receives a measurement of the voltage from the probe 124 (Figure 3A). The processor 184 determines a value of the variable at an output of the ESC model 182 based on the measurement of the voltage received from the probe 124 and the characteristics of the strap model 192 and the ESC model 182. For example, the processor 184 receives the current at the output of the RF rod 152 (Figure 3A), receives a magnitude of the voltage at the output of the RF rod 152, receives a phase of the voltage, and determines a directed sum of the voltage, and voltages generated by the capacitances, inductances, and/or resistances of the strap model 192 and the ESC model 182 to determine voltage and current at the output of the ESC model 182.

[00112] The processor 184 uses the voltage at the output of the ESC model 182 instead of the measurement of the voltage from the probe 124 to determine waveforms of voltages of plasma within the plasma chamber 123 (Figure 3A).

[00113] In various embodiments, the probe 124 is connected to an input of the RF rod 152 instead of to the output of the RF rod 152. In these embodiments, the processor 184 determines a voltage at an output of the ESC model 182 based on the measurement of the voltage received from the probe 124 and the characteristics of the tunnel model 190, the strap model 192 and the ESC model 182.

[00114] In some embodiments, instead of using the ESC model 182 in addition to the strap model 192, the processor 184 uses the strap model 192 to determine the voltage at the output of the strap model 192 and uses the voltage to determine waveforms of voltage of plasma within the plasma chamber 123 (Figure 3A). For example, the processor 184 determines a voltage at an output of the strap model 192 based on the measurement of the voltage received from the probe 124 and the characteristics of the strap model 192.

[00115] In various embodiments, the probe 124 is coupled to any point between the x MHz RF generator and the wafer 154 (Figure 3A). For example, the probe 124 is coupled to the RF cable 134. In these embodiments, a computer-generated model of elements of the plasma system 172 between the point and the wafer 154 is generated and voltage at a computer-generated model of the ESC 127 is determined based on the voltage measured with the probe 124 and impedances of elements between the point and the wafer 154. For example, when the probe 124 is coupled to a point on the RF cable 134, a computer-

13. A method for compensating for harmonics produced during plasma processing in a plasma chamber, the method comprising:

- retrieving a measurement of a combined waveform, the combined waveform including a fundamental waveform and a harmonic waveform, the combined waveform defining a variable proximate to a surface of a chuck, the chuck coupled to a radio frequency (RF) transmission line, the RF transmission line coupled to an impedance matching circuit, the impedance matching circuit coupled to an RF generator;

- extracting the fundamental waveform from the combined waveform;

- determining a difference between a phase of the combined waveform and a phase of the fundamental waveform; and

- receiving an indication of a change to a plasma system, the change made to compensate for the difference, the plasma system including the RF transmission line, an RF cable coupling the impedance matching circuit to the RF generator, the impedance matching circuit, or a combination thereof,

- wherein the method is executed by one or more processors.

14. The method of claim 13, wherein the change to the plasma system comprises:

- a replacement of the RF transmission line with another RF transmission line;

- a replacement of the RF cable with another RF cable;

- a replacement of the impedance matching circuit with another matching circuit; or

- a combination thereof.

15. A method for performing chamber-to-chamber matching, the method comprising:

- retrieving a measurement of a combined waveform, the combined waveform including a fundamental waveform and a harmonic waveform, the combined waveform defining a voltage proximate to a surface of a chuck, the chuck coupled to a radio frequency (RF) transmission line, the RF transmission line coupled to an impedance matching circuit, the impedance matching circuit coupled to an RF generator;

- extracting the fundamental waveform from the combined waveform;

- receiving an indication of coupling another chuck to the RF transmission line;

- retrieving a measurement of another combined waveform, the other combined waveform defining a voltage proximate to a surface of the other chuck;

- determining a difference between a magnitude of the other combined waveform and a magnitude of the fundamental waveform; and

transmission line coupled to an impedance matching circuit, the impedance matching circuit coupled to an RF generator;

extracting the fundamental waveform from the combined waveform;

receiving an indication of a change in the plasma chamber from the first condition to a second condition;

retrieving a measurement of another combined waveform generated within the plasma chamber, the other combined waveform generated when the plasma chamber is in the second condition;

determining a difference between a magnitude of the other combined waveform and a magnitude of the fundamental waveform; and

controlling the RF generator to compensate for the difference,

wherein the method is executed by one or more processors.

20. The method of claim 19, wherein the second condition occurs after occurrence of the first condition.

21. The method of claim 19, wherein the second condition occurs after using the plasma chamber for processing a wafer.

22. A method for performing intra-chamber matching, the method comprising:

retrieving a measurement of a combined waveform, the combined waveform including a fundamental waveform and a harmonic waveform, the combined waveform defining a voltage proximate to a surface of a chuck of a plasma chamber in a first condition, the chuck coupled to a radio frequency (RF) transmission line, the RF transmission line coupled to an impedance matching circuit, the impedance matching circuit coupled to an RF generator;

extracting the fundamental waveform from the combined waveform;

receiving an indication of a change in the plasma chamber from the first condition to a second condition;

retrieving a measurement of another combined waveform, the other combined waveform generated when the plasma chamber is in the second condition;

determining a difference between a phase of the other combined waveform and a phase of the fundamental waveform; and