

Description

A semiconductor processing device

5 **Technical field**

The present invention relates to the technical field of semiconductor manufacturing, and in particular to a semiconductor processing device comprising a radio-frequency system.

10 **Background**

Thin film deposition technology is used to manufacture thin films for microelectronic devices, forming deposits on a substrate. Common thin film deposition technologies include physical vapor deposition, chemical vapor deposition, and the like. As semiconductor technology nodes continue to develop, in the semiconductor field, thin film deposition is a crucial process that directly affects the performance and reliability of semiconductor devices. The process parameters for thin film deposition include substrate temperature, gas flow rate, pressure, power, etc. The selection and control of these parameters directly affect the quality and performance of the thin film. However, there are mutual influences and constraints among the process parameters of thin film deposition, so they require precise control and adjustment.

Semiconductor processing devices that perform plasma processing on semiconductor wafers, such as PECVD (Plasma Enhanced Chemical Vapor Deposition) processes, are often referred to as radio-frequency (RF) systems. Such systems include radio-frequency control circuits, whose core function is to provide radio-frequency signals to electrodes of the semiconductor processing device. These signals generate an electric field in a specific processing region within the processing chamber. When the reaction gas is ionized under the influence of the electric field, it reacts with the wafer to be processed, and these reactions may involve processes such as etching or deposition.

In a semiconductor processing device of the prior art, for example, a 4.6 GHz

PECVD radio-frequency system, radio-frequency power is introduced from a shower plate. Fig. 1 shows a schematic principle diagram of a semiconductor processing device in the prior art. The semiconductor processing device 100 shown in Fig. 1 is a device for performing semiconductor process treatments, comprising at least main components such as a reaction chamber 101, a shower plate 102, a heating plate 104, an radio-frequency power supply 105, and a heating plate radio-frequency electrode 106.

The reaction chamber 101 is a sealed chamber capable of providing a stable process environment for a substrate 103 to be processed.

The shower plate 102 is located inside the reaction chamber 101 and is used to supply reaction gas to the substrate 103 to be processed. During device operation, the reaction gas is sprayed onto the substrate to be processed through the shower plate 102, causing it to undergo a chemical reaction with materials on the surface of the substrate 103 to be processed, thereby achieving the purpose of process treatment.

The design of the shower plate 102 also considers the flow and distribution of the gas to ensure that the gas can uniformly cover the entire surface of the substrate 103 to be processed.

The heating plate 104 is another important component, located below the shower plate 102, and can provide a suitable heating environment for the substrate 103 to be processed, enabling the substrate 103 to be processed to reach the temperature required for the process. This heating method can achieve efficient and uniform heat distribution and ensure the thermal stability and reliability of the substrate 103 to be processed.

To enhance the efficiency and stability of the process treatment, the semiconductor processing device 100 also adopts the design of an radio-frequency power supply 105 and a heating plate radio-frequency electrode 106. The radio-frequency power supply 105 provides radio-frequency power to the shower plate 102 via an radio-frequency matcher, and forms an electric field between the shower plate 102 and the heating plate 104. This electric field can promote the chemical reaction of the reaction gas on the surface of the substrate to be processed and control the reaction rate and effect.

As shown in the radio-frequency loop of Fig. 1, the radio-frequency signal emitted by the radio-frequency power supply 105 returns to the radio-frequency power supply 105 via the shower plate 102, the substrate 103 to be processed, the heating plate radio-frequency electrode 106, and the sidewall of the reaction chamber. The components of this circuit together constitute the radio-frequency loop, allowing radio-frequency power to flow between the shower plate 102 and the heating plate 104 and take effect.

Radio-frequency power is introduced from the shower plate 102. Since there is a first impedance $Z1$ between the heating plate radio-frequency electrode 106 and ground, and a second impedance $Z2$ between the sidewall of the reaction chamber 101 and ground, influenced by the first impedance $Z1$ and the second impedance $Z2$, the current flowing through various parts of the substrate 103 to be processed is not uniform. Therefore, the film formation quality on the substrate 103 to be processed is affected.

Summary

The purpose of the present invention is to provide a semiconductor processing device, which solves the problem of film formation quality on a substrate to be processed caused by the radio-frequency (radio-frequency) system of semiconductor processing devices in the prior art.

To achieve the above purpose, the present invention provides a semiconductor processing device, comprising at least a reaction chamber, a radio-frequency receiving electrode, and a radio-frequency emitting electrode:

the radio-frequency receiving electrode is arranged at an upper part inside the reaction chamber;

the radio-frequency emitting electrode is arranged at a lower part inside the reaction chamber, and is used for emitting a radio-frequency power signal towards the upper part of the reaction chamber.

In one embodiment, the semiconductor processing device further comprises a shower plate, wherein the radio-frequency receiving electrode is arranged within the shower plate.

In one embodiment, the semiconductor processing device further comprises a substrate support apparatus, wherein the radio-frequency emitting electrode is arranged within the substrate support apparatus.

5 In one embodiment, the semiconductor processing device further comprises an adapter structure and a matcher structure:

the adapter structure is arranged below the substrate support apparatus, connected to the substrate support apparatus, and is internally provided with a plurality of filters for processing an input radio-frequency power signal and then sending the radio-frequency power signal to a heating plate;

10 the matcher structure is connected to the adapter structure, comprises a matcher and a radio-frequency power supply, and is used for inputting the radio-frequency power signal to the adapter structure.

In one embodiment, the semiconductor processing device further comprises a radio-frequency connection structure, arranged at a bottom of the substrate support apparatus, and internally provided with a radio-frequency circuit;

one end of the radio-frequency circuit is connected to the radio-frequency emitting electrode, and the other end is connected to the adapter structure.

In one embodiment, the adapter structure and the radio-frequency connection structure are directly connected via a connector.

20 In one embodiment, a heating unit is installed inside the substrate support apparatus for heating a heating plate;

the radio-frequency connection structure is internally provided with a heating circuit, one end of which is connected to the heating unit, and the other end is connected to the adapter structure.

25 In one embodiment, an electrostatic chuck electrode is installed inside the substrate support apparatus for fixing a substrate to be processed by electrostatic adsorption;

the radio-frequency connection structure is internally provided with an electrostatic chuck circuit, one end of which is connected to the electrostatic chuck electrode, and the other end is connected to the adapter structure.

In one embodiment, the adapter structure and the matcher structure are directly

connected via a connector.

In one embodiment, the adapter structure is internally provided with an alternating current filter, one end of which is connected to the heating circuit, and the other end is connected to the matcher structure;

5 the matcher structure supplies the alternating current filter with alternating current, which is filtered by the alternating current filter and then transmitted to the heating unit inside the substrate support apparatus for heating the substrate support apparatus.

10 In one embodiment, the adapter structure is internally provided with an electrostatic chuck filter, one end of which is connected to the electrostatic chuck circuit, and the other end is connected to the matcher structure;

15 the matcher structure supplies the electrostatic chuck filter with direct current, which is processed by the electrostatic chuck filter and then transmitted to the electrostatic chuck electrode inside the substrate support apparatus for adsorbing the substrate to be processed.

In one embodiment, the adapter structure is internally provided with a temperature control filter, one end of which is connected to a temperature control circuit, and the other end is connected to the matcher structure;

20 the temperature control circuit is arranged inside the radio-frequency connection structure, with one end arranged inside the substrate support apparatus for collecting temperature information of the substrate support apparatus, which is then transmitted to the matcher structure after passing through the temperature control filter;

25 the matcher structure changes the alternating current output power according to the collected temperature information to adjust the heating power, thereby achieving feedback control of the temperature of the substrate support apparatus.

In one embodiment, the matcher structure further comprises a power divider for dividing power among multiple radio-frequency signals.

In one embodiment, the adapter structure further comprises a radio-frequency switch for switching among multiple radio-frequency signals.

30 The semiconductor processing device proposed by the present invention, by introducing radio-frequency power from the bottom of the heating plate in the

reaction chamber and adopting a method of directly connecting the connector to the matcher, achieves a significant increase in the deposition rate on the substrate to be processed, while effectively controlling the consistency of the current flowing through the substrate to be processed, thereby improving process uniformity and stability.

Brief Description of the Drawings

The above and other features, characteristics, and advantages of the present invention will become more apparent from the following description in conjunction with the drawings and embodiments. In the drawings, the same reference numerals consistently denote the same features, wherein:

Fig. 1 shows a schematic principle diagram of a semiconductor processing device in the prior art;

Fig. 2 shows a partial structural schematic diagram of a semiconductor processing device according to one embodiment of the present invention;

Fig. 3 shows a partial schematic principle diagram of a semiconductor processing device according to one embodiment of the present invention;

Fig. 4 shows thickness curve diagrams for semiconductor processing devices in the prior art and according to one embodiment of the present invention.

The meanings of the symbols marked in the figure are as follows:

100: semiconductor processing device;

101: reaction chamber;

102: shower plate;

103: substrate to be processed;

104: heating plate;

105: radio-frequency power supply;

106: heating plate radio-frequency electrode;

200: heating plate;

201: radio-frequency emitting electrode;

202: heating unit;

203: electrostatic chuck electrode;
210: radio-frequency connection structure;
211: radio-frequency circuit;
212: heating circuit;
5 213: electrostatic chuck circuit;
214: temperature control circuit;
300: adapter structure;
301: alternating current filter;
302: temperature control filter;
10 303: electrostatic chuck filter;
400: matcher structure.

Detailed Description

15 In order to make the objectives, technical solutions, and advantages of the present invention clearer, the following further describes the present invention in detail with reference to the accompanying drawings and embodiments. It should be understood that the specific embodiments described herein are only used to explain the invention and are not intended to limit the invention.

The present invention proposes a semiconductor processing device, comprising
20 at least a reaction chamber, a radio-frequency receiving electrode, and a radio-frequency emitting electrode:

the reaction chamber provides a process environment for a substrate to be processed;

25 the radio-frequency receiving electrode is arranged at an upper part inside the reaction chamber;

the radio-frequency emitting electrode is arranged at a lower part inside the reaction chamber, and is used for emitting a radio-frequency power signal towards the upper part of the reaction chamber.

Furthermore, the semiconductor processing device also includes a shower plate,
30 arranged at the upper part inside the reaction chamber, for supplying reaction gas to the substrate to be processed, wherein the radio-frequency receiving electrode is

arranged within the shower plate.

Furthermore, the semiconductor processing device also includes a substrate support apparatus for supporting the substrate to be processed, wherein the radio-frequency emitting electrode is arranged within the substrate support apparatus.

5 Furthermore, the semiconductor processing device also includes an adapter structure and a matcher structure:

the adapter structure is connected to the matcher structure, and is internally provided with a plurality of filters for processing an radio-frequency signal input from the matcher structure and then sending it to the substrate support apparatus;

10 the matcher structure comprises a matcher and an radio-frequency power supply, and provides an radio-frequency power signal to the substrate support apparatus through the adapter structure.

The design of the reaction chamber and the shower plate can refer to the prior art shown in Fig. 1, which will not be repeated here.

15 Fig. 2 shows a partial structural diagram of a semiconductor processing device according to one embodiment of the present invention. In the embodiment shown in Fig. 2, the substrate support apparatus is a heating plate 200. The heating plate 200 is internally provided with a radio-frequency emitting electrode 201, which is connected to the adapter structure 300 below.

20 The adapter structure 300 is connected to the matcher structure 400, and internally provided with a plurality of filters for processing an radio-frequency signal input from the matcher structure 400 and then sending the radio-frequency signal to the heating plate 200.

The matcher structure 400 comprises the matcher and the radio-frequency power supply, and provides a radio-frequency power signal to the heating plate 200 through the adapter structure 300, introducing the radio-frequency power from the bottom of the heating plate 200 can, on one hand, significantly increase the deposition rate on the substrate to be processed, and on the other hand, more effectively control the consistency of the current flowing through the substrate to be processed, thereby
30 improving process uniformity and stability.

Fig. 3 shows a partial schematic principle diagram of a semiconductor

processing device according to one embodiment of the present invention. As shown in Fig. 3, a radio-frequency emitting electrode 201 is installed inside the heating plate 200, which function as an radio-frequency electrode plate.

5 A heating unit 202 is installed inside the heating plate 200 and may heat the heating plate 200.

In some cases, to avoid the issue of impedance changes causing the heating unit 202 to malfunction, a plurality of heating units 202 may be arranged below the heating plate. Thus, even if one heating unit 202 fails, it will not affect the operation of the entire system.

10 The heating plate 200 has an electrostatic chuck electrode 203 installed therein, for fixing the substrate to be processed by means of electrostatic adsorption.

ESC (electrostatic chuck), also known as an electrostatic suction chuck, is now widely used in semiconductor processes in plasma and vacuum environments, such as etching, chemical vapor deposition, ion implantation, etc. During wafer processing,
15 it mainly serves to provide support for the backside of the wafer and ensure its fixation by electrostatic adsorption.

The semiconductor processing device proposed by the present invention also includes a radio-frequency connection structure 210, arranged at the bottom of the heating plate 200.

20 In this embodiment, the radio-frequency connection structure 210 is internally provided with a radio-frequency circuit 211.

One end of the radio-frequency circuit 211 is connected to the radio-frequency emitting electrode 201, and the other end is connected to the adapter structure 300.

In this embodiment, the radio-frequency connection structure 210 is internally
25 provided with a heating circuit 212.

One end of the heating circuit 212 is connected to the heating unit 202, and the other end is connected to the adapter structure 300.

In this embodiment, the radio-frequency connection structure 210 is internally provide with an electrostatic chuck circuit 213.

30 One end of the electrostatic chuck circuit 213 is connected to the electrostatic chuck electrode 203, and the other end is connected to the adapter structure 300.

In this embodiment, the adapter structure 300 is internally provide with an alternating current filter 301.

One end of the alternating current filter 301 is connected to the heating circuit 212, and the other end is connected to the matcher structure 400.

5 The matcher structure 400 supplies the alternating current filter 301 with alternating current, which is filtered by the alternating current filter 301 and then transmitted to the heating unit 202 inside the heating plate 200 for heating the heating plate 200.

10 In this embodiment, the adapter structure 300 is internally provide with a temperature control (TC) filter 302.

One end of the temperature control filter 302 is connected to a temperature control circuit 214, and the other end is connected to the matcher structure 400.

15 The temperature control circuit 214 is arranged inside the radio-frequency connection structure 210, with one end connected inside the heating plate 200 for collecting temperature information of the heating plate 200, which is transmitted to the matcher structure 400 after passing through the temperature control filter 302.

The matcher structure 400 changes the alternating current output power according to the collected temperature information to adjust the heating power, thereby achieving feedback control of the temperature of the heating plate.

20 In this embodiment, the adapter structure 300 is internally provide with an electrostatic chuck filter 303.

One end of the electrostatic chuck (ESC) filter 303 is connected to the electrostatic chuck circuit 213, and the other end is connected to the matcher structure 400.

25 The matcher structure 400 supplies the electrostatic chuck filter 303 with direct current, which is processed by the electrostatic chuck filter 303 and then transmitted to the electrostatic chuck electrode 203 inside the heating plate 200 for adsorbing the substrate to be processed.

30 In some embodiments, the alternating current filter 301, the temperature control (TC) filter 302, and the electrostatic chuck filter 303 are combined. This design facilitates user maintenance and replacement of the filter set. In other embodiments,

the alternating current filter 301, the temperature control (TC) filter 302, and the electrostatic chuck filter 303 are separate parts, allowing users to use or replace them according to their needs. This design is more flexible and convenient.

When there are multiple radio-frequency circuits 211, the matcher structure 400 further comprises a power divider for dividing power among the multiple radio-frequency signals.

When there are multiple radio-frequency circuits 211, the adapter structure 300 further comprises a radio-frequency switch for switching among the multiple radio-frequency signals.

In this embodiment, the matcher structure 400 comprises a matcher and an radio-frequency power supply:

the matcher is used for matching the impedance of the radio-frequency loop;

the radio-frequency power supply is used for providing an radio-frequency power signal, and provides the radio-frequency power to the heating plate 200 through the matcher and the adapter structure 300.

As shown in Fig. 3, the heating plate 200 is structurally connected to the matcher structure 400 via the adapter structure 300, avoiding connection through cables, which can improve the stability of the radio-frequency circuit.

More specifically, the radio-frequency connection structure 210 at the bottom of the heating plate 200 is directly connected with the adapter structure 300 via a connector.

The adapter structure 300 and the matcher structure 400 are directly connected via a connector.

The adapter structure 300 includes alternating current connection structures and radio-frequency connection structures, which can be used for various different applications. Corresponding connectors can be rigid connectors. Rigid connectors may include copper material or other similar conductive materials, substantially cylindrical in shape, and can effectively ensure the transmission quality and stability of the signal.

Through the connection of the radio-frequency connection structure 210 at the bottom of the heating plate 200 with the adapter structure 300, the alternating current

filters and the like within the adapter structure 300 can move up and down together with the heating plate 200, avoiding impedance changes caused by relative motion.

For the purpose of simplifying the description, Figs. 2 and 3 only show some structures of the semiconductor processing device. Those skilled in the art should understand that the semiconductor processing device may also include other components not shown. Moreover, the specific sizes, shapes, positions, etc. of the structures shown in Figs. 2 and 3 are only for illustrative purposes and are not limiting.

Fig. 4 shows thickness curve diagrams for semiconductor processing devices in the prior art and according to one embodiment of the present invention. The left curve in Fig. 4 represents the film thickness curve of a substrate to be processed of a semiconductor processing device of the prior art, where the radio-frequency signal is input from the shower plate, the film thickness of the substrate on a first side (side1) is 1041 ± 17 (Angstrom), and the film thickness of the substrate on a second side (side2) is 1180 ± 3 (A). The right curve in Fig. 4 represents the film thickness curve of a substrate to be processed of a semiconductor processing device according to one embodiment of the present invention, where the radio-frequency signal is input from the heating plate, the film thickness of the substrate on the first side (side1) is 1455 ± 3 (A), and the film thickness of the substrate on the second side (side2) is 1563 ± 1 (A). Compared to the prior art, the semiconductor processing device proposed by the present invention produces film thickness that is more uniform and of higher quality stability.

The semiconductor processing device proposed by the present invention, by introducing radio-frequency power from the bottom of the heating plate in the reaction chamber and adopting a method of directly connecting the connector to the matcher, achieves a significant increase in the deposition rate on the substrate to be processed, while effectively controlling the consistency of the current flowing through the substrate to be processed, thereby improving process uniformity and stability. This device can be widely used in 3D semiconductor processing processes, atomic layer deposition processes, plasma-enhanced chemical vapor deposition processes, or other similar processes. For example, the device of the present invention can be applied to plasma vapor deposition equipment with radio-frequency systems

of various operating frequencies, exhibiting excellent performance and reliability.

As used in this application and the claims, unless the context clearly indicates an exception, the terms "a," "an," "the," and/or "said" do not specifically refer to the singular but may also include the plural. Generally speaking, the terms "comprising" and "including" merely indicate the inclusion of explicitly identified steps and elements, which do not constitute an exhaustive list, and methods or devices may also include other steps or elements.

In the description of the present invention, it should be noted that terms indicating orientation or positional relationships, such as "upper," "lower," "front," "rear," "left," "right," "vertical," "inner," "outer," etc., are based on the orientation or positional relationships shown in the drawings. They are only for the convenience of describing the present invention and simplifying the description, and do not indicate or imply that the referred device or element must have a specific orientation, be constructed and operated in a specific orientation. Therefore, they should not be construed as limiting the present invention.

In the present invention, unless otherwise explicitly specified and defined, a first feature being "on" or "under" a second feature may include direct contact between the first and second features, or may include contact between the first and second features not directly but through another feature between them. Moreover, a first feature being "above," "over," and "on" a second feature includes the first feature being directly above and obliquely above the second feature, or merely indicates that the horizontal height of the first feature is greater than that of the second feature. A first feature being "below," "beneath," and "under" a second feature includes the first feature being directly below and obliquely below the second feature, or merely indicates that the horizontal height of the first feature is less than that of the second feature.

In the description of the present invention, it should be noted that, unless otherwise explicitly specified and defined, the terms "installed," "connected," and "coupled" should be understood in a broad sense. For example, they may be fixed connections, detachable connections, or integral connections; they may be direct connections, or indirect connections through an intermediary, or internal

communications between two elements. Those of ordinary skill in the art can understand the specific meanings of the above terms in the present invention based on specific situations.

The above embodiments are provided to enable persons skilled in the art to make or use the present invention. Persons skilled in the art can make various modifications or changes to the above embodiments without departing from the inventive concept of the present invention. Therefore, the scope of protection of the present invention is not limited by the above embodiments, but should conform to the broadest scope of the innovative features mentioned in the claims.

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Claims

1. A semiconductor processing device, comprising at least a reaction chamber, a radio-frequency receiving electrode, and a radio-frequency emitting electrode:

5 the radio-frequency receiving electrode is arranged at an upper part inside the reaction chamber;

 the radio-frequency emitting electrode is arranged at a lower part inside the reaction chamber, and is used for emitting a radio-frequency power signal towards the upper part of the reaction chamber.

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2. The semiconductor processing device of claim 1, further comprising a shower plate, wherein the radio-frequency receiving electrode is arranged within the shower plate.

15 3. The semiconductor processing device of claim 1, further comprising a substrate support apparatus, the radio-frequency emitting electrode is arranged within the substrate support apparatus.

20 4. The semiconductor processing device of claim 3, further comprising an adapter structure and a matcher structure:

 the adapter structure is arranged below the substrate support apparatus, connected to the substrate support apparatus, and is internally provided with a plurality of filters for processing an input radio-frequency power signal and then sending the radio-frequency power signal to a heating plate;

25 the matcher structure is connected to the adapter structure, comprises a matcher and a radio-frequency power supply, and is used for inputting the radio-frequency power signal to the adapter structure.

30 5. The semiconductor processing device of claim 4, further comprising a radio-frequency connection structure, which is arranged at a bottom of the substrate support apparatus, and internally provided with a radio-frequency circuit;

one end of the radio-frequency circuit is connected to the radio-frequency emitting electrode, and the other end is connected to the adapter structure.

5 6. The semiconductor processing device of claim 5, wherein the adapter structure and the radio-frequency connection structure are directly connected via a connector.

7. The semiconductor processing device of claim 5, wherein a heating unit is installed inside the substrate support apparatus for heating a heating plate;
10 the radio-frequency connection structure is internally provided with a heating circuit, one end of which is connected to the heating unit, and the other end is connected to the adapter structure.

8. The semiconductor processing device of claim 5, wherein an electrostatic
15 chuck electrode is installed inside the substrate support apparatus for fixing a substrate to be processed by electrostatic adsorption;
the radio-frequency connection structure is internally provided with an electrostatic chuck circuit, one end of which is connected to the electrostatic chuck electrode, and the other end is connected to the adapter structure.

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9. The semiconductor processing device of claim 4, wherein the adapter structure and the matcher structure are directly connected via a connector.

10. The semiconductor processing device of claim 7, wherein the adapter
25 structure is internally provided with an alternating current filter, one end of which is connected to the heating circuit, and the other end is connected to the matcher structure;

the matcher structure supplies the alternating current filter with alternating current, which is filtered by the alternating current filter and then transmitted to the
30 heating unit inside the substrate support apparatus for heating the substrate support apparatus.

11. The semiconductor processing device of claim 8, wherein the adapter structure is internally provided with an electrostatic chuck filter, one end of which is connected to the electrostatic chuck circuit, and the other end is connected to the
5 matcher structure;

the matcher structure supplies the electrostatic chuck filter with direct current, which is processed by the electrostatic chuck filter and then transmitted to the electrostatic chuck electrode inside the substrate support apparatus for adsorbing the substrate to be processed.

12. The semiconductor processing device of claim 7, wherein the adapter structure is internally provided with a temperature control filter, one end of which is connected to a temperature control circuit, and the other end is connected to the
10 matcher structure;

15 the temperature control circuit is arranged inside the radio-frequency connection structure, with one end arranged inside the substrate support apparatus for collecting temperature information of the substrate support apparatus, which is then transmitted to the matcher structure after passing through the temperature control filter;

the matcher structure changes the alternating current output power according to
20 the collected temperature information to adjust the heating power, thereby achieving feedback control of the temperature of the substrate support apparatus.

13. The semiconductor processing device of claim 4, wherein the matcher structure further comprises a power divider for dividing power among multiple radio-
25 frequency signals.

14. The semiconductor processing device of claim 4, wherein the adapter structure further comprises a radio-frequency switch for switching among multiple radio-frequency signals.