

GAS FLOW REGULATING STRUCTURE AND GAS FLOW REGULATING METHOD

FIELD OF THE INVENTION

The present application relates to the field of semiconductor manufacturing equipment, and in particular, relates to a gas flow regulating structure and a gas flow regulating method.

BACKGROUND

In chemical vapor deposition (CVD) equipment, various dielectric thin films are deposited on the surface of a substrate during the manufacturing process. The thickness uniformity of thin films is one of the critical process parameters, which directly affects the performance characteristics of thin films and the product yield. To satisfy the continuous demands of the present semiconductor industry for high quality, high efficiency, low cost, and compatibility with large-size substrate processes, it is particularly important to improve the uniformity of thin film deposition on the substrate.

During the thin film deposition process, the uniformity of gas flow exerts a significant impact on the uniformity of thin film deposition on the substrate. For example, gas flow regulation is required to improve thin film thickness uniformity in the following application scenarios:

1. Due to manufacturing tolerances and other factors, a heating tray fails to be positioned at the exact center of a processing chamber, which causes nonuniform circumferential distribution of gas flow and further affects the film thickness at the edge of the substrate.

2. Affected by uncontrollable gas flow factors, the film thickness at the edge of the substrate presents a nonuniform state, and thus gas flow regulation is required to adjust the thickness of thin films at the edge of the substrate.

Therefore, it is of vital importance to design a structure capable of regulating gas flow in a simple and rapid manner.

SUMMARY

The objective of the present invention is to provide a gas flow regulating structure, so as to solve the problem existing in the prior art that gas flow cannot be regulated in a simple and rapid manner.

To achieve the foregoing objective and other related objectives, the present invention provides a gas flow regulating structure applied to a thin film deposition apparatus. The thin film deposition apparatus comprises a processing chamber and a heating tray. The gas flow regulating structure comprises a first regulating ring arranged to surround a substrate and a second regulating ring arranged to surround the first regulating ring. The outer circle of the first regulating ring is coincident with the inner circle of the second regulating ring. The inner circle and the outer circle of each of the first regulating ring and the second regulating ring are arranged in an eccentric manner. And the distance between the center of the inner circle and the center of the outer circle of the first regulating ring is equal to the distance between the center of the inner circle and the center of the outer circle of the second regulating ring.

Preferably, the distance L1 between the center of the inner circle and the center of the outer circle satisfies the range of $0 \text{ millimeter} < L1 < 20 \text{ millimeters}$.

Preferably, the distance L1 between the center of the inner circle and the center of the outer circle is 2 millimeters.

Preferably, the gas flow regulating structure further comprises supporting members. The supporting members are installed inside openings formed at the top of the heating tray, and are configured to support the first regulating ring above the heating tray. The outer edge of the first regulating ring is provided with a shelf portion extending downward from the upper surface of the first regulating ring, and the shelf portion is configured to support the second regulating ring.

Preferably, the shelf portion is a bevel edge or a step structure.

Preferably, a plurality of positioning holes are uniformly arranged along the circumferential direction at the bottom of the first regulating ring, and the top ends of

the supporting members are placed inside the positioning holes.

Preferably, both the first regulating ring and the second regulating ring are made of dielectric materials.

The present invention further provides a gas flow regulating method adopting the above-mentioned gas flow regulating structure. The gas flow regulating method comprises the following steps:

rotating the first regulating ring and the second regulating ring until the center of the outer circle of the first regulating ring is coincident with the center of the inner circle of the second regulating ring, and then performing thin film deposition on the substrate;

when nonuniform thin film deposition occurs on the substrate, rotating the second regulating ring to reduce the gas gap between the second regulating ring and the inner wall of the processing chamber corresponding to a region with a slightly thick thin film.

Preferably, before rotating the second regulating ring, the first regulating ring is rotated to drive the second regulating ring to rotate, so as to reduce the gas gap between the first regulating ring and the inner wall of the processing chamber corresponding to a region with a slightly thick thin film.

Preferably, the rotation angle of the first regulating ring is an integral multiple of 360 degrees divided by N, wherein N represents the quantity of the positioning holes uniformly arranged along the circumferential direction at the bottom of the first regulating ring.

The present invention further provides a gas flow regulating method adopting the above-mentioned gas flow regulating structure. The gas flow regulating method comprises the following steps:

before performing thin film deposition on the substrate, measuring the concentricity between the heating tray and the processing chamber;

when the heating tray is not concentric with the processing chamber, adjusting the

position of the first regulating ring and/or the second regulating ring to reduce the gas gap between the second regulating ring and the inner wall of the processing chamber at the position where the gas gap between the heating tray and the processing chamber is the largest.

The present invention further provides a gas flow regulating method adopting the above-mentioned gas flow regulating structure, comprising: when nonuniform thin film deposition occurs on the substrate, adjusting the height of the supporting members to change the gas gap between the first regulating ring and the heating tray.

As described above, the gas flow regulating structure provided by the present invention has the following beneficial effects. Two regulating rings with eccentrically arranged inner circles and outer circles are arranged around the substrate. In accordance with the non-uniformity of a thin film at the edge of the substrate, the relative position of the two regulating rings can be adjusted to change the gas gap between the inner wall of the processing chamber and the regulating rings, so as to adjust the gas flow in the circumferential direction and further improve the uniformity of thin film deposition on the substrate.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and performance of the present application will be further described in conjunction with the following embodiments and accompanying drawings of the embodiments.

FIG. 1 is a schematic view of the gas flow regulating structure according to the present invention;

FIG. 2 is a schematic view of the regulating rings of the gas flow regulating structure according to the present invention;

FIG. 3A and FIG. 3B are schematic views illustrating the circumferential gas flow state before and after regulation of the gas flow regulating structure according to the present invention;

FIG. 4A and FIG. 4B are cross-sectional views of partial components of the gas

flow regulating structure according to the present invention;

FIG. 5 is a schematic view of the bottom of the first regulating ring of the gas flow regulating structure according to the present invention;

FIG. 6A and FIG. 6B are schematic views illustrating the radial gas flow state before and after regulation of the gas flow regulating structure according to the present invention;

FIG. 7 is another schematic view for implementing gas flow regulation by the gas flow regulating structure according to the present invention.

PREFERRED EMBODIMENTS OF THE PRESENT APPLICATION

The embodiments of the present invention are described hereinafter through specific examples. Those skilled in the art can readily understand other advantages and effects of the present invention from the disclosure of the present specification. The present invention can also be implemented or applied through other specific embodiments. Various modifications and changes can be made to all details recorded in the present specification based on different perspectives and application scenarios without departing from the spirit of the present invention.

It should be noted that the drawings provided in the present embodiments only schematically illustrate the basic conception of the present invention. Although the drawings show only the components related to the present invention, the components are not drawn to reflect the quantity, shape, and size of components in actual implementation. The shape, quantity, and proportion of each component in actual implementation can be changed arbitrarily, and the component layout configuration can be more complex. In addition, the same reference numerals are used to denote the same or equivalent parts or components in the various drawings.

As shown in FIG. 1, the present embodiment provides a gas flow regulating structure 3 applied to a thin film deposition apparatus. The thin film deposition apparatus comprises a processing chamber 1 for performing thin film deposition processes and a heating tray 2 for carrying and heating a substrate w. With reference to

FIG. 1 and FIG. 2, the gas flow regulating structure 3 comprises a first regulating ring 31 arranged to surround the substrate w and a second regulating ring 32 arranged to surround the first regulating ring 31. A tiny gap can be reserved between the first regulating ring 31 and the substrate w, and the gap ranges from 0.5 millimeter to 1 millimeter. This design facilitates the placement of the substrate w, and meanwhile prevents an excessively large gap from causing gas to flow toward the back surface of the substrate w. Generally, a circular ring includes an inner circle and an outer circle, and the inner circle and the outer circle have the same center. However, in the present application, the inner circle and the outer circle of each of the first regulating ring 31 and the second regulating ring 32 are arranged in an eccentric manner. The eccentric arrangement means that the center of the inner circle is not coincident with the center of the outer circle. Besides, the distance between the center of the inner circle and the center of the outer circle of the first regulating ring 31 is equal to the distance between the center of the inner circle and the center of the outer circle of the second regulating ring 32, and the above distance is defined as $L1$, where $0 \text{ millimeter} < L1 < 20 \text{ millimeters}$. Preferably, the value of $L1$ is 2 millimeters.

The rotation center of the first regulating ring 31 is coincident with the rotation center of the substrate w. The center of the inner circle of the first regulating ring 31, the center of the substrate w, and the center of the heating tray 2 are coincident, that is, the rotation center of the first regulating ring 31 is the center of the inner circle of the first regulating ring 31. When the first regulating ring 31 is rotated, the first regulating ring 31 drives the second regulating ring 32 to rotate synchronously. When the second regulating ring 32 is rotated independently, the rotation center of the second regulating ring 32 is the center of the outer circle of the first regulating ring 31, that is, the rotation center of the second regulating ring 32 is the center of the inner circle of the second regulating ring 32.

When the gas flow regulation is not required, or in the initial state (before thin film deposition is performed), the center of the inner circle of the first regulating ring 31 is coincident with the center of the outer circle of the second regulating ring 32, as shown in FIG. 2. At this time, the first regulating ring 31 and the second regulating ring 32 jointly form a concentric large circular ring. The center of the outer circle and the center of the inner circle of the large circular ring are both coincident with the

center of the substrate w. Therefore, the gas gap between the inner wall of the processing chamber 1 and the large circular ring keeps uniform and consistent, which can ensure the uniformity of thin film deposition on the substrate w.

When nonuniform thin film deposition occurs on the substrate w, gas flow regulation is required. The circumferential gas flow can be adjusted by rotating the first regulating ring 31 and/or the second regulating ring 32 to adjust the gas gap between the inner wall of the processing chamber 1 and the second regulating ring 32, so as to adjust the film thickness in the circumferential direction of the substrate w. For example, the second regulating ring 32 can be rotated to reduce the gas gap between the inner wall of the processing chamber 1 and the second regulating ring 32 corresponding to a region with a slightly thick thin film. When a large adjustment range of the gas gap is needed, the relative position of the first regulating ring 31 and the second regulating ring 32 can be adjusted to make the wider parts of the first regulating ring 31 and the second regulating ring 32 approach the region with a slightly thick thin film on the substrate w. For example, the first regulating ring 31 can be rotated first to drive the second regulating ring 32 to rotate synchronously, so as to reduce the gas gap between the first regulating ring 31 and the inner wall of the processing chamber 1 corresponding to the region with a slightly thick thin film, and then the second regulating ring 32 is rotated to reduce the gas gap between the second regulating ring 32 and the inner wall of the processing chamber 1. FIG. 3A and FIG. 3B are schematic views illustrating the circumferential gas flow state before and after regulation. With reference to FIG. 3A, in the initial state, the first regulating ring 31 and the second regulating ring 32 form a concentric large circular ring. The gas gap S0 between the inner wall of the processing chamber 1 and the second regulating ring 32 is equal to L0, and the distance from the inner wall of the processing chamber 1 to the second regulating ring 32 remains consistent in the entire circumferential direction. L0 refers to the radius difference between the processing chamber 1 and the outer circle of the second regulating ring 32. After the second regulating ring 32 is rotated counterclockwise by 180 degrees, as shown in FIG. 3B, the gas gap between the inner wall of the processing chamber 1 and the second regulating ring 32 changes. The minimum gas gap S1 is equal to L0 minus L1, and the maximum gas gap S2 is equal to L0 plus L1. The present embodiment is applicable to regulating the film thickness in the circumferential direction of the substrate w. For example, if the thin film in the

nine o'clock direction region on the substrate w is slightly thick, the first regulating ring 31 and/or the second regulating ring 32 can be rotated to reduce the gas gap between the inner wall of the processing chamber 1 and the second regulating ring 32 corresponding to the above region, so as to decrease the circumferential gas flow and further improve the uniformity of thin film deposition.

As shown in FIG. 1, both the first regulating ring 31 and the substrate w are supported above the heating tray 2 by supporting members 33. During the process operation, the substrate w is in point contact with the heating tray 2 rather than surface contact. This arrangement avoids the problem of nonuniform heat distribution caused by manufacturing tolerances, and further guarantees the uniformity of thin film deposition. Specifically, the supporting members 33 are thimbles made of sapphire, which are fixedly installed inside the openings formed at the top of the heating tray 2. With reference to FIG. 4A and FIG. 4B, the outer edge of the first regulating ring 31 is provided with a shelf portion 311 extending downward from the upper surface of the first regulating ring 31, and the shelf portion 311 is used to support the second regulating ring 32. FIG. 4A and FIG. 4B show some shapes of the shelf portion 311. In FIG. 4A, the shelf portion 311 of the first regulating ring 31 is a bevel edge, and correspondingly, the inner edge of the second regulating ring 32 is provided with a bevel edge matched therewith. In FIG. 4B, the shelf portion 311 of the first regulating ring 31 is a step structure, and the second regulating ring 32 is provided with a step structure matched therewith.

As shown in FIG. 5, a plurality of positioning holes 312 are uniformly arranged along the circumferential direction at the bottom of the first regulating ring 31, and the top ends of the supporting members 33 are placed inside the positioning holes 312. Preferably, the quantity of the positioning holes 312 is six, and the angular spacing between every two adjacent positioning holes 312 is 60 degrees. When the first regulating ring 31 is rotated, the first regulating ring 31 is lifted to separate from the supporting members 33. After the rotation is completed, the first regulating ring 31 falls down to make the top ends of the supporting members 33 still placed inside the positioning holes 312. Therefore, the rotation angle of the first regulating ring 31 is an integral multiple of 60 degrees. The second regulating ring 32 can rotate freely relative to the first regulating ring 31.

In some embodiments, the height of the supporting members 33 arranged below the first regulating ring 31 can be adjusted to regulate the radial gas flow. FIG. 6A and FIG. 6B are schematic views illustrating the radial gas flow state before and after regulation, wherein the arrows indicate the direction of radial gas flow. In FIG. 6A, the first regulating ring 31, the second regulating ring 32, and the substrate w are located at the same height. In FIG. 6B, the supporting members 33 with a higher height than the supporting members 33 in FIG. 6A are adopted to adjust the gas gap between the first regulating ring 31 and the heating tray 2, and the gas gap between the second regulating ring 32 and the heating tray 2, so that the first regulating ring 31 and the second regulating ring 32 are higher than the substrate w. This structure changes the direction of radial gas flow and further adjusts the film thickness at the edge of the substrate w. The present embodiment is applicable to regulating the film thickness in the radial direction of the substrate w. For example, if the thin film arranged around the periphery of the substrate w is slightly thick, the supporting members 33 with a higher height can be adopted to increase the gas gap between the first regulating ring 31 and the heating tray 2, and the gas gap between the second regulating ring 32 and the heating tray 2, so as to reduce the radial gas flow on the surface of the substrate w and further improve the uniformity of thin film deposition.

In some embodiments, the heating tray 2 may fail to be positioned at the exact center of the processing chamber due to manufacturing tolerances and other factors. As shown in FIG. 7, the gas gaps between two sides of the heating tray 2 and the inner wall of the processing chamber 1 are respectively d_1 and d_2 , where $d_1 < d_2$. In this case, the positions of the first regulating ring 31 and the second regulating ring 32 can be set before thin film deposition to compensate for the non-uniformity of the gas gap between the heating tray 2 and the inner wall of the processing chamber 1. Specifically, the gas gap between the second regulating ring 32 and the inner wall of the processing chamber 1 at the position corresponding to the minimum gas gap d_1 is set as S_3 , and the gas gap between the second regulating ring 32 and the inner wall of the processing chamber 1 at the position corresponding to the maximum gas gap d_2 is set as S_4 . The positions of the first regulating ring 31 and the second regulating ring 32 are adjusted to make $S_3 > S_4$. The minimum gas gap between the heating tray 2 and the inner wall of the processing chamber 1 is compensated by increasing the gas gap between the second regulating ring 32 and the inner wall of the processing chamber 1, so as to

regulate the uniformity of gas flow and improve the uniformity of thin film deposition.

Both the first regulating ring 31 and the second regulating ring 32 are made of dielectric materials. The dielectric materials include but are not limited to quartz, aluminum oxide, and ceramics. When the first regulating ring 31 and the second regulating ring 32 made of dielectric materials are applied to plasma-enhanced chemical vapor deposition (PECVD) equipment, the first regulating ring 31 and the second regulating ring 32 can also serve as focus rings. By introducing additional impedance, radio frequency energy is focused on the substrate w, gas is prevented from flowing toward the back surface of the substrate w, and thin film deposition on the back surface of the substrate w is reduced.

The above embodiments merely illustratively explain the principles, functions, and effects of the present invention, and are not intended to limit the present invention. Any person skilled in the art can make modifications or variations to the above embodiments without departing from the spirit and scope of the present invention. Therefore, all equivalent modifications and variations implemented by those of ordinary skill in the art without departing from the spirit and technical conception disclosed by the present invention shall still fall within the scope of the claims of the present invention.

What is claimed is:

1. A gas flow regulating structure applied to a thin film deposition apparatus, wherein the thin film deposition apparatus comprises a processing chamber and a heating tray, the gas flow regulating structure comprising: a first regulating ring arranged to surround a substrate and a second regulating ring arranged to surround the first regulating ring, wherein the outer circle of the first regulating ring is coincident with the inner circle of the second regulating ring, the inner circle and the outer circle of each of the first regulating ring and the second regulating ring are arranged in an eccentric manner, and the distance between the center of the inner circle and the center of the outer circle of the first regulating ring is equal to the distance between the center of the inner circle and the center of the outer circle of the second regulating ring.

2. The gas flow regulating structure according to claim 1, wherein the distance L1 between the center of the inner circle and the center of the outer circle satisfies the range of $0 \text{ millimeter} < L1 < 20 \text{ millimeters}$.

3. The gas flow regulating structure according to claim 2, wherein the distance L1 between the center of the inner circle and the center of the outer circle is 2 millimeters.

4. The gas flow regulating structure according to claim 1, wherein the gas flow regulating structure further comprises supporting members, and the supporting members are installed inside openings formed at the top of the heating tray and are configured to support the first regulating ring above the heating tray; the outer edge of the first regulating ring is provided with a shelf portion extending downward from the upper surface of the first regulating ring, and the shelf portion is configured to support the second regulating ring.

5. The gas flow regulating structure according to claim 4, wherein the shelf portion is a bevel edge or a step structure.

6. The gas flow regulating structure according to claim 4, wherein a plurality of positioning holes are uniformly arranged along the circumferential direction at the bottom of the first regulating ring, and the top ends of the supporting members are placed inside the positioning holes.

7. The gas flow regulating structure according to claim 1, wherein both the first regulating ring and the second regulating ring are made of dielectric materials.

8. A gas flow regulating method applied to the gas flow regulating structure according to any one of claims 1 to 7, comprising the following steps:

rotating the first regulating ring and the second regulating ring until the center of the outer circle of the first regulating ring is coincident with the center of the inner circle of the second regulating ring, and then performing thin film deposition on the substrate;

when nonuniform thin film deposition occurs on the substrate, rotating the second regulating ring to reduce the gas gap between the second regulating ring and the inner wall of the processing chamber corresponding to a region with a slightly thick thin film.

9. The gas flow regulating method according to claim 8, wherein before rotating the second regulating ring, the first regulating ring is rotated to drive the second regulating ring to rotate, so as to reduce the gas gap between the first regulating ring and the inner wall of the processing chamber corresponding to a region with a slightly thick thin film.

10. The gas flow regulating method according to claim 9, wherein the rotation angle of the first regulating ring is an integral multiple of 360 degrees divided by N, and N represents the quantity of positioning holes uniformly arranged along the circumferential direction at the bottom of the first regulating ring.

11. A gas flow regulating method applied to the gas flow regulating structure according to any one of claims 1 to 7, comprising:

before performing thin film deposition on the substrate, measuring the concentricity between the heating tray and the processing chamber;

when the heating tray is not concentric with the processing chamber, adjusting the position of the first regulating ring and/or the second regulating ring to reduce the gas gap between the second regulating ring and the inner wall of the processing chamber at the position where the gas gap between the heating tray and the processing chamber

is the largest.

12. A gas flow regulating method applied to the gas flow regulating structure according to any one of claims 4 to 6, comprising:

when nonuniform thin film deposition occurs on the substrate, adjusting the height of the supporting members to change the gas gap between the first regulating ring and the heating tray.