

MATCHING NETWORK DEVICE AND SYSTEM THEREOF**BACKGROUND OF THE INVENTION****1. Field of the Invention**

5 **[0001]** The present disclosure relates to a matching network device and system thereof; in particular, to a matching network device coupled between an RF generator and a plasma processing device.

2. Description of Related Art

10 **[0002]** Conventional plasma processing devices of various designs are used for performing a processing of, for example, either substrate etching or depositing a thin layer on a substrate. In a plasma processing device, semiconductor wafers or substrates are operated in a plasma chamber of, for example, high RF frequency (for example, 13.56 MHz), so as to perform a desired processing of the wafer, such as plasma etching and plasma aided chemical vapor deposition or sputtering; in a different process, the plasma
15 processing device will be filled with different special gases to perform the aforementioned processes. Thus, the plasma processing device generates different impedance values according to different special gases, wherein for a matching network device various matching impedance circuits are designed to match the impedance value of the plasma processing device, or the matching network device cannot transmit in an
20 optimal power mode an RF energy to the plasma processing device, thereby the quality of the aforementioned process is affected.

25 **[0003]** According to the impedance of an RF generator and the impedance of the plasma processing device, a general matching network device controls a motor to drive and change a shunt impedance, and a load impedance of the matching network device or a mechanical junction point is switched to change a circuit impedance, so that the RF

energy outputted by the RF generator can be transmitted in an optimal or a maximum power mode to the plasma processing device. However, such a question as the motor drive speed is too slow or a mechanical junction point is contacted badly is always confronted in prior arts, so the quality of the aforementioned process is affected.

5 SUMMARY OF THE INVENTION

[0004] The present disclosure provides a matching network device and system thereof, which can match a plasma processing device filled with different special gases, such that the RF energy outputted by an RF generator can be transmitted in an optimal or a maximum power mode through the matching network device to the plasma processing
10 device, thereby the quality of a wafer production process in a plasma processing device is enhanced.

[0005] The present disclosure provides a matching network device coupled between an RF generator and a plasma processing device, the matching network device comprises an impedance matching module, a control module and a detection module.
15 The impedance matching module is coupled between the RF generator and the plasma processing device. The control module is coupled to the impedance matching module and has a default mode. According to the impedance range of the plasma processing device, the default mode indicates a matching impedance conversion of the impedance matching module. The detection module is coupled among the control module, the RF generator
20 and the plasma processing device. The detection module detects the impedance of the RF generator and the impedance of the plasma processing device so as to output a detection signal to the control module. The control module adjusts the default mode according to the detection signal, so that the impedance matching module can transmit an RF energy outputted by the RF generator to the plasma processing device.

[0006] In an embodiment of the present disclosure, the impedance matching module comprises a first variable capacitance unit, a second variable capacitance unit and an inductance unit.

[0007] In an embodiment of the present disclosure, the first terminal of the first variable capacitance unit is coupled to the RF generator and the inductance unit, while the first terminal of the second variable capacitance unit is coupled to the plasma processing device and the inductance unit. The second terminal of the first variable capacitance unit and the second terminal of the second variable capacitance unit are coupled to a ground terminal.

[0008] In an embodiment of the present disclosure, the first terminal of the first variable capacitance unit is coupled to the RF generator and the first terminal of the second variable capacitance unit. The second terminal of the second variable capacitance unit is coupled to the inductance unit. The inductance unit is coupled to the plasma processing device, and the second terminal of the first variable capacitance unit is coupled to a ground terminal.

[0009] In an embodiment of the present disclosure, the first terminal of the first variable capacitance unit is coupled to the RF generator, the second terminal of the first variable capacitance unit is coupled to the inductance unit, the first terminal of the second variable capacitance unit is coupled to the inductance unit and the plasma processing device, and the second terminal of the second variable capacitance unit is coupled to a ground terminal.

[0010] In an embodiment of the present disclosure, the first variable capacitance unit has several capacitors and several switches, while the second variable capacitance unit has several capacitors and several switches, wherein the control module adjusts the default mode according to a detection signal, and the default mode indicates the

operations of the switches of the first variable capacitance unit, and/or the operations of the switches of the second variable capacitance unit.

[0011] In an embodiment of the present disclosure, the default mode indicates a series or a parallel state of the capacitors of the first variable capacitance unit, and/or a series or a parallel state of the capacitors of the second variable capacitance unit.

[0012] The present disclosure provides a matching network system comprising an RF generator, a plasma processing device and a matching network device. The RF generator is used for outputting an RF energy according to a default frequency. The plasma processing device is used for receiving the RF energy to perform a wafer production process. The matching network device is coupled between the RF generator and the plasma processing device.

[0013] A concrete means of the present disclosure is to use a matching network device coupled between an RF generator and a plasma processing device, wherein the control module of the matching network device controls a series and/or a parallel state of the capacitors of an impedance matching module according to a detection signal of the detection module, so that the matching network device transmits in an optimal power mode the RF energy to the plasma processing device, thereby the quality of the wafer production processing in the plasma processing device is enhanced.

[0014] For further understanding of the present disclosure, reference is made to the following detailed description illustrating the embodiments and examples of the present disclosure. The description is only for illustrating the present disclosure, not for limiting the scope of the claim.

BRIEF DESCRIPTION OF THE DRAWINGS

[0015] The drawings included herein provide further understanding of the present disclosure. A brief introduction of the drawings is as follows:

[0016] FIG. 1 shows a function block diagram of a matching network device according to an embodiment of the present disclosure;

[0017] FIG. 2 shows a circuit diagram of a matching network device according to another embodiment of the present disclosure;

5 **[0018]** FIG. 3 shows a circuit diagram of a matching network device according to another embodiment of the present disclosure;

[0019] FIG. 4 shows a circuit diagram of a matching network device according to another embodiment of the present disclosure.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

10 **[0020]** FIG. 1 shows a function block diagram of a matching network device according to an embodiment of the present disclosure. Please refer to FIG. 1. A matching network device 1 is coupled between an RF generator 8 and a plasma processing device 9, and the matching network device 1 comprises an impedance matching module 10, a control module 12 and a detection module 14. In practice, the impedance matching
15 module 10 is coupled among the RF generator 8, the plasma processing device 9 and the control module 12. The control module 12 is coupled between the impedance matching module 10 and the detection module 14. The detection module 14 is coupled among the RF generator 8, the plasma processing device 9 and the control module 12. Therefore, the detection module 14 of the matching network device 1 of the present disclosure can detect
20 the impedance of the RF generator 8 and the impedance of the plasma processing device 9, and outputs a detection signal to the control module 12, while the control module 12 adjusts the speed and stability of the matching impedance conversion of the impedance matching module 10 according to the detection signal, so as to decrease the reflection power among the RF generator 8, matching network device 1 and the plasma processing

device 9, such that a stable forward power is enhanced. The operation mode of the matching network device 1 is not limited in the present disclosure.

[0021] Specifically, the RF generator 8 is, for example, an RF power generator. The RF generator 8 outputs an RF energy to the matching network device 1 according to a default frequency, wherein the default frequency comprises for example Low Frequency (LF), Medium Frequency (MF), narrow frequency, High Frequency (HF), Very High Frequency (VHF) and Ultra High Frequency (UHF) but not limited thereto. The type of the default frequency is not limited in the present disclosure. The matching network device 1 is used for transmitting totally the RF energy generated by the RF generator 8 to the plasma processing device 9, thereby a semiconductor wafer or a substrate will be operated in the plasma processing device 9 of a plasma chamber of a default frequency, and a desired production process of the wafer is performed in different special gases.

[0022] The impedance matching module 10 is for example an LC circuit (inductance/capacitance circuit), or a matching network of L type, T type or Pi type, wherein the matching network is composed of, for example, several capacitors, several switches and inductors. The type of the impedance matching module 10 is not limited in the present embodiment. In practice, the impedance matching module 10 is used for decreasing the reflection power between the RF generator 8 and the impedance matching module 10, and also used for decreasing the reflection power between the impedance matching module 10 and the plasma processing device 9, thereby a stable forward power is enhanced, wherein the impedance matching module 10 changes, for example, the series and/or parallel states of the capacitors in the matching network, so that the impedance matching module 10 transmits totally the RF energy to the plasma processing device 9.

[0023] The control module 12 is, for example, a control chip or a control circuit composed of solid state elements such as diodes, Zener diodes, transistors, power

transistors, bipolar junction transistors, metal-oxide-semiconductor field effect transistors (MOSFETs) etc. The type of the control module 12 is not limited in the present embodiment. In practice, the control module 12 has a default mode. According to the impedance range of the plasma processing device 9, the default mode indicates a matching impedance conversion of the impedance matching module 10. In other words, the plasma processing device 9 of different impedances will have corresponding default modes, wherein the default mode is used for indicating that the impedance matching module 10 has reached a matching impedance conversion, so as to decrease the reflection power between the RF generator 8 and the impedance matching module 10 as well as the reflection power between the impedance matching module 10 and the plasma processing device 9.

[0024] To describe in detail, the impedance value of the RF generator 8 is, for example, a fixed impedance value, while the plasma processing device 9 has different impedance values according to different special gases. For example, the impedance value of the RF generator 8 is several ohms, several ten ohms or several hundred ohms, while the impedance value range of the plasma processing device 9 is several ohms to several hundred ohms, several ohms to several thousand ohms or several ohms to several ten thousand ohms. Therefore, the default mode of the control module 12 indicates a matching impedance conversion of the impedance matching module 10 according to the impedance range of the plasma processing device 9. For example, the control module 12 controls the series and/or parallel state of the capacitors in the impedance matching module 10, so that the impedance matching module 10 can transmit rapidly, stably and totally the RF energy to the plasma processing device 9.

[0025] For example, when the impedance value of the RF generator 8 is 50 ohms and the impedance value of the plasma processing device 9 is 250 ohms, the default mode

indicates the series and/or parallel states of the capacitors in the impedance matching module 10 according to the impedance value of the plasma processing device 9, so that these capacitors form a larger capacitance value. In addition, when the impedance value of the RF generator 8 is 50 ohms and the impedance value of the plasma processing device 9 is 50 ohms, the default mode indicates the series and/or parallel states of the capacitors in the impedance matching module 10 according to the impedance value of the plasma processing device 9, so that these capacitors form a smaller capacitance value, wherein either the larger or the smaller capacitance value can let the RF energy be transmitted without distortion from the RF generator 8 to the plasma processing device 9.

The impedance value of the RF generator 8, the impedance range of the plasma processing device 9 and the operation modes thereof are not limited in the present embodiment.

[0026] The detection module 14 is, for example, a resistance sensor or an impedance sensor coupled among the control module 12, the RF generator 8 and the plasma processing device 9. The type of the detection module 14 is not limited in the present embodiment. In practice, the detection module 14 is used for detecting the impedance value of the RF generator 8 and the impedance value of the plasma processing device 9. When the detection module 14 detects the impedance value of the RF generator 8 and the impedance value of the plasma processing device 9, the detection module 14 will generate a detection signal to the control module 12, so that the control module 12 can adjust automatically the default mode according to the detection signal.

[0027] It is worth mentioning that the detection module 14 can also detect a signal outside the matching network device 1, wherein the signal outside the matching network device 1 is, for example, a digital logic signal, an analog signal (0~10Vdc) or a serial communication signal. Thus, the detection module 14 can also provide such a signal to

the control module 12, so that the control module 12 can control forcedly the impedance matching module 10 to attain a specific impedance value. For example, the impedance value of the impedance matching module 10 is forced to 30 ohms, thereby the matching network device 1 is forced to attain a specific and stable matching impedance value, such that the RF generator 8 and the plasma processing device 9 attain an effect of optimal power matching mode. The type of the signal outside the matching network device 1, the size of the specific impedance value the impedance matching module 10 is forced to attain, and the operation types of the detection module 14, the control module 12 or the matching network device 1 are all not limited in the present embodiment.

10 **[0028]** For example, the detection module 14 detects the impedance value of the RF generator 8 and the impedance value of the plasma processing device 9, so as to output a detection signal to the control module 12. For example, the impedance values of the RF generator 8 and the plasma processing device 9 are 50 and 250 ohms respectively, the control module 12 adjusts automatically the default mode according to the detection signal, and the default mode indicates a connection state of the capacitors within the impedance matching module 10, so that the capacitors can form a larger capacitance value. In addition, for example, the impedance values of the RF generator 8 and the plasma processing device 9 are 50 and 50 ohms respectively, the control module 12 adjusts automatically the default mode according to the detection signal, and the default mode indicates a connection state of the capacitors in the impedance matching module 10, so that the capacitors can form a smaller capacitance value. Thus, the impedance matching module 10 can transmit in an optimal power mode the RF energy generated by the RF generator 8 to the plasma processing device 9. Therefore, the matching network device 1 can transmit in an optimal power mode the RF energy to a plasma processing

device 9 filled with different special gases, thereby the quality of a wafer production process is enhanced.

[0029] Next, a detailed operation and flow chart of the matching network device is further described.

5 **[0030]** FIG. 2 shows a circuit diagram of a matching network device 1 according to another embodiment of the present disclosure. Please refer to FIG. 2. An impedance matching module 10 comprises a first variable capacitance unit 101, a second variable capacitance unit 102 and an inductance unit 103. In practice, the first variable capacitance unit 101 has several capacitors and several switches (not shown), while the
10 second variable capacitance unit 102 has several capacitors and several switches (not shown), wherein a control module 12 adjusts a default mode according to a detection signal, and the default mode indicates, for example, the operation of the switches (not shown) of the first variable capacitance unit 101 and/or the operation of the switches (not shown) of the second variable capacitance unit 102, thereby the capacitors of the first
15 variable capacitance unit 101 form a series or a parallel state, and/or the capacitors of the second variable capacitance unit 102 form a series or a parallel state. Therefore, the impedance matching module 10 can generate a corresponding matching impedance value according to the default mode, so that the RF energy outputted by the RF generator 8 can be transmitted in an optimal power or a maximum power mode to the plasma processing
20 device 9.

[0031] To describe in detail, the first terminal 1011 of the first variable capacitance unit 101 is coupled to the RF generator 8 and the first terminal 1031 of the inductance unit 103. The first terminal 1021 of the second variable capacitance unit 102 is coupled to the plasma processing device 9 and the second terminal 1032 of the
25 inductance unit 103, while the second terminal 1012 of the first variable capacitance unit

101 and the second terminal 1022 of the second variable capacitance unit 102 are coupled to a ground terminal, wherein the first variable capacitance unit 101 and the second variable capacitance unit 102 are respectively controlled by the control module 12, as shown in FIG. 2. The type of the impedance matching module 10 is not limited in the present embodiment.

[0032] It's worth noting that the first variable capacitance unit 101, the second variable capacitance unit 102 and the inductance unit 103 are respectively energy-storing devices which stores RF energies according to a default frequency, wherein the capacitance values of the first and the second variable capacitance units 101, 102 are, for example, respectively several pico-farads, several ten pico-farads, several hundred pico-farads or several thousand pico-farads, and the switches (not shown) are, for example, transistors, power transistors, bipolar junction transistors, or metal-oxide-semiconductor field effect transistors (MOSFETs). The types of the switches (not shown) are not limited in the present embodiment. Therefore, by means of on or off of the switches (not shown), the capacitors of the first and the second variable capacitance units 101, 102 form an impedance matching module 10 of optimal power transmission. The impedance matching module 10 can match with the plasma processing device 9 filled with different special gases, so as to adjust the matching impedance, the matching impedance conversion speed and stability of the impedance matching module 10, thereby a stable forward power is enhanced for the plasma processing device 9 filled with different special gases. The operation type of the matching network device 1 is not limited in the present embodiment.

[0033] FIG. 3 shows a circuit diagram of a matching network device according to another embodiment of the present disclosure. Please refer to FIG. 3. The matching network device 1a of the present embodiment is similar to the matching network device 1 of the previous embodiments. For example, when the detection module 14 detects the

impedance of the RF generator 8 and the impedance of the plasma processing device 9, the detection module 14 generates a detection signal and outputs it to the control module 12. The control module 12 adjusts a default mode according to the detection signal, such that the impedance matching module 10a can attain an optimal power or a maximum power transmission mode, so as to transmit the RF energy to the plasma processing device 9.

[0034] However, there still exists difference between the matching network device 1a and 1, and the difference consists in that the first terminal 1011a of the first variable capacitance unit 101a is coupled to the RF generator 8 and the first terminal 1021a of the second variable capacitance unit 102a, the second terminal 1022a of the second variable capacitance unit 102a is coupled to the first terminal 1031a of the inductance unit 103a, the second terminal 1032a of the inductance unit 103a is coupled to the plasma processing device 9, and the second terminal 1012a of the first variable capacitance unit 101a is coupled to a ground terminal, wherein the first variable capacitance unit 101a and the second variable capacitance unit 102a are respectively controlled by a control module 12, as shown in FIG. 3. The type of the impedance matching module 10a is not limited in the present embodiment.

[0035] Except the difference described above, if a person skilled in the art refers to the above embodiments and the difference, other embodiments can be easily inferred and will not be described herein.

[0036] FIG. 4 shows a circuit diagram of a matching network device according to another embodiment of the present disclosure. The matching network device 1b of the present embodiment is similar to the matching network device 1 of the previous embodiments. However, there still exists difference between the matching network device 1b and 1, and the difference consists in that the first terminal 1011b of the first

variable capacitance unit 101b is coupled to the RF generator 8, the second terminal 1012b of the first variable capacitance unit 101b is coupled to the first terminal 1031b of the inductance unit 103b, the first terminal 1021b of the second variable capacitance unit 102b is coupled to the second terminal 1032b of the inductance 103b and the plasma processing device 9, and the second terminal 1022b of the second variable capacitance unit 102b is coupled to a ground terminal, wherein the first variable capacitance unit 101b and the second variable capacitance unit 102b are respectively controlled by a control module 12. The type of the impedance matching module 10b is not limited in the present embodiment.

10 **[0037]** Except the difference described above, if a person skilled in the art refers to the above embodiments and the difference, other embodiments can be easily inferred and will not be described herein.

15 **[0038]** On the basis of the above, the present disclosure discloses a matching network device coupled between an RF generator and a plasma processing device. When a detection module detects the impedance of the RF generator and the impedance of the plasma processing device, a detection signal is outputted to a control module. The control module adjusts a default mode according to the detection signal, wherein the default mode indicates the matching impedance, the matching impedance conversion speed or the matching impedance conversion stability of the impedance matching module according to the impedance range of the plasma processing device, so that the impedance matching module can transmit the RF energy generated by the RF generator to the plasma processing device. In addition, the first and the second variable capacitance units of the impedance matching module have respectively several capacitors and several switches, wherein the control module adjusts a default mode according to a detection signal, and the default mode indicates a series or a parallel state of the capacitors of the first variable

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capacitance unit, and/or a series or a parallel state of the capacitors of the second variable capacitance unit. In such a manner, the matching network device can really enhance the quality of wafer production process in a plasma processing device, and different special gases are suitable to be filled into the plasma processing device to attain an effect of wafer
5 production.

[0039] Some modifications of these examples, as well as other possibilities will, on reading or having read this description, or having comprehended these examples, occur to those skilled in the art. Such modifications and variations are comprehended within this disclosure as described here and claimed below. The description above
10 illustrates only a relative few specific embodiments and examples of the present disclosure. The present disclosure, indeed, does include various modifications and variations made to the structures and operations described herein, which still fall within the scope of the present disclosure as defined in the following claims.

CLAIMS:

1. A matching network device, coupled between an RF generator and a plasma processing device, comprising:

an impedance matching module, coupled between the RF generator and
5 the plasma processing device;

a control module, coupled to the impedance matching module and having
a default mode, wherein the default mode indicates a matching impedance
conversion of the impedance matching module according to an impedance
range of the plasma processing device; and

10 a detection module, coupled among the control module, the RF generator
and the plasma processing device;

wherein the detection module detects the impedance of the RF generator
and the impedance of the plasma processing device, so as to output a detection
signal to the control module, and the control module adjusts the default mode
15 according to the detection signal, so that the impedance matching module
transmits an RF energy outputted by the RF generator to the plasma processing
device.

2. The matching network device according to claim 1, wherein the impedance
20 matching module comprises a first variable capacitance unit, a second variable
capacitance unit and an inductance unit.

3. The matching network device according to claim 2, wherein the first terminal
of the first variable capacitance unit is coupled to the RF generator and the
25 inductance unit, the first terminal of the second variable capacitance unit is

coupled to the plasma processing device and the inductance unit, and the second terminal of the first variable capacitance unit and the second terminal of the second variable capacitance unit are coupled to a ground terminal.

- 5 4. The matching network device according to claim 2 or 3, wherein the first terminal of the first variable capacitance unit is coupled to the RF generator and the first terminal of the second variable capacitance unit, the second terminal of the second variable capacitance unit is coupled to the inductance unit, the inductance unit is coupled to the plasma processing device, and the second
- 10 terminal of the first variable capacitance unit is coupled to a ground terminal.
5. The matching network device according to any of the preceding claims 2 to 4, wherein the first terminal of the first variable capacitance unit is coupled to the RF generator, the second terminal of the first variable capacitance unit is
- 15 coupled to the inductance unit, the first terminal of the second variable capacitance unit is coupled to the inductance unit and the plasma processing device, and the second terminal of the second variable capacitance unit is coupled to a ground terminal.
- 20 6. The matching network device according to any of the preceding claims 2 to 5, wherein the first variable capacitance unit has several capacitors and several switches, and the second variable capacitance unit has several capacitors and several switches, wherein the control module adjusts the default mode according to the detection signal, and the default mode indicates the operation

of the switches of the first variable capacitance unit, and/or the operation of the switches of the second variable capacitance unit.

7. The matching network device according to any of the preceding claims 2 to 6,
5 wherein the default mode indicates a series or a parallel state of the capacitors of the first variable capacitance unit, and/or a series or a parallel state of the capacitors of the second variable capacitance unit.

8. A matching network system, comprising:

10 an RF generator, for outputting an RF energy according to a default frequency;

a plasma processing device, for receiving the RF energy to perform a wafer production process; and

15 a matching network device, coupled between the RF generator and the plasma processing device, the matching network device comprising:

an impedance matching module, coupled between the RF generator and the plasma processing device;

20 a control module, coupled to the impedance matching module and having a default mode, wherein the default mode indicates a matching impedance conversion of the impedance matching module according to an impedance range of the plasma processing device; and

a detection module, coupled among the control module, the RF generator and the plasma processing device;

25 wherein the detection module detects the impedance of the RF generator and the impedance of the plasma processing device, so as to

output a detection signal to the control module, and the control module adjusts the default mode according to the detection signal, so that the impedance matching module transmits an RF energy outputted by the RF generator to the plasma processing device.

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9. The matching network system according to claim 8, wherein the impedance matching module comprises a first variable capacitance unit, a second variable capacitance unit and an inductance unit.

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10. The matching network system according to claim 9, wherein the first variable capacitance unit has several capacitors and several switches, and the second variable capacitance unit has several capacitors and several switches, wherein the control module adjusts the default mode according to the detection signal, and the default mode indicates the operation of the switches of the first variable capacitance unit, and/or the operation of the switches of the second variable capacitance unit, so that the capacitors of the first variable capacitance unit form a series or a parallel state, and/or the capacitors of the second variable capacitance unit form a series or a parallel state.

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