

THIN-FILM DEPOSITION APPARATUS AND THIN-FILM

DEPOSITION METHOD

TECHNICAL FIELD

The present invention relates to the technical field of semiconductor manufacturing, and in particular to a thin-film deposition apparatus and a thin-film deposition method.

BACKGROUND

In a vacuum processing chamber of plasma-enhanced chemical vapor deposition (PECVD), layer stack structures of different materials are deposited on a substrate. Wherein, the substrate is placed in the vacuum processing chamber, and a first processing gas is first introduced to form a first material of a first layer on the substrate; then plasma cleaning and gas cleaning are performed, and subsequently, a second processing gas is introduced to form a second material of a second layer on the substrate. The plasma cleaning and gas cleaning described above are repeated, and the first material and the second material are stacked and deposited on the substrate to form thin films with layer stack structures. Wherein, three-dimensional (3D) memory can be made of the layer stack structures of the alternating thin-film materials deposited on the substrate.

Currently, 3D memory uses alternating layers of oxide and nitride films to achieve data storage in a 3D structure through related processes. These stack structures may include a plurality of layers of the first material and the second material, such as a continuous stack of more than 300 layers or even 500 layers.

Specifically, in some cases, the stack structures of the first material and the second material in the thin-film materials of the 3D memory stack may be oxide and silicon, silicon and doped silicon, or silicon and nitride. Correspondingly, the thin-film materials of the 3D memory stack composed of these materials can mostly be applied to Bit-Cost Scalable (BiCS), Terabit Cell Array Transistor (TCAT), or other 3D memory structures. In addition, the stack structures of the first material and the second material may also be other material compositions, and the order in which the first

material layer and the second material layer are deposited on the substrate may also be reversed.

However, existing PECVD equipment has the following problems:

1. As the number of layers of the layer stack structures on the substrate surface increases, the thickness of the thin films increases accordingly, which leads to poor uniformity between layers of the thin films and overall poor uniformity of the stacked thin films. Further, a vertical structure cannot be obtained during subsequent etching process, thereby limiting the continuous increase in the number of thin-film layers during the thin-film stacking process.

Under current existing equipment conditions, when the number of deposited thin-film layers exceeds 200, the uniformity and quality of the thin films degrade. During the continuous stacking of different types of thin films, the deviation at fixed positions continues to be amplified, making the uniformity of the thin films on the substrate deviate beyond a controllable range. As a result, subsequent etching process fails to achieve the required through-hole etching accuracy, resulting in the deviation of the etched through-holes from the vertical direction during the etching process, which further leads to the failure of the semiconductor device.

2. Deformation of a gas showerhead due to long-term use or evacuation of exhaust gas by an external pump leads to non-uniform distribution of process gas supplied by a gas supply assembly, thereby resulting in deviation in the thickness of the thin films during the thin-film deposition process. Hence, the etched through-holes deviate from the vertical direction during the etching process, leading to the failure of the semiconductor device.

3. When the thin films are deposited using the conventional PECVD method, a heating tray needs to be fixed to ensure the flatness of the heating tray. However, while the heating tray is fixed, the temperature distribution of the substrate forms a fixed pattern, resulting in non-uniform heating of the substrate. Hence, the etched through-holes deviate from the vertical direction during the etching process, leading to the failure of the semiconductor device.

In summary, it is necessary to propose a new thin-film deposition apparatus and a method using the thin-film deposition apparatus to solve the problems described above.

SUMMARY

In view of the shortcomings of the prior art described above, the object of the present invention is to propose a thin-film deposition apparatus and a thin-film deposition method to solve the problem of poor uniformity of thin films deposited on a substrate in the prior art.

To achieve the above object and other related objects, the present invention provides a thin-film deposition apparatus, comprising:

- a processing chamber, for performing thin-film deposition;

- a heating tray, for supporting and heating a substrate, including a central raised substrate-support portion and a peripheral portion for placing a support ring;

- a support mechanism, including a support ring arranged around the substrate-support portion and a support shaft for supporting the support ring;

- a lift mechanism, for driving the support shaft to move up and down and/or driving the heating tray to move up and down;

- a rotating mechanism, for driving the heating tray to rotate;

wherein, the thin-film deposition apparatus is configured as: after one thin-film deposition is completed, the rotating mechanism drives the heating tray to rotate the substrate from a first angular position to a second angular position; after the rotation is completed, the heating tray is separated from the substrate, and the substrate is supported by the support ring; the rotating mechanism drives the heating tray to rotate to a third angular position, while the support ring and the substrate remain at the second angular position; after the heating tray contacts the substrate, the next thin-film deposition is performed.

Preferably, the third angular position is the same as the first angular position.

Preferably, the inner diameter of the support ring is greater than the outer diameter of the substrate-support portion.

Preferably, the support shaft is not fixedly connected to the support ring.

Preferably, the surface height difference between the substrate-support portion and the peripheral portion is the same as the thickness of the support ring.

Preferably, the thickness of the support ring is between 0.3 mm and 0.7 mm.

Preferably, the support ring is fixedly connected to the support shaft.

Preferably, the surface height difference between the substrate-support portion and the peripheral portion is between 1.5 mm and 2.9 mm.

Preferably, the thickness of the support ring is between 0.3 mm and 0.7 mm.

Preferably, when the rotating mechanism drives the heating tray to rotate together with the substrate, the support ring remains in a non-contact state with the heating tray and the substrate.

The present invention further provides a thin-film deposition method, comprising:

placing a substrate into a processing chamber and depositing a thin film of a first thickness on the substrate;

a heating tray driving the substrate to rotate from a first angular position to a second angular position;

separating the heating tray from the substrate, supporting the substrate using a support ring, and the heating tray rotating from the second angular position to a third angular position;

bringing the heating tray into contact with the substrate, and depositing a thin film of a second thickness.

Preferably, the first angular position is the same as the third angular position.

Preferably, the separation of the heating tray from the substrate is achieved by a lift mechanism driving the heating tray to move down.

Preferably, the separation of the heating tray from the substrate is achieved by the lift mechanism driving the heating tray to move down and driving the support shaft to move up.

Preferably, the separation of the heating tray from the substrate is achieved by the lift mechanism driving the support shaft to move up.

Preferably, the support shaft is not fixedly connected to the support ring, and the support and separation between the support shaft and the support ring are achieved via relative movement.

Preferably, when thin films are deposited on the substrate, the upper surface of the support ring is in close contact with the substrate, and the lower surface of the support ring is in close contact with the heating tray.

Preferably, when the heating tray drives the substrate to rotate, the support ring is in a separated state from the support shaft, and the support ring is driven by the heating tray to rotate together.

Preferably, the support ring is fixedly connected to the support shaft, and the support shaft drives the support ring to move up and down.

Preferably, after the support shaft drives the support ring to move down until the support ring loses contact with the substrate and the heating tray, the heating tray drives the substrate to rotate, and the support ring does not rotate.

By using the present invention, the problem of poor uniformity of deposited thin films during the deposition of an ultra-large number of layers (for example, more than 200 layers) is solved. By virtue of the present invention, when the number of thin-film deposition layers exceeds 200, the uniformity and stability of PECVD layer-stack thin-film deposition are achieved, preventing the through-holes to be etched on the thin

films deposited on the substrate from deviating from the vertical direction during subsequent etching process. Therefore, the performance of the semiconductor device remains stable.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and performance of the present invention are further described by the following embodiments and the accompanying drawings of the embodiments.

FIG. 1 shows a schematic view of the tilting of a large number of thin-film layers deposited using a PECVD thin-film deposition technology.

FIGS. 2A and 2B respectively show schematic views of a substrate in the thin-film deposition apparatus provided in embodiment 1 of the present invention before and after being lifted.

FIGS. 3A and 3B respectively show top views of lift pins in the thin-film deposition apparatus provided in embodiment 1 of the present invention before and after rotating by a preset angle.

FIGS. 4A and 4B respectively show schematic views of a substrate in the thin-film deposition apparatus provided in embodiment 5 of the present invention before and after being lifted.

FIG. 5 shows a top view of the support ring provided in embodiment 5 of the present invention.

FIGS. 6A and 6B respectively show schematic views of a substrate in the thin-film deposition apparatus provided in embodiment 6 of the present invention before and after being lifted.

FIG. 7 shows a top view of the lift pins and the support ring provided in embodiment 6 of the present invention.

FIGS. 8A to 8D respectively show schematic views of a substrate rotating by different preset angles provided in the present invention.

FIG. 9 shows a schematic structural view of the thin-film deposition apparatus provided in embodiments 7 and 10 of the present invention.

FIG. 10 shows a schematic structural view of the thin-film deposition apparatus provided in embodiments 8 and 11 of the present invention.

FIG. 11 shows a schematic structural view of the thin-film deposition apparatus provided in embodiment 9 of the present invention.

FIG. 12A shows a schematic view of non-uniform deposition of thin films caused by non-uniform distribution of gas supplied by a gas supply assembly in the existing PECVD thin-film deposition technology.

FIG. 12B shows a schematic view of non-uniform deposition of thin films caused by exhaust gas evacuation via a pump in the existing PECVD thin-film deposition technology.

FIG. 13A shows a schematic structural view of the thin-film deposition apparatus provided in embodiment 12 of the present invention.

FIGS. 13B to 13C respectively show schematic views of the side walls of the gas regulating assembly provided in embodiment 12 of the present invention being stretched downward and compressed upward.

FIG. 14A shows a schematic structural view of the thin-film deposition apparatus provided in embodiment 13 of the present invention.

FIGS. 14B to 14C respectively show schematic views of the telescopic rod provided in embodiment 13 of the present invention being compressed upward and stretched downward.

FIGS. 15A to 15B respectively show process flow diagrams of the thin-film deposition method provided in embodiment 14 of the present invention.

FIG. 16 shows a process flow diagram of the thin-film deposition method provided in embodiment 18 of the present invention.

FIG. 17 shows a process flow diagram of the thin-film deposition method provided in embodiment 19 of the present invention.

FIG. 18 shows a process flow diagram of the thin-film deposition method provided in embodiment 20 of the present invention.

FIG. 19 shows a process flow diagram of the thin-film deposition method provided in embodiment 21 of the present invention.

FIGS. 20A to 20K respectively show layout schematic views of the thin-film deposition equipment provided in embodiments 22 and 23 of the present invention.

FIG. 21 shows a schematic structural view of the thin-film deposition apparatus provided in embodiment 25 of the present invention.

FIGS. 22 to 23 show schematic structural views of the thin-film deposition apparatus provided in embodiment 26 of the present invention.

FIGS. 24 to 25 show schematic structural views of the thin-film deposition apparatus provided in embodiment 27 of the present invention.

FIGS. 26 to 27 show schematic structural views of the thin-film deposition apparatus provided in embodiment 28 of the present invention.

FIGS. 28 to 29 show schematic structural views of the thin-film deposition apparatus provided in embodiment 29 of the present invention.

FIGS. 30 to 31 show schematic structural views of the thin-film deposition apparatus provided in embodiment 30 of the present invention.

FIGS. 32 to 33 show schematic structural views of the thin-film deposition apparatus provided in embodiment 31 of the present invention.

FIG. 34 shows a connection relationship between the controller and various components provided in the present invention.

FIGS. 35 to 36 show schematic structural views of the thin-film deposition

apparatus provided in embodiment 32 of the present invention.

FIG. 37 shows a schematic structural view of the arrangement of a plurality of groups of lift pins provided in embodiment 33 of the present invention.

FIG. 38 shows a schematic structural view of the thin-film deposition apparatus provided in embodiment 34 of the present invention.

FIG. 39 shows an enlarged partial view of region A in FIG. 38.

FIGS. 40A to 40D respectively show process flow diagrams of using the thin-film deposition apparatus provided in embodiment 34 of the present invention.

FIG. 41 shows a schematic structural view of the thin-film deposition apparatus provided in embodiment 35 of the present invention.

FIG. 42 shows an enlarged partial view of region B in FIG. 41.

FIGS. 43A to 43D respectively show process flow diagrams of using the thin-film deposition apparatus provided in embodiment 35 of the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

The implementation methods of the present invention are described below through specific embodiments. Those skilled in the art can easily understand other advantages and effects of the present invention from the content disclosed in this specification. The present invention can also be implemented or applied through other different specific embodiments, and various modifications or changes can be made to the details in this specification based on different viewpoints and application without departing from the spirit of the present invention.

It should be understood that when a component is referred to as being "on another component," "connected to another component," "coupled to another component," or "in contact with another component," the component may be directly on, connected to, coupled to, or in contact with another component, or an insert component may be present. In contrast, when a component is referred to as being "directly on another

component," "directly connected to," "directly coupled to," or "in direct contact with" another component, no insert component is present.

Please refer to FIGS. 1 to 37. It should be noted that the drawings provided in the embodiments only illustrate the basic concept of the present invention in a schematic manner. Only the components related to the present invention are shown in the drawings, and the drawings are not drawn according to the number, shape, and size of the components in actual implementation. The shape, number, and proportion of each component in actual implementation can be arbitrarily changed, and the layout of the components may also be more complex.

Embodiment 1

During the PECVD thin-film deposition process, due to non-uniform temperature distribution on a heating tray or different flatness of a substrate on the heating tray caused by stress, the uniformity during the thin-film deposition process is deteriorated. When thin films of different materials are alternately deposited on the substrate, as the number of layers of a first material and a second material alternately stacked on a substrate w increases, the thickness of the thin films with a layer stack structure formed on the substrate w increases, as shown in FIG. 1, resulting in an inclination angle Δ of the stacked thin films. In other words, as the number of layers in the layer stack structure increases, the uniformity of the stacked thin films deteriorates, making the uniformity of the thin films on the substrate w deviate from a controllable range. As a result, subsequent etching process fails to achieve the required through-hole etching accuracy, resulting in the deviation of the etched through-holes from the vertical direction during the etching process, which further leads to the failure of the semiconductor device.

To solve the above problem, embodiment 1 provides a thin-film deposition apparatus. Specifically, as shown in FIGS. 2A, 2B, and 34, the thin-film deposition apparatus comprises: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w ; a radio-frequency (RF) source 5, for providing RF power to form RF electric field within the

processing chamber 1 and exciting the process gas within the processing chamber 1 to dissociate into plasma gas, and the dissociated plasma gas performing thin-film deposition on the substrate w; a rotating mechanism 403, for controlling the rotation of the substrate w, the rotation axis AA' of the rotation being vertical and passing through the substrate w; a controller, respectively connected to the gas supply assembly 2, the RF source 5, the heating tray 3, and the rotating mechanism 403, for controlling the operation of the gas supply assembly 2, the RF source 5, the heating tray 3, and the rotating mechanism 403. The controller is further configured to construct a program menu, which includes maintaining the RF source 5 in an on state when the substrate w rotates. In embodiment 1, the rotation axis AA' of the rotation passes through the center O of the substrate w, allowing the substrate w to rotate around the rotation axis AA'.

When the rotating mechanism 403 drives the substrate w to rotate, the introduction of process gas into the processing chamber 1 is stopped, and an inert gas or nitrogen is introduced into the processing chamber 1 to maintain the pressure within the processing chamber 1 and maintain the RF source 5 in the on state. After a certain number of thin-film layers are deposited on the substrate w, some contaminant particles are suspended within the processing chamber 1. At this time, the RF source 5 is maintained in the on state to fill the processing chamber 1 with RF electric field. The contaminant particles are electrically charged under the action of the RF electric field within the processing chamber 1, and the charged contaminant particles remain suspended and will not fall on the surface of the substrate w, preventing the contaminant particles from falling on the thin films deposited on the substrate w and avoiding contamination on the thin films deposited on the substrate w.

Therefore, embodiment 1 proposes driving the substrate w to rotate while maintaining the RF source 5 in the on state, which compensates for the non-uniform thickness of the thin films deposited on the substrate w, achieves the uniformity and stability of PECVD layer-stack thin-film deposition, and avoids the phenomenon that the through-holes to be etched on the thin films deposited on the substrate w deviate from the vertical direction during subsequent etching process, thereby further ensuring the performance stability of the semiconductor device.

Wherein, as shown in FIGS. 2A and 2B, the thin-film deposition apparatus further comprises: a support mechanism, for supporting the substrate w; a lift mechanism 402,

connected to the support mechanism, for driving the support mechanism to move up or down in the vertical direction to lift the substrate w off the heating tray 3 or place the substrate w on the heating tray 3. The lift mechanism 402 is connected to the controller, and the controller controls the operation of the lift mechanism 402.

In embodiment 1, the rotating mechanism 403 is disposed at the bottom end of the lift mechanism 402 for driving the support mechanism and the lift mechanism 402 to rotate synchronously in the horizontal circumferential direction to drive the substrate w to rotate.

In embodiment 1, the support mechanism may be lift pins 401 that can move in the vertical direction and the horizontal circumferential direction, and the heating tray 3 is provided with first through-holes 301, and the lift pins 401 are disposed in the first through-holes 301. As shown in FIGS. 3A and 3B, the cross-sections of the first through-holes 301 on the horizontal plane are arc-shaped or circular, and the center M of the arcs or circles and the center O of the substrate w are aligned on the same vertical line.

In embodiment 1, the lift mechanism 402 may be a pneumatic cylinder 402, the pneumatic cylinder 402 is connected to the bottom ends of the lift pins 401; the rotating mechanism 403 may be a motor 403, the motor 403 is connected to the bottom of the pneumatic cylinder 402, the pneumatic cylinder 402 drives the lift pins 401 to move up or down, and the motor 403 drives the pneumatic cylinder 402 and the lift pins 401 to rotate synchronously.

When the substrate w needs to be rotated, as shown in FIG. 2B, the lift mechanism 402 drives the lift pins 401 to move up in the vertical direction and extend out of the first through-holes 301, and the lift pins 401 lift the substrate w to separate the substrate w from the heating tray 3; then the rotating mechanism 403 drives the lift pins 401 to move along an arc-shaped trajectory in the first through-holes 301, allowing the substrate w to rotate by a preset angle, as shown in FIGS. 3A and 3B; after the substrate w rotates by a preset angle, the substrate w stops rotating, and the lift mechanism 402 drives the lift pins 401 to move down in the vertical direction, placing the substrate w on the heating tray 3 for subsequent thin-film deposition.

At least three lift pins 401 may be required, and correspondingly, at least three first through-holes 301 are required, and the first through-holes are in one-to-one correspondence with the lift pins 401. In embodiment 1, as shown in FIGS. 3A and 3B, three lift pins 401 are present, three first through-holes 301 are present correspondingly, and the cross-sections of the three first through-holes 301 on the horizontal plane are three arcs.

In embodiment 1, at least three lift pins 401 are used to lift the substrate w, allowing the substrate w to rotate by a preset angle, which compensates for the non-uniform thickness of the thin films deposited on the substrate w, achieves the uniformity and stability of PECVD layer-stack thin-film deposition, and avoids the phenomenon that the through-holes to be etched on the thin films deposited on the substrate w deviate from the vertical direction during subsequent etching process, thereby further ensuring the performance stability of the semiconductor device.

Wherein, the side wall of the processing chamber 1 is provided with a door 101 for a manipulator to enter the processing chamber 1 to place the substrate w on or remove the substrate w from the heating tray 3 before and after the thin-film deposition process of the substrate w.

Wherein, after the thin-film deposition is completed, (number of rotations of the substrate w + 1) x preset angle of each rotation of the substrate w = 360°. In embodiment 1, as shown in FIGS. 8A to 8D, after the thin-film deposition is completed, the number of rotations of the substrate w is 5, and the preset angle of each rotation is 60 degrees; alternatively, the number of rotations of the substrate w is 3, and the preset angle of each rotation is 90 degrees; alternatively, the number of rotations of the substrate w is 2, and the preset angle of each rotation is 120 degrees; alternatively, the number of rotations of the substrate w is 1, and the preset angle of each rotation is 180 degrees.

Wherein, the deposition rate of the thin films on the substrate w is related to the multiple of the RF power of the RF source 5: the high frequency of the RF source 5 is an integer multiple n of 13.56 MHz, and n satisfies: n = 1, 2, 3,..., 8; the low frequency range of the RF source 5 is 20 KHz to 400 KHz.

However, during the rotation of the substrate w, the RF source 5 is maintained in the on state. After the substrate w is separated from the heating tray 3, the gap between the back side of the substrate w and the heating tray 3 is excessively large, which tends to cause arc discharge. Therefore, in embodiment 1, to avoid arc discharge when the substrate w is separated from the heating tray 3 with the RF source 5 turned on, as shown in FIGS. 2A and 2B, it is necessary to adjust the gap between the substrate w and the heating tray 3 to be less than a preset value to prevent the arc discharge caused by the substrate w being separated from the heating tray 3 in a plasma-gas atmosphere. In embodiment 1, the preset value of the gap between the substrate w and the heating tray 3 is m, and m is a value greater than 0 and smaller than or equal to 5 mm. Therefore, under the condition that the gap between the substrate w and the heating tray 3 is less than the preset value, maintaining the RF source 5 in the on state reduces the risk of arc discharge of the substrate w and ensures the safety and stability of the thin-film deposition process.

Embodiment 2

Embodiment 2 provides a thin-film deposition apparatus, which is different from embodiment 1 in that:

As shown in FIGS. 2A and 2B, the heating tray 3 is provided with a second through-hole 302. During the rotation of the substrate w, the RF source 5 is maintained in the on state, and a non-process gas is introduced into the gap between the substrate w and the heating tray 3 through the second through-hole 302 to reduce the risk of arc discharge when the substrate w is separated from the heating tray 3. Wherein, in embodiment 2, the non-process gas is an inert gas or nitrogen.

After a certain number of thin-film layers are deposited on the substrate w, some contaminant particles are suspended within the processing chamber 1. At this time, the RF source 5 is maintained in the on state to fill the processing chamber 1 with RF electric field. The contaminant particles are electrically charged under the action of the RF electric field within the processing chamber 1, and the charged contaminant particles remain suspended and will not fall on the surface of the substrate w, preventing the contaminant particles from falling on the thin films deposited on the substrate w and avoiding contamination on the thin films deposited on the substrate w.

Therefore, when the gap between the substrate w and the heating tray 3 is filled with the non-process gas, maintaining the RF source 5 in the on state reduces the risk of arc discharge of the substrate w and ensures the safety and stability of the thin-film deposition process.

Other settings of this embodiment are the same as the settings of embodiment 1, and will not be repeated herein.

Embodiment 3

Embodiment 3 provides a thin-film deposition apparatus, which is different from embodiment 1 in that:

During the rotation of the substrate w, the RF source 5 is maintained in the on state, and the RF power of the RF source 5 is reduced to be less than the RF power of the RF source 5 during the thin-film deposition process, so as to reduce the risk of arc discharge when the substrate w is separated from the heating tray 3 and ensure the safety and stability of the thin-film deposition process.

Other settings of this embodiment are the same as the settings of embodiment 1, and will not be repeated herein.

Embodiment 4

Embodiment 4 provides a thin-film deposition apparatus, which is different from embodiment 1 in that:

Before the substrate w rotates, the RF source 5 is adjusted to an off state, and the processing chamber 1 is purified.

After a certain number of thin-film layers are deposited on the substrate w, contaminant particles are present within the processing chamber 1. The greater the contamination level within the processing chamber 1, the higher the probability of arc discharge when the substrate w is separated from the heating tray 3 inside the processing chamber 1. Therefore, before the substrate w rotates, preferably, the RF source 5 is turned off, and nitrogen is supplied into the processing chamber 1 through

the gas supply assembly 2 to purify the processing chamber 1.

Other settings of this embodiment are the same as the settings of embodiment 1, and will not be repeated herein.

Embodiment 5

Please refer to FIGS. 4A to 5. Embodiment 5 provides a thin-film deposition apparatus, which is different from embodiment 1 in that:

As shown in FIGS. 4A and 4B, the support mechanism is a support ring 404 disposed at the bottom of the edge of the substrate w, and the support ring 404 can move up and down in the vertical direction and rotate about the center line AA' of the substrate w as the rotation axis.

In embodiment 5, as shown in FIG. 5, the support ring 404 is a circular ring with a gap a, or the support ring 404 includes a plurality of arc segments located on the same circle. Correspondingly, the side wall of the processing chamber 1 is provided with a door 101 for a manipulator to enter the processing chamber 1 to place the substrate w on the support ring 404 or remove the substrate w from the support ring 404 before and after the thin-film deposition process of the substrate w.

As shown in FIGS. 4A and 4B, when the substrate w needs to be rotated, the lift mechanism 402 drives the support ring 404 to move up in the vertical direction to lift the substrate w, allowing the substrate w to be separated from the heating tray 3; then the rotating mechanism 403 drives the support ring 404 to rotate to drive the substrate w to rotate by a preset angle; the substrate w stops rotating after rotating by the preset angle, and the lift mechanism 402 drives the support ring 404 to move down in the vertical direction to place the substrate w on the heating tray 3 for thin-film deposition.

In embodiment 5, the support ring 404 disposed at the bottom of the outer periphery of the substrate w is used to lift the substrate w to adjust the substrate w to rotate by a preset angle, allowing the substrate w to rotate about the rotation axis AA', which compensates for the non-uniform thickness of the thin films deposited on the substrate w and achieves the uniformity and stability of PECVD layer-stack thin-film deposition.

Other settings of this embodiment are the same as the settings of embodiment 1, and will not be repeated herein.

Embodiment 6

Please refer to FIGS. 6A to 7. Embodiment 6 provides a thin-film deposition apparatus, which is different from embodiment 1 in that:

As shown in FIGS. 6A to 7, the thin-film deposition apparatus comprises: a support mechanism, for supporting the substrate w, wherein the support mechanism includes lift pins 401 and a support ring 404; a first lift mechanism 402 is connected to the lift pins 401 for driving the lift pins 401 to move up or down in the vertical direction, allowing a manipulator to remove the substrate w from the heating tray 3 or place the substrate w on the heating tray 3; a second lift mechanism 405 is connected to the support ring 404 for driving the support ring 404 to move up or down in the vertical direction to lift the substrate w off the heating tray 3 or place the substrate w on the heating tray 3.

In embodiment 6, the rotating mechanism 403 is disposed at the bottom of the second lift mechanism 405 for driving the support ring 404 and the second lift mechanism 405 to rotate synchronously about the center line AA' of the substrate w as the rotation axis to drive the substrate w to rotate.

As shown in FIGS. 6A and 6B, the heating tray 3 is provided with first through-holes 301, and the lift pins 401 are disposed in the first through-holes 301 for supporting the substrate w through the first through-holes 301.

When the manipulator places the substrate w into the processing chamber 1, the first lift mechanism 402 drives the lift pins 401 to move up in the vertical direction and extend out of the first through-holes 301 to support the substrate w placed by the manipulator; then the first lift mechanism 402 drives the lift pins 401 to move down in the vertical direction, and the lift pins 401 are retracted into the first through-holes 301, allowing the substrate w to be placed on the heating tray 3 for subsequent thin-film deposition. When the manipulator removes the substrate w from the processing chamber 1, the first lift mechanism 402 drives the lift pins 401 to move up in the

vertical direction and extend out of the first through-holes 301 to lift the substrate w off the heating tray 3, allowing a manipulator to remove the substrate w; then the first lift mechanism 402 drives the lift pins 401 to move down in the vertical direction, and the lift pins 401 are retracted into the first through-holes 301.

When the substrate w needs to be rotated, the second lift mechanism 405 drives the support ring 404 to move up in the vertical direction to lift the substrate w, allowing the substrate w to be separated from the heating tray 3; then the rotating mechanism 403 drives the support ring 404 to rotate to drive the substrate w to rotate by a preset angle; the substrate w stops rotating after rotating by the preset angle, and the second lift mechanism 405 drives the support ring 404 to move down in the vertical direction to place the substrate w on the heating tray 3 for thin-film deposition.

Other settings of this embodiment are the same as the settings of embodiment 1, and will not be repeated herein.

Embodiment 7

As shown in FIG. 9, embodiment 7 provides a thin-film deposition apparatus, comprising: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; an RF source 5, for providing RF power to form RF electric field within the processing chamber 1, exciting the process gas within the processing chamber 1 to dissociate into plasma gas, and the dissociated plasma gas performing thin-film deposition on the substrate w; a rotating mechanism 403, connected to the heating tray 3, for driving the heating tray 3 to rotate about the axis AA' passing through the center of the substrate w as the rotation axis, thereby driving the substrate w to rotate synchronously.

When the rotating mechanism 403 drives the heating tray 3 and the substrate w to rotate, the introduction of process gas into the processing chamber 1 is stopped, and an inert gas or nitrogen is introduced into the processing chamber 1 to maintain the pressure within the processing chamber 1 and maintain the RF source 5 in the on state.

In embodiment 7, the heating tray 3 driving the substrate w to rotate in synchronization about axis AA' passing through the center of the substrate w as the rotation axis includes: the heating tray 3 first rotating forward by a preset angle about axis AA' and then rotating reversely about axis AA'.

Embodiment 8

As shown in FIG. 10, embodiment 8 provides a thin-film deposition apparatus, comprising: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, and configured to supply process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; an RF source 5, for providing RF power to form RF electric field within the processing chamber 1, exciting the process gas within the processing chamber 1 to dissociate into plasma gas, and the dissociated plasma gas performing thin-film deposition on the substrate w.

The thin-film deposition apparatus further comprises: a support mechanism, for supporting the substrate w, wherein the support mechanism is a support ring 404 disposed at the bottom of the edge of substrate w, a lift mechanism 402, connected to the support ring 404, for driving the support ring 404 to move up or down in the vertical direction, and lifting the substrate w off the heating tray 3 or placing the substrate w on the heating tray 3.

In embodiment 8, a rotating mechanism 403 is connected to the heating tray 3 for driving the heating tray 3 to rotate about the axis AA' passing through the center of the substrate w as the rotation axis.

When the rotating mechanism 403 drives the heating tray 3 to rotate, the introduction of process gas into the processing chamber 1 is stopped, and an inert gas or nitrogen is introduced into the processing chamber 1 to maintain the pressure within the processing chamber 1 and maintain the RF source 5 in the on state.

In embodiment 8, the rotation of the heating tray 3 about the axis AA' passing through the center of the substrate w as the rotation axis includes: the heating tray 3 rotating forward by a preset angle about the rotation axis AA' and then rotating

reversely about the rotation axis AA'.

As shown in FIG. 10, when the heating tray 3 needs to be rotated, the lift mechanism 402 drives the support ring 404 to move up in the vertical direction to lift the substrate w, allowing the substrate w to be separated from the heating tray 3, and then the rotating mechanism 403 drives the heating tray 3 to rotate by a preset angle; the heating tray 3 stops rotating after rotating by the preset angle, and the lift mechanism 402 drives the support ring 404 to move down in the vertical direction to place the substrate w on the heating tray 3 for thin-film deposition.

Embodiment 9

As shown in FIG. 11, embodiment 9 provides a thin-film deposition apparatus, comprising: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; an RF source 5, for providing RF power to excite the process gas within the processing chamber 1 to dissociate into plasma gas, and the plasma gas performing thin-film deposition on the substrate w; a rotating mechanism 403, connected to the gas supply assembly 2, for driving the gas supply assembly 2 to rotate.

In embodiment 9, the rotating mechanism 403 may be a motor 403, and the motor 403 is connected to the gas supply assembly 2 to drive the gas supply assembly 2 to rotate. In embodiment 9, after sequentially placing a plurality of substrates w into the processing chamber 1 to complete the thin-film deposition process, the rotating mechanism 403 drives the gas supply assembly 2 to rotate by a preset angle.

Preferably, when the rotating mechanism 403 drives the gas supply assembly 2 to rotate, the introduction of process gas into the processing chamber 1 is stopped, and an inert gas or nitrogen is introduced into the processing chamber 1 to maintain the pressure within the processing chamber 1 and maintain the RF source 5 in the on state. After a certain number of thin-film layers are deposited on the substrate w, some contaminant particles are suspended within the processing chamber 1. At this time, the RF source 5 is maintained in the on state to fill the processing chamber 1 with RF

electric field. The contaminant particles are electrically charged under the action of the RF electric field within the processing chamber 1, and the charged contaminant particles remain suspended and will not fall on the surface of the substrate w, preventing the contaminant particles from falling on the thin films deposited on the substrate w and avoiding contamination on the thin films deposited on the substrate w.

By rotating the gas supply assembly 2, the uniformity of the process gas supplied by the gas supply assembly 2 is improved, thereby improving the thickness uniformity of the thin films deposited on the substrate w and achieving the uniformity and stability of PECVD layer-stack thin-film deposition.

Embodiment 10

As shown in FIG. 9, embodiment 10 provides a thin-film deposition apparatus, which is different from embodiment 7 in that:

The rotating mechanism 403 is connected to the heating tray 3 for driving the heating tray 3 to rotate about the axis AA' passing through the center of the substrate w as the rotation axis, thereby driving the substrate w to rotate synchronously. When the rotating mechanism 403 drives the heating tray 3 to rotate synchronously with the substrate w, the RF source 5 is adjusted to the off state.

Other settings of this embodiment are the same as the settings of embodiment 7, and will not be repeated herein.

Embodiment 11

As shown in FIG. 10, embodiment 11 provides a thin-film deposition apparatus, which is different from embodiment 8 in that:

When the rotating mechanism 403 drives the heating tray 3 to rotate, the RF source 5 is adjusted to the off state.

Other settings of this embodiment are the same as the settings of embodiment 8, and will not be repeated herein.

Embodiment 12

During PECVD, due to the deformation of the gas supply assembly 2 caused by long-term use, the process gas delivered into the processing chamber 1 is non-uniformly distributed, resulting in different gas flow rates at different positions of the substrate. This further leads to deviation in the thickness of the thin films deposited by the plasma gas on the substrate, which causes etched through-holes to deviate from the vertical direction during the etching process, and ultimately leads to the failure of the semiconductor device.

As shown in FIG. 12A, when the process gas is introduced into a gas supply assembly 2, the gas flow rate at the central position of the gas supply assembly 2 is greater than the gas flow rate at the outer periphery of the gas supply assembly 2. Therefore, the thickness of the thin films deposited on the central position of the substrate w is greater than the thickness of the thin films at the outer edge during the thin-film deposition process, causing the thin films stacked on the surface of the substrate w to incline by a certain angle Δ . This leads to non-uniform thickness of the thin films deposited on the substrate w , thereby causing the defect that etched through-holes deviate from the vertical direction during subsequent etching process.

As shown in FIG. 12B, the processing chamber 1 is connected to a pump for evacuating exhaust gas during the deposition process in the processing chamber 1. However, the evacuation of exhaust gas by the pump tends to cause the gas flow rate at the outer periphery of the gas supply assembly 2 to be greater than the gas flow rate at the central position of the gas supply assembly 2. Therefore, the thickness of the thin films deposited on the central position of the substrate w is greater than the thickness of the thin films at the outer edge during the thin-film deposition process, causing the thin films stacked on the surface of the substrate w to incline by a certain angle Δ . This leads to non-uniform thickness of the thin films deposited on the substrate w , thereby causing the defect that etched through-holes deviate from the vertical direction during subsequent etching process.

To solve the above defect of non-uniform deposition between the outer periphery and the central position of the deposited thin films, please refer to FIGS. 13A to 13C. Embodiment 12 provides a thin-film deposition apparatus. Specifically, as shown in

FIG. 13A, the thin-film deposition apparatus comprises: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1, and the gas supply assembly 2 having a first porous plate 21; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; a gas regulating assembly 200, disposed inside the gas supply assembly 2, the bottom end of the gas regulating assembly 200 being provided with a second porous plate 201, and the second porous plate 201 being disposed opposite to the first porous plate 21 of the gas supply assembly 2. By adjusting the gap between the second porous plate 201 and the first porous plate 21, the flow direction of the process gas within the gas supply assembly 2 is adjusted, allowing the process gas within the gas supply assembly 2 to be fully mixed. This improves the non-uniform distribution of the plasma gas within the processing chamber 1, achieves the uniformity and stability of PECVD layer-stack thin-film deposition on the substrate w, and avoids the phenomenon that the etched through-holes of the thin films deposited on the substrate w deviate from the vertical direction during subsequent etching process, thereby further ensuring the performance stability of the semiconductor device. In addition, the thin-film deposition apparatus further comprises a controller respectively connected to the gas supply assembly 2, the heating tray 3, and the gas regulating assembly 200 for controlling the operation of the gas supply assembly 2, the heating tray 3, and the gas regulating assembly 200.

As shown in FIG. 13A, the thin-film deposition apparatus further comprises an RF source 5 for providing RF power to form RF electric field within the processing chamber 1, exciting the process gas within the processing chamber 1 to dissociate into plasma gas, and the dissociated plasma gas performing thin-film deposition on the substrate w. Wherein, the high frequency of the RF source 5 is an integer multiple n of 13.56 MHz, and n satisfies: $n = 1, 2, 3, \dots, 8$; the low frequency range of the RF source 5 is 20 KHz to 400 KHz.

As shown in FIGS. 13B to 13C, the side wall 202 of the gas regulating assembly 200 can be stretched downward or compressed upward in the vertical direction to adjust the gap between the second porous plate 201 and the first porous plate 21. Therefore, the process gas within the gas supply assembly 2 can be fully mixed, improving the defect of non-uniform thin-film deposition on the surface of the

substrate w caused by non-uniform distribution of the plasma gas during the thin-film deposition process.

In embodiment 12, as shown in FIGS. 13B and 13C, the side wall 202 of the gas regulating assembly 200 is a bellow, and can be stretched downward or compressed upward in the vertical direction to make the second porous plate 201 at the bottom end of the gas regulating assembly 200 be curved or bent into an arc, thereby adjusting the gap between the second porous plate 201 and the first porous plate 21. Therefore, the process gas within the gas supply assembly 2 can be fully mixed, thereby improving the defect of non-uniform thin-film deposition on the surface of the substrate w caused by non-uniform distribution of the plasma gas.

Embodiment 13

Please refer to FIGS. 14A to 14C. Embodiment 13 provides a thin-film deposition apparatus, which is different from embodiment 12 in that:

The gas regulating assembly 200 includes a telescopic rod 203, and the telescopic rod 203 is connected to the second porous plate 201. The telescopic rod 203 can be stretched or compressed in the vertical direction, allowing the second porous plate 201 to be curved or bent into an arc to adjust the gap between the second porous plate 201 and the first porous plate 21. Therefore, the process gas within the gas supply assembly 2 can be fully mixed, thereby improving the defect of non-uniform thin-film deposition on the surface of the substrate w caused by non-uniform distribution of the plasma gas within the processing chamber 1.

In embodiment 13, as shown in FIG. 14A, the telescopic rod 203 is disposed at the central position inside the gas regulating assembly 200 and connected to the center of the second porous plate 201.

Other settings of this embodiment are the same as the settings of embodiment 12, and will not be repeated herein.

Embodiment 14

To solve the problem of non-uniform thin-film deposition on the surface of the

substrate w in the prior art, please refer to FIGS. 2A to 10 and FIG. 15A. Embodiment 14 provides a thin-film deposition method implemented based on the thin-film deposition apparatus in embodiments 1 to 8 and 10 to 11 described above.

Specifically, the thin-film deposition method includes the following steps:

Step S1: Place the substrate w into the processing chamber 1 of PECVD, and evacuate the processing chamber 1 to place the substrate w, on which thin films are to be deposited, in a vacuum environment;

Step S2: Introduce process gas into the processing chamber 1, turn on the RF source 5 to dissociate the process gas within the processing chamber 1 into plasma gas, and deposit a certain number of thin-film layers on the substrate w;

Step S3: Stop introducing the process gas into the processing chamber 1, and introduce a non-process gas, such as an inert gas or nitrogen, into the processing chamber 1 to maintain the pressure within the processing chamber 1;

Step S4: Maintain the RF source 5 in the on state, and rotate the substrate w, or rotate the heating tray 3, or rotate the substrate w and the heating tray 3 synchronously by a preset angle;

Step S5: Reintroduce the process gas into the processing chamber 1, and then deposit a certain number of thin-film layers on the substrate w;

Step S6: Stop introducing the process gas into the processing chamber 1, and introduce a non-process gas, such as an inert gas or nitrogen, into the processing chamber 1 to maintain the pressure within the processing chamber 1;

Step S7: Determine whether the number of thin-film layers deposited on the substrate w reaches a preset number of layers; if the preset number of layers has not been reached, repeat the above steps S2 to S6; if the preset number of layers has been reached, execute Step S8;

Step S8: Remove the substrate w from the processing chamber 1 of PECVD to complete the thin-film deposition process of the substrate w.

Wherein, the rotation axis AA' for the substrate w to rotate, or for the heating tray 3 to rotate, or for the substrate w and the heating tray 3 to rotate synchronously is vertical and passes through the center O of the substrate w.

The thin films deposited on the substrate w include a first material and a second material deposited alternately. In embodiment 14, the first material is silicon oxide, and the second material is silicon nitride.

Wherein, the thin-film deposition method further includes: after each material is deposited on the surface of the substrate w, evacuating the exhaust gas from the processing chamber 1 before performing subsequent process steps.

While rotating the substrate w, or rotating the heating tray 3, or rotating the substrate w and the heating tray 3 synchronously, the introduction of the process gas is stopped, an inert gas or nitrogen is introduced to maintain the pressure within the processing chamber 1, and the RF source 5 is maintained in the on state. After a certain number of thin-film layers are deposited on the substrate w, some contaminant particles are suspended inside the processing chamber 1. At this time, the RF source 5 is maintained in the on state to fill the processing chamber 1 with RF electric field. The contaminant particles are electrically charged under the action of the RF electric field within the processing chamber 1, and the charged contaminant particles remain suspended and will not fall on the surface of the substrate w, preventing the contaminant particles from falling on the thin films deposited on the substrate w and avoiding contamination on the thin films deposited on the substrate w.

After the thin-film deposition is completed, (number of rotations of the substrate w + 1) x preset angle of each rotation of the substrate w = 360°. In embodiment 14, as shown in FIGS. 8A to 8D, after the thin-film deposition is completed, the number of rotations of the substrate w is 5, and the preset angle of each rotation is 60 degrees; alternatively, the number of rotations of the substrate w is 3, and the preset angle of each rotation is 90 degrees; alternatively, the number of rotations of the substrate w is 2, and the preset angle of each rotation is 120 degrees; alternatively, the number of rotations of the substrate w is 1, and the preset angle of each rotation is 180 degrees.

However, during the rotation of the substrate w or the heating tray 3, the RF source

5 is maintained in the on state, after the substrate w is separated from the heating tray 3, the gap between the back side of the substrate w and the heating tray 3 is excessively large, which tends to cause arc discharge. Therefore, in embodiment 14, to avoid arc discharge when the substrate w is separated from the heating tray 3 with the RF source 5 turned on, it is necessary to adjust the gap between the substrate w and the heating tray 3 to be less than a preset value to prevent the arc discharge caused by the substrate w being separated from the heating tray 3 in a plasma-gas atmosphere. In embodiment 14, the preset value of the gap between the substrate w and the heating tray 3 is m, and m is a value greater than 0 and smaller than or equal to 5 mm. Therefore, under the condition that the gap between the substrate w and the heating tray 3 is less than the preset value, maintaining the RF source 5 in the on state reduces the risk of arc discharge of the substrate w and ensures the safety and stability of the thin-film deposition process.

In embodiment 14, when the number of thin-film layers deposited on the surface of the substrate w is small (for example, less than 150 layers), the method of driving the heating tray 3 to rotate synchronously with the substrate w can be adopted to avoid the arc discharge caused by the substrate w being lifted. In the case where the heating tray 3 has a non-flat surface, the method of lifting the substrate w and driving the substrate w to rotate or driving the heating tray 3 to rotate can be adopted to eliminate the impact of non-uniform temperature distribution on the heating tray 3 on the uniformity of the thin films deposited on the surface of the substrate w.

Optionally, when depositing thin films of a single material, please refer to FIG. 15B.

Specifically, the thin-film deposition method includes the following steps:

Step S11: Place the substrate into the processing chamber, and evacuate the processing chamber;

Step S12: Introduce process gas, turn on the RF source, and deposit thin films of a certain thickness on the substrate;

Step S13: Continue to introduce the process gas, maintain the RF source in the on

state, and rotate the substrate, or rotate the heating tray, or rotate the substrate and the heating tray synchronously by a preset angle;

Step S14: Continue to deposit thin films on the substrate;

Step S15: Determine whether the thickness of the deposited thin films on the substrate meets a preset requirement; if the preset requirement has not been met, repeat the above steps S12 to S14; if the preset requirement has been met, execute Step S16;

Step S16: Remove the substrate from the processing chamber.

Rotating the substrate w during the thin-film growth ensures that the thin films deposited on the surface of the substrate w are more uniform.

Embodiment 15

Embodiment 15 provides a thin-film deposition method, which is different from embodiment 14 in that:

With the RF source 5 in the on state, a non-process gas is introduced into the gap between the substrate w and the heating tray 3 through the second through-hole 302 on the heating tray 3 to reduce the risk of arc discharge when the substrate w is separated from the heating tray 3. Wherein, in embodiment 15, the non-process gas is an inert gas or nitrogen.

When the gap between the substrate w and the heating tray 3 is filled with the non-process gas, maintaining the RF source 5 in the on state reduces the risk of arc discharge of the substrate w and ensures the safety and stability of the thin-film deposition process.

Other settings of this embodiment are the same as the settings of embodiment 14, and will not be repeated herein.

Embodiment 16

Embodiment 16 provides a thin-film deposition method, which is different from embodiment 14 in that:

With the RF source 5 in the on state, the RF power of the RF source 5 is reduced to be less than the RF power of the RF source 5 during the thin-film deposition process, so as to reduce the risk of arc discharge when the substrate w is separated from the heating tray 3, thereby ensuring the safety and stability of the thin-film deposition process.

Other settings of this embodiment are the same as the settings of embodiment 14, and will not be repeated herein.

Embodiment 17

Embodiment 17 provides a thin-film deposition method, which is different from embodiment 14 in that:

Before the substrate w or the heating tray 3 rotates, or the substrate w and the heating tray 3 rotate synchronously, the RF source 5 is adjusted to the off state, and the processing chamber 1 is purified.

After a certain number of thin-film layers are deposited on the substrate w, contaminant particles are present within the processing chamber 1. The greater the contamination level within the processing chamber 1, the higher the probability of arc discharge when the substrate w is separated from the heating tray 3 inside the processing chamber 1. Therefore, before the substrate w or the heating tray 3 rotates, or the substrate w and the heating tray 3 rotate synchronously, preferably, the RF source 5 is turned off, and nitrogen is supplied into the processing chamber 1 through the gas supply assembly 2 to purify the processing chamber 1. After the purification is completed, the RF source 5 is adjusted back to the on state.

Other settings of this embodiment are the same as the settings of embodiment 14, and will not be repeated herein.

Embodiment 18

Please refer to FIGS. 8A to 9 and FIG. 16. Embodiment 18 provides a thin-film deposition method implemented based on the thin-film deposition apparatus in embodiments 7 and 10 described above.

Specifically, the thin-film deposition method includes the following steps:

Step S21: Place the substrate w in the processing chamber 1 of PECVD, and evacuate the processing chamber 1 to place the substrate w, on which thin films are to be deposited, in a vacuum environment;

Step S22: Introduce process gas into the processing chamber 1, turn on the RF source 5 to dissociate the process gas within the processing chamber 1 into plasma gas, and deposit a certain number of thin-film layers on the substrate w;

Step S23: Stop introducing the process gas into the processing chamber 1, and introduce an inert gas or nitrogen into the processing chamber 1 to maintain the pressure within the processing chamber 1;

Step S24: Adjust the RF source 5 to the off state, and drive the heating tray 3 to rotate synchronously with the substrate w by a preset angle;

Step S25: Reintroduce the process gas into the processing chamber 1, and adjust the RF source 5 to the on state, then deposit a certain number of thin-film layers on the substrate w;

Step S26: Stop introducing the process gas into the processing chamber 1, and introduce an inert gas or nitrogen into the processing chamber 1 to maintain the pressure within the processing chamber 1;

Step S27: Determine whether the number of thin-film layers deposited on the substrate w reaches a preset number of layers; if the preset number of layers has not been reached, repeat the above steps S22 to S26; if the preset number of layers has been reached, execute Step S28;

Step S28: Remove the substrate w from the processing chamber 1 to complete the thin-film deposition process.

Wherein, the rotation axis AA' for the synchronous rotation of the heating tray 3 and the substrate w is vertical and passes through the center O of the substrate w. In embodiment 18, the synchronous rotation of the heating tray 3 and the substrate w

about the axis AA' passing through the center of the substrate w as the rotation axis further includes: the heating tray 3 rotating forward by a preset angle about the rotation axis AA' and then rotating reversely about the rotation axis AA'.

The thin films deposited on the substrate w include a first material and a second material deposited alternately.

Wherein, the thin-film deposition method further includes: after each material is deposited on the surface of the substrate w, evacuating the exhaust gas from the processing chamber 1 before performing subsequent process steps.

After the thin-film deposition is completed, (number of rotations of the substrate w + 1) x preset angle of each rotation of the substrate w = 360°. In embodiment 18, as shown in FIGS. 8A to 8D, after the thin-film deposition is completed, the number of rotations of the substrate w is 5, and the preset angle of each rotation is 60 degrees; alternatively, the number of rotations of the substrate w is 3, and the preset angle of each rotation is 90 degrees; alternatively, the number of rotations of the substrate w is 2, and the preset angle of each rotation is 120 degrees; alternatively, the number of rotations of the substrate w is 1, and the preset angle of each rotation is 180 degrees.

Embodiment 19

Please refer to FIGS. 10 and 17. Embodiment 19 provides a thin-film deposition method implemented based on the thin-film deposition apparatus in embodiments 8 and 11 described above.

Specifically, the thin-film deposition method includes the following steps:

Step S31: Place the substrate w in the processing chamber 1 of PECVD, and evacuate the processing chamber 1 to place the substrate w, on which thin films are to be deposited, in a vacuum environment;

Step S32: Introduce process gas into the processing chamber 1, turn on the RF source 5 to dissociate the process gas within the processing chamber 1 into plasma gas, and deposit a certain number of thin-film layers on the substrate w;

Step S33: Stop introducing the process gas into the processing chamber 1, and introduce an inert gas or nitrogen into the processing chamber 1 to maintain the pressure within the processing chamber 1;

Step S34: Adjust the RF source 5 to the off state, lift the substrate w, drive the heating tray 3 to rotate by a preset angle, and then place the substrate w back on the heating tray 3;

Step S35: Introduce the process gas into the processing chamber 1, and adjust the RF source 5 to the on state, then deposit a certain number of thin-film layers on the substrate w;

Step S36: Stop introducing the process gas into the processing chamber 1, and introduce an inert gas or nitrogen into the processing chamber 1 to maintain the pressure within the processing chamber 1;

Step S37: Determine whether the number of thin-film layers deposited on the substrate w meets a preset number of layers; if the preset number of layers has not been met, repeat the above steps S32 to S36; if the preset number of layers has been met, execute Step S38;

Step S38: Remove the substrate w from the processing chamber 1 to complete the thin-film deposition process.

Wherein, the rotation axis AA' of the heating tray 3 is vertical and passes through the center O of the substrate w. In embodiment 19, the rotation of the heating tray 3 about the axis AA' passing through the center of the substrate w as the rotation axis further includes: the heating tray 3 rotating forward by a preset angle about the rotation axis AA' and then rotating reversely about the rotation axis AA'.

In embodiment 19, the thin films deposited on the substrate w include a first material and a second material deposited alternately.

Wherein, the thin-film deposition method further includes: after each material is deposited on the surface of the substrate w, evacuating the exhaust gas from the processing chamber 1 before performing subsequent process steps.

Embodiment 20

Please refer to FIGS. 11 and 18. Embodiment 20 provides a thin-film deposition method implemented based on the thin-film deposition apparatus in embodiment 9 described above.

Specifically, the thin-film deposition method includes the following steps:

Step S41: Sequentially place a plurality of substrates w into the processing chamber 1 to complete the thin-film deposition process;

Step S42: Rotate the gas supply assembly 2 by a preset angle;

Step S43: Clean the processing chamber 1 to ensure the cleanliness of the processing chamber 1; after the cleaning is completed, repeat steps S41 to S43.

In embodiment 20, the thin films deposited on the substrate w include a first material and a second material deposited alternately. Wherein, sequentially placing a plurality of substrates w into the processing chamber 1 for the thin-film deposition process includes: after each material is deposited on the surface of each substrate w, evacuating the exhaust gas from the processing chamber 1 before performing subsequent process steps.

Embodiment 21

Please refer to FIGS. 13A to 13C and FIG. 19. Embodiment 21 provides a thin-film deposition method implemented based on the thin-film deposition apparatus in embodiment 12 described above.

As shown in FIGS. 13A to 13C, the bottom end of the gas supply assembly 2 is provided with a first porous plate 21; the gas supply assembly 2 is provided with a gas regulating assembly 200 inside, the bottom end of the gas regulating assembly 200 is provided with a second porous plate 201, and the second porous plate 201 is disposed opposite to the first porous plate 21 of the gas supply assembly 2. By adjusting the gap between the second porous plate 201 and the first porous plate 21, the flow direction of the process gas within the gas supply assembly 2 is adjusted, allowing the process

gas within the gas supply assembly 2 to be fully mixed. This improves the defect of non-uniform thin-film deposition on the surface of the substrate w caused by non-uniform distribution of the plasma gas within the processing chamber 1.

Specifically, as shown in FIGS. 13A to 13C, adjusting the gap between the second porous plate 201 and the first porous plate 21 is achieved by stretching or compressing the side wall 202 of the gas regulating assembly 200 in the vertical direction. For details, please refer to the adjustment method of the side wall 202 of the gas regulating assembly 200 in embodiment 12 described above, which will not be repeated herein. The thin-film deposition method provided in embodiment 21 includes the following steps:

Step S51: Sequentially place a plurality of substrates w into the processing chamber 1 to complete the thin-film deposition process;

Step S52: Adjust the gap between the second porous plate 201 and the first porous plate 21 to adjust the flow direction of the process gas within the gas supply assembly 2;

Step S53: Clean the processing chamber 1 to ensure the cleanliness of the processing chamber 1; after the cleaning is completed, repeat steps S51 to S53.

Embodiment 22

Please refer to FIGS. 14A to 14C and FIG. 19. Embodiment 22 provides a thin-film deposition method implemented based on the thin-film deposition apparatus in embodiment 13 described above. Embodiment 22 is different from embodiment 21 in that:

As shown in FIGS. 14A to 14C, a telescopic rod 203 is disposed inside the gas regulating assembly 200. Adjusting the gap between the second porous plate 201 and the first porous plate 21 is achieved by stretching or compressing the telescopic rod 203 in the vertical direction. For details, refer to the adjustment method of the telescopic rod 203 of the gas regulating assembly 200 in embodiment 13 described above, which will not be repeated herein.

Other settings of this embodiment are the same as the settings of embodiment 21, and will not be repeated herein.

Embodiment 23

Please refer to FIGS. 20A to 20E. Embodiment 23 provides a thin-film deposition equipment, comprising: a substrate load port 002, for placing the substrate w; a buffer 003; a front-end manipulator 001, for transferring the substrate w between the substrate load port 002 and the buffer 003; the thin-film deposition apparatus in embodiments 1 to 13 described above for performing thin-film deposition on the substrate w; a process manipulator 004, for transferring the substrate w between the buffer 003 and the processing chamber 1 of the thin-film deposition apparatus.

Specifically, the front-end manipulator 001 removes the substrate w to be deposited from the substrate load port 002 and places the substrate w on the buffer 003; the process manipulator 004 removes the substrate w from the buffer 003 and places the substrate w into the processing chamber 1 of the thin-film deposition apparatus to perform thin-film deposition on the surface of the substrate w; after the thin-film deposition is completed, the process manipulator 004 removes the substrate w from the processing chamber 1 and places the substrate w on the buffer 003; the front-end manipulator 001 removes the substrate w from the buffer 003 and place the substrate w back onto the substrate load port 002 to complete the process operation of the thin-film deposition equipment.

In embodiment 23, as shown in FIGS. 20A to 20C, a plurality of processing chambers 1 are disposed inside the thin-film deposition apparatus, and the plurality of processing chambers 1 are symmetrically arranged on both sides of the process manipulator 004.

In addition, the number of process manipulators 004 may be one or more. When a plurality of process manipulators 004 are present, as shown in FIG. 20A, a plurality of buffers 003 are present. When one process manipulator 004 is present, as shown in FIGS. 20B and 20C, a contact-free magnetic levitation track is provided below the process manipulator 004 to ensure that the process manipulator 004 is oil-free and frictionless during sliding. The interior of each processing chamber 1 may also be

provided with a plurality of heating trays 3 for performing thin-film deposition on a plurality of substrates w simultaneously to improve the process efficiency of thin-film deposition.

In embodiment 23, as shown in FIGS. 20A and 20C, the plurality of heating trays 3 inside each processing chamber 1 may be arranged in a matrix structure. Alternatively, in other embodiments, as shown in FIGS. 20B, 20D, and 20E, the plurality of heating trays 3 inside each processing chamber 1 are arranged in a triangular structure.

Optionally, the buffer 003 can house a plurality of substrates w, the centers of the plurality of substrates w are on the same circle, and the plurality of substrates w can rotate about a rotation axis perpendicular to the center of the circle to change the positions of the plurality of substrates w inside the buffer 003.

As shown in FIGS. 20D and 20E, the buffer 003 can house three substrates w, and the three substrates w inside the buffer 003 are arranged in a triangular structure, and the three substrates w can rotate. The structure of the process manipulator 004 is matched with the triangular structure formed by the three substrates w inside the buffer 003 and the three heating trays 3 inside the processing chamber 1. The process manipulator 004 includes three substrate transfer arms for picking and placing substrates, and the positions and quantities of the three substrate transfer arms are set corresponding to the plurality of heating trays 3. The process manipulator 004 removes three substrates w from the buffer 003 simultaneously and places the substrates on the three heating trays 3 in the processing chamber 1 to improve the process efficiency of thin-film deposition.

Further, as shown in FIG. 20E, one process manipulator 004 is present. The process manipulator 004 is a telescopic arm. In addition, the process manipulator 004 can rotate and swing left and right to pick and place substrates w into processing chambers 1 at different positions.

Embodiment 24

Embodiment 24 provides a thin-film deposition equipment, which is different from embodiment 23 in that:

As shown in FIGS. 20F to 20I and FIG. 20K, a plurality of processing chambers 1 are sequentially arranged on the outer periphery of the process manipulator 004.

Wherein, as shown in FIG. 20G, five processing chambers 1 are sequentially arranged on the outer periphery of the process manipulator 004. Each processing chamber 1 is provided with three heating trays 3 for performing thin-film deposition on three substrates w simultaneously, and the three heating trays 3 are arranged in a triangular structure.

In a preferred embodiment, the buffer 003 is provided with two layers of storage platforms, each layer of storage platform can be used to place three substrates w, one layer of storage platform is used to place substrates w to be deposited, and the deposited substrates w are unloaded from the other layer of storage platform. The double-layer structure can reduce the waiting time of the substrates w, which is beneficial to improving the tool throughput. The two layers of storage platforms may be disconnected, and two rotating units are used to drive the respective storage platforms to rotate. The two layers of storage platforms may also be connected and placed on the same rotating unit, and one rotating shaft is used to drive the two layers of storage platforms to rotate synchronously.

Based on the overall operating speed of the equipment, optionally, the thin-film deposition equipment is provided with a plurality of buffers 003. The plurality of buffers 003 may be connected or disconnected to each other.

Preferably, as shown in FIG. 20J, the thin-film deposition equipment is provided with two buffers 003, namely buffer 0031 and buffer 0032. Each buffer 003 is provided with three layers of storage platforms 0033 in the vertical direction, and each layer of storage platform 0033 can be used to place three substrates w. The buffer 0031 is driven by a rotating unit 7, and the buffer 0032 is driven by a rotating unit 8. The three layers of storage platforms 0033 in each of buffer 0031 and buffer 0032 are driven by one rotating unit to rotate synchronously. The two buffers 0031 and 0032 are arranged in the vertical direction, and the vertical distance between the two buffers 0031 and 0032 is within a preset range where the process manipulator 004 can pick and place a substrate w. Optionally, one of the three layers of storage platforms 0033 can be left empty, and the other two layers of storage platforms are used to pick and place

substrates w. According to process requirements, the number of process manipulators 004 is not limited to one.

Further, one side of the buffer 0031 is open, and the front-end manipulator 001 removes the substrate w to be deposited from the substrate load port 002 and places the substrate w on the buffer 0031; one side of the buffer 0032 is open, and the process manipulator 004 removes the deposited substrate from the processing chamber 1, and places the substrate w on the buffer 0032. Conversely, the other side of the buffer 0032 is open for placing the substrate w to be deposited, and the other side of the buffer 0031 is open for placing the deposited substrate w. In other words, the opening modes of the buffer 0031 and the buffer 0032 are alternately set to improve the production efficiency. Other settings of this embodiment are the same as the settings of embodiment 23, and will not be repeated herein.

Embodiment 25

Please refer to FIG. 21. Embodiment 25 provides a thin-film deposition apparatus, comprising: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; an RF source 5, for providing RF power to excite the process gas within the processing chamber 1 to dissociate into plasma gas, and the plasma gas performing thin-film deposition on the substrate w; a lift mechanism 402, connected to the gas supply assembly 2, for driving the gas supply assembly 2 to move up and down.

The lift mechanism 402 may be a pneumatic cylinder 402. The pneumatic cylinder 402 drives the gas supply assembly 2 to move up or down to adjust the distance between the gas supply assembly 2 and the substrate w. Adjusting the distance between the gas supply assembly 2 and the substrate w within a preset range further improves the uniformity of PECVD layer-stack thin-film deposition.

Embodiment 25 can be combined with any one of embodiments 1 to 13 described above to adjust the distance between the gas supply assembly 2 and the substrate w.

Embodiment 26

Please refer to FIGS. 22 to 23. Embodiment 26 provides a thin-film deposition apparatus, comprising: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; an RF source 5, for providing RF power to form RF electric field within the processing chamber 1, exciting the process gas within the processing chamber 1 to dissociate into plasma gas, and the dissociated plasma gas performing thin-film deposition on the substrate w; a rotating mechanism 403, connected to the heating tray 3, for driving the heating tray 3 to rotate about the axis AA' passing through the center of the substrate w as the rotation axis.

The heating tray 3 can also move up and down. A lift mechanism 402 is connected to the heating tray 3 for driving the heating tray 3 to move up and down. A support mechanism is used to support the substrate w. The support mechanism may be a support ring 404 and/or lift pins 401.

As shown in FIG. 23, when the heating tray 3 needs to be rotated, the lift mechanism 402 drives the heating tray 3 to move down in the vertical direction to separate the heating tray 3 from the substrate w, leaving the substrate w supported by the support mechanism. The rotating mechanism 403 then drives the lift mechanism 420 and the heating tray 3 to rotate together by a preset angle; the heating tray 3 stops rotating after rotating by the preset angle, the lift mechanism 402 drives the heating tray 3 to move up in the vertical direction, and the substrate w is placed on the heating tray 3 for thin-film deposition.

Moreover, when the gap between the gas supply assembly 2 and the substrate w needs to be adjusted, the heating tray 3 drives the substrate w to move up or down together, maintaining the distance within a preset range and thereby further improving the uniformity of the PECVD layer-stack thin-film deposition.

Embodiment 27

Please refer to FIGS 24 to 25. Embodiment 27 provides a thin-film deposition apparatus, which is different from embodiment 26 in that:

The thin-film deposition apparatus further comprises: a support mechanism, for supporting the substrate w , and a second lift mechanism 405. Wherein, the support mechanism can be a support ring 404 disposed at the bottom of the edge of the substrate w , and the support ring 404 is a circular ring with a gap a as shown in FIG. 5.

The first lift mechanism 402 is connected to the rotating mechanism 403 for driving the rotating mechanism 403 and the heating tray 3 to move up and down. The rotating mechanism 403 is disposed at the bottom end of the heating tray 3 for driving the heating tray 3 to rotate about the axis AA' passing through the center of the substrate w as the rotation axis, thereby driving the substrate w to rotate synchronously.

A second lift mechanism 405 is connected to the support ring 404 for driving the support ring 404 to move up or down in the vertical direction to lift the substrate w off the heating tray 3 or place the substrate w on the heating tray 3. In addition, the second lift mechanism 405 is also connected to the first lift mechanism 402, and the second lift mechanism 405 drives the first lift mechanism 402 and the support ring 404 to move up and down together to drive the substrate w to move up and down, thereby adjusting the distance between the gas supply assembly 2 and the substrate w .

In this embodiment, as shown in FIG. 25, when the heating tray 3 needs to be rotated, the second lift mechanism 405 drives the support ring 404 to move up in the vertical direction to lift the substrate w , allowing the substrate w to be separated from the heating tray 3. Then the rotating mechanism 403 drives the first lift mechanism 402 and the heating tray 3 to rotate by a preset angle. The heating tray 3 stops rotating after rotating by the preset angle, and the second lift mechanism 405 drives the support ring 404 to move down in the vertical direction to place the substrate w on the heating tray 3 for thin-film deposition. Optionally, the first lift mechanism 402 drives the heating tray 3 to move down to separate the substrate w from the heating tray 3.

The support mechanism may also be lift pins that move in the vertical direction. The heating tray 3 is provided with first through-holes, and the lift pins are disposed in the first through-holes. The second lift mechanism 405 drives the lift pins to move

up or down in the vertical direction.

Embodiment 28

Please refer to FIGS. 26 to 27. Embodiment 28 provides a thin-film deposition apparatus, comprising: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; an RF source 5, for providing RF power to form RF electric field within the processing chamber 1, exciting the process gas within the processing chamber 1 to dissociate into plasma gas, and the dissociated plasma gas performing thin-film deposition on the substrate w; a lift mechanism 402, connected to the heating tray 3, for driving the heating tray 3 to move up and down.

The thin-film deposition apparatus further comprises: a support mechanism, for supporting the substrate w; a rotating mechanism 403, connected to the support mechanism, for driving the support mechanism and the substrate w to rotate.

A controller is respectively connected to the gas supply assembly 2, the RF source 5, the heating tray 3, the rotating mechanism 403, and the lift mechanism 402 for controlling the operation of the gas supply assembly 2, the RF source 5, the heating tray 3, the rotating mechanism 403, and the lift mechanism 402. The controller is further configured to construct a program menu, which includes maintaining the RF source 5 in the on state when the substrate w rotates.

Wherein, as shown in FIG. 27, the support mechanism is a support ring 404 disposed at the bottom of the edge of the substrate w; the rotating mechanism 403 is connected to the support ring 404 for driving the support ring 404 to rotate about the center line AA' of the substrate w as the rotation axis.

When the substrate w needs to be rotated, the lift mechanism 402 drives the heating tray 3 to move down in the vertical direction to separate the heating tray 3 from the support ring 404. The support ring 404 supports the substrate w, and the rotating mechanism 403 drives the support ring 404 to rotate. The support ring 404 lifts the

substrate w to adjust the substrate w to rotate by a preset angle, enabling the rotation of the substrate w about the rotation axis AA'. This compensates for the non-uniform thickness of the thin films deposited on the substrate w and achieves the uniformity and stability of PECVD layer-stack thin-film deposition.

Embodiment 29

Please refer to FIGS. 28 to 29. Embodiment 29 provides a thin-film deposition apparatus, which is different from embodiment 28 in that:

The support mechanism is lift pins 401. The heating tray 3 is provided with first through-holes 301, and the lift pins 401 are disposed in the first through-holes 301. As shown in FIGS. 3A and 3B, the cross-sections of the first through-holes 301 on the horizontal plane are arc-shaped or circular, and the center M of the arcs or circles and the center O of the substrate w are aligned on the same vertical line. When the substrate w needs to be rotated, the lift mechanism 402 drives the heating tray 3 to move down in the vertical direction to separate the heating tray 3 from the substrate w. The lift pins 401 lift and support the substrate w. The rotating mechanism 403 drives the lift pins 401 to move along an arc-shaped trajectory in the first through-holes 301, allowing the substrate w to rotate by a preset angle. The substrate w stops rotating after rotating by the preset angle, and the lift mechanism 402 drives the heating tray 3 to move up in the vertical direction to place the substrate w on the heating tray 3 for subsequent thin-film deposition.

Embodiment 30

Please refer to FIGS. 30 to 31. Embodiment 30 provides a thin-film deposition apparatus, which is different from embodiment 28 in that:

The support mechanism includes lift pins 401 and a support ring 404. The thin-film deposition apparatus comprises a first lift mechanism 402 and a second lift mechanism 405. The first lift mechanism 402 is connected to the heating tray 3 for driving the heating tray 3 to move up and down; the second lift mechanism 405 is connected to the lift pins 401 for driving the lift pins 401 to move up or down in the vertical direction, allowing a manipulator to remove the substrate w from the heating

tray 3 or place the substrate w on the heating tray 3.

Embodiment 31

Please refer to FIGS. 32 to 33. Embodiment 31 provides a thin-film deposition apparatus, which is different from embodiment 30 in that:

The thin-film deposition apparatus further comprises a third lift mechanism 406, and the third lift mechanism 406 is connected to the support ring 404.

In this embodiment, the second lift mechanism 405 drives the lift pins 401 to move up or down in the vertical direction, allowing a manipulator to remove the substrate w from the heating tray 3 or place the substrate w on the heating tray 3. The first lift mechanism 402 drives the heating tray 3 to move up and down, and the third lift mechanism 406 drives the support ring 404 and the substrate w to move up and down. The heating tray 3 and the substrate w synchronously move under the drive of the first lift mechanism 402 and the third lift mechanism 406 respectively to adjust the distance between the gas supply assembly 2 and the substrate w, controlling the distance within a preset range, further improving the uniformity of PECVD layer-stack thin-film deposition. Optionally, the third lift mechanism 406 is respectively connected to the first lift mechanism 402 and the support ring 404, and the third lift mechanism 406 drives the first lift mechanism 402 and the support ring 404 to move up and down in the vertical direction simultaneously.

When the substrate w needs to be rotated, the third lift mechanism 406 drives the support ring 404 to move up in the vertical direction, separating the support ring 404 from the heating tray 3. The support ring 404 supports the substrate w, and the rotating mechanism 403 drives the support ring 404 to rotate. The support ring 404 lifts the substrate w to adjust the substrate w to rotate by a preset angle.

Embodiment 32

Please refer to FIGS. 35 to 36. Embodiment 32 provides a thin-film deposition apparatus, which is different from embodiment 28 in that: the thin-film deposition apparatus further comprises lift pins 401 and a second lift mechanism 405, and the lift mechanism 402 is a first lift mechanism 402.

The first lift mechanism 402 drives the heating tray 3 to move, and the second lift mechanism 405 is connected to the support ring 404 for driving the support ring 404 to move up or down in the vertical direction. The heating tray 3 is provided with first through-holes 301, and the lift pins 401 are disposed in the first through-holes 301. The lower ends of the lift pins 401 abut against a base 6, and the base 6 is connected to the bottom of the processing chamber 1. According to the height at which the substrate w is loaded into the processing chamber 1, the height of the base 6 is preset. When the lift pins 401 abut against the base 6, the upper ends of the lift pins 401 are higher than the support ring 404 and the heating tray 3, and the upper ends of the lift pins 401 are used to receive the substrate w.

The heating tray 3 and the substrate w synchronously move under the drive of the first lift mechanism 402 and the second lift mechanism 405 respectively to adjust the distance between the gas supply assembly 2 and the substrate w. In one embodiment, the heating tray 3 is provided with grooves at the positions corresponding to the lift pins 401, and the top ends of the lift pins 401 are provided with protrusions. When the heating tray 3 moves up, the protrusions of the lift pins 401 are accommodated within the grooves, and the heating tray 3 continues to move up and drives the lift pins 401 to move up together. After the lift pins 401 move up, the lift pins 401 are separated from the base 6, and the lift pins 401 are in a suspended state.

When the substrate w needs to be rotated, the second lift mechanism 405 drives the support ring 404 to move up in the vertical direction, separating the support ring 404 from the heating tray 3. The support ring 404 supports the substrate w, and the rotating mechanism 403 drives the support ring 404 to rotate to adjust the substrate w to rotate by a preset angle.

Embodiment 33

Please refer to FIG. 37. Embodiment 33 provides a thin-film deposition apparatus, comprising: a processing chamber 1, for performing thin-film deposition; a gas supply assembly 2, disposed on the top wall of the processing chamber 1, for supplying process gas into the processing chamber 1; a heating tray 3, disposed below the gas supply assembly 2, for supporting and heating the substrate w; an RF source 5, for providing RF power to excite the process gas within the processing chamber 1 to

dissociate into plasma gas, and the plasma gas performing thin-film deposition on the substrate w; lift pins 401, disposed in the heating tray 3, one ends of the lift pins 401 disposed at the bottom of the processing chamber 1, and the other ends of the lift pins 401 used to receive the substrate w.

In this embodiment, three heating trays 3 are disposed inside each processing chamber 1 for performing thin-film deposition on three substrates w simultaneously. The thin-film deposition apparatus comprises three groups of lift pins. Each group of lift pins includes three lift pins 401, and the three lift pins 401 have the same height and are used to receive one substrate w. Each group of lift pins has a different height.

Preferably, the heights of the three groups of lift pins are stepped, and the received substrates w are correspondingly configured to be stepped. The three heating trays 3 are arranged in a triangular structure. The structure of a process manipulator 004 is matched with the triangular structure formed by the three heating trays 3 inside the processing chamber 1. The process manipulator 004 places three substrates w in descending order according to the heights of the three groups of lift pins. Specifically, as shown in FIG. 37, first, the substrate w1 is centered on the heating tray 3 corresponding to the lift pins 4011, and after centering, the substrate w1 is placed on the heating tray 3; then the substrate w2 is centered on the heating tray 3 corresponding to the lift pins 4012 and then placed on the heating tray 3; similarly, the substrate w3 is first centered on the heating tray 3 corresponding to the lift pins 4013 and then placed on the heating tray 3. The above arrangement improves the centering accuracy of the three substrates w with their respective heating trays 3. In addition, the lift pins 401 can achieve centering without moving up and down, simplifying the structure of the thin-film deposition apparatus.

Embodiment 34

As shown in FIGS. 38 and 39, embodiment 34 provides a thin-film deposition apparatus, which is different from embodiment 1 in that:

As shown in FIG. 38, the thin-film deposition apparatus further comprises a support mechanism for supporting the substrate w. The support mechanism includes lift pins 501 and a support ring 504. The heating tray 3 is provided with through-holes

301, and the lift pins 501 are disposed in the through-holes 301. A first lift mechanism 502 is connected to the lift pins 501, and drives the lift pins 501 to move up or down in the vertical direction, allowing a manipulator to remove the substrate w from the heating tray 3 or place the substrate w on the heating tray 3. The support ring 504 is disposed below the edge of the substrate w to support the substrate w. The support mechanism further includes a support shaft 505 disposed below the support ring 504, and the support shaft 505 is not fixedly connected to the support ring 504. The lift mechanism includes the first lift mechanism 502 and a second lift mechanism. In one specific implementation method, the second lift mechanism is connected to the support shaft 505 to drive the support shaft 504 to move up until the support shaft 505 contacts the support ring 504, allowing the substrate w to be lifted off the heating tray 3, or be lowered to be placed on the heating tray 3. In another specific implementation method, the support shaft 505 is fixed, and the support and separation between the support shaft 505 and the support ring 504 are achieved by the first lift mechanism 502 driving the heating tray 3 to move up and down.

In embodiment 34, a rotating mechanism 503 is disposed at the bottom of the first lift mechanism 502 for driving the first lift mechanism 502 to rotate about the center line AA' of the substrate w as the rotation axis to drive the heating tray 3 to rotate. The rotating mechanism 503 can also directly drive the heating tray 3 to rotate.

As shown in FIG. 39, which is an enlarged partial view of region A in FIG. 38, the heating tray 3 is configured with a central raised substrate-support portion 148 and a peripheral portion 147. The diameter of the substrate-support portion 148 is smaller than the diameter of the substrate w. The height difference between the substrate-support portion 148 and the peripheral portion 147 is between 0.3 mm and 0.7 mm, and the thickness of the support ring 504 equals the height difference between the substrate-support portion 148 and the peripheral portion 147. During the thin-film deposition process, the support ring 504 is separated from the support shaft 505, and the support ring 504 is supported by the peripheral portion 147 of the heating tray 3. At this time, the upper surface of the support ring 504 is in contact with the substrate w, and the lower surface of the support ring 504 is in contact with the heating tray 3, which can better conduct heat to the substrate w and prevent insufficient temperature at the edge of the substrate w. The inner diameter of the support ring 504 is smaller

than the diameter of the substrate-support portion 148. When the support ring 504 is placed on the peripheral portion 147, a gap is left between the support ring 504 and the substrate-support portion 148 to prevent excessive particles on the substrate w caused by the friction between the support ring 504 and the heating tray 3. The upper surface of the support ring 504 is provided with a first step 5041 and a second step 5042. The height of the second step 5042 is higher than the height of the first step 5041, and the first step 5041 is flush with the surface of the substrate-support portion 148. Placing the substrate w on the first step 5041 of the support ring 504 can prevent shaking. The first step 5041 and the second step 5042 are connected by a slope. When the substrate w is placed on the heating tray 3, the slope of the support ring 504 can play a guiding role.

As shown in FIGS. 40A to 40D, the present invention further discloses a process flow of using the thin-film deposition apparatus provided in this embodiment to perform thin-film deposition. The specific flow includes:

S1: A manipulator places the substrate w into the processing chamber. The first lift mechanism 502 drives the lift pins 501 to move up in the vertical direction and extend out of the through-holes 301 to support the substrate w placed by the manipulator; then the first lift mechanism 502 drives the lift pins 501 to move down in the vertical direction, and the lift pins 501 are retracted into the through-holes 301, allowing the substrate w to be placed on the heating tray 3;

S2: Deposit a thin film of a first thickness on the substrate w. FIG. 38 shows the state of the first thin-film deposition on the substrate w using the apparatus;

S3: The rotating mechanism 503 drives the first lift mechanism 502 to rotate, and simultaneously drives the heating tray 3 and the substrate w to rotate by a first angle from a first angular position (initial position) to a second angular position. As shown in FIG. 40A, the positions of the lift pins 501 change compared with the positions of the lift pins 501 in FIG. 38. In this step, the support ring 504 is driven to rotate together by the heating tray 3;

S4: The first lift mechanism 502 drives the heating tray 3 to move down, and drives the substrate w and the support ring 504 to move down together until the support

ring 504 contacts the support shaft 505. The support ring 504 stops moving down together with the substrate w after being supported by the support shaft 505. At this time, the first lift mechanism 502 continues to move down until the heating tray 3 is separated from the substrate w. In this step, the first lift mechanism 502 may not work, and the second lift mechanism drives the support shaft 505 to move up until the support shaft 505 contacts the support ring 504. The support shaft 505 continues to move up to separate the substrate w from the heating tray 3. In this step, the first lift mechanism 502 and the second lift mechanism may also work together. The first lift mechanism 502 drives the heating tray 3 to move down, and the second lift mechanism drives the support shaft 505 to move up and drive the support ring 504 and the substrate w to move up, allowing the support ring 504 to be separated from the heating tray 3;

S5: The rotating mechanism 503 drives the first lift mechanism 502 to rotate again, and simultaneously drives the heating tray 3 to rotate by a second angle to a third angular position. After this step is completed, the relative position between the substrate w and the heating tray 3 only needs to change. Preferably, in this step, the heating tray 3 rotates to the initial position, and the heating tray 3 can directly rotate back to the initial position or continuously rotate to the initial position. As shown in FIG. 40C, the positions of the lift pins 501 return to the initial positions of the lift pins 501 shown in FIG. 38. At this time, the relative position between the substrate w and the heating tray 3 changes. In this step, the support ring 504 does not rotate, and the rotating mechanism 503 may also directly drive the heating tray 3 to rotate;

S6: The first lift mechanism 502 drives the heating tray 3 to move up, driving the substrate w and the support ring 504 to move up together until the heating tray 3 contacts the substrate w. In this step, the first lift mechanism 502 may not work, and the second lift mechanism drives the support shaft 505 to move down until the substrate w contacts the heating tray 3. In this step, the first lift mechanism 502 and the second lift mechanism may also work together. The first lift mechanism 502 drives the heating tray 3 to move up, and the second lift mechanism drives the support shaft 505 to drive the support ring 504 and the substrate w to move down to achieve the contact between the support ring 504 and the heating tray 3;

S7: Deposit a thin film of a second thickness on the substrate w;

S8: Repeat S3 to S7 until n times of thin-film deposition are completed;

S9: When the manipulator removes the substrate w from the processing chamber, the first lift mechanism 502 drives the lift pins 501 to move up in the vertical direction and extend out of the through-holes of the heating tray 3 to lift the substrate w off the heating tray 3, allowing the manipulator to remove the substrate w. Then the first lift mechanism 502 drives the lift pins 501 to move down in the vertical direction, and the lift pins 501 are retracted into the through-holes.

When the rotating mechanism 503 drives the heating tray 3 to rotate, the introduction of process gas into the processing chamber is stopped, and an inert gas or nitrogen is introduced into the processing chamber to maintain the pressure within the processing chamber and maintain the RF source in the on state. After depositing a certain number of thin-film layers on the substrate w, some contaminant particles are suspended inside the processing chamber. At this time, the RF source is maintained in the on state to fill the processing chamber with RF electric field. The contaminant particles are electrically charged under the action of the RF electric field within the processing chamber, and the charged contaminant particles remain suspended and will not fall on the surface of the substrate w, preventing the contaminant particles from falling on the thin films deposited on the substrate w and avoiding contamination on the thin films deposited on the substrate w.

Other settings of this embodiment are the same as the settings of embodiment 1, and will not be repeated herein.

Embodiment 35

According to FIGS. 41 and 42, embodiment 35 provides a thin-film deposition apparatus, which is different from embodiment 34 in that:

As shown in FIG. 41, the support shaft 505 of the thin-film deposition apparatus is fixedly connected to the support ring 504. In one specific implementation method, the second lift mechanism is connected to the support shaft 505, and the support shaft 505 is driven to move up and down. In another specific implementation method, the support shaft 505 is fixed and stationary.

As shown in FIG. 42, which is an enlarged partial view of region B in FIG. 41, the heating tray 3 is configured with a central raised substrate-support portion 148 and a peripheral portion 147. The diameter of the substrate-support portion 148 is smaller than the diameter of the substrate w. The height difference between the substrate-support portion 148 and the peripheral portion 147 is between 1.5 mm and 2.9 mm, and the thickness of the support ring 504 is between 0.3 mm and 0.7 mm. When the substrate w is placed on the heating tray 3, the support ring 504 can move up and down within the space between the substrate w and the peripheral portion 147. During the thin-film deposition process, the second lifting mechanism drives the support shaft 505 to move up, driving the support ring 504 to the same height as the substrate-support portion 148. Alternatively, the support shaft 505 remains stationary, and the first lifting mechanism 502 drives the heating tray 3 to move down until the heating tray 3 is level with the support ring 504. At this time, the support ring 504 loses contact with the heating tray 3, and the support ring 504 and the heating tray 3 support the substrate w.

According to FIGS. 43A to 43D, the present invention also discloses a process flow for thin-film deposition using the thin-film deposition apparatus provided by this embodiment. The specific flow includes:

S1: A manipulator places the substrate w inside the processing chamber. The first lifting mechanism 502 drives the lift pins 501 to move up in the vertical direction, and extend out of the through-holes 301 to support the substrate w placed by the manipulator; then the first lift mechanism 502 drives the lift pins 501 to move down in the vertical direction, and the lift pins 501 are retracted into the through-holes 301, allowing the substrate w to be placed on the heating tray 3;

S2: Deposit a thin film of a first thickness on the substrate w. FIG. 41 shows the state of the first thin-film deposition on the substrate w using the apparatus;

S3: The first lift mechanism 502 drives the heating tray 3 to move up until the support ring 504 loses contact with the substrate w and the heating tray 3, or the second lift mechanism drives the support shaft 505 to move down and drive the support ring 504 to move down until the support ring 504 loses contact with the substrate w and the heating tray 3, or the first lift mechanism 502 and the second lift mechanism work together. The first lift mechanism 502 drives the heating tray 3 to move up, and the

second lift mechanism drives the support shaft 505, thereby driving the support ring 504 to move down until the support ring 504 loses contact with the substrate w and the heating tray 3. The rotating mechanism 503 drives the first lift mechanism 502 to rotate, and simultaneously drives the heating tray 3 and the substrate w to rotate by a preset angle from a first angular position (initial position) to a second angular position. As shown in FIG. 43A, the positions of the lift pins 501 change compared with the positions of the lift pins 501 in FIG. 41. In this step, the support ring 504 does not rotate, and the rotating mechanism 503 may also directly drive the heating tray 3 to rotate;

S4: The first lift mechanism 502 drives the heating tray 3 to move down, and drives the substrate w to move down together until the substrate w contacts the support ring 504. The substrate w stops moving down after being supported by the support ring 504. At this time, the first lift mechanism 502 continues to move down until the heating tray 3 is separated from the substrate w. In this step, the first lift mechanism 502 may not work, and the second lift mechanism drives the support shaft 505 to move up, thereby driving the support ring 504 to continue to move up after the support ring 504 contacts the substrate w, allowing the substrate w to be separated from the heating tray 3. In this step, the first lift mechanism 502 and the second lift mechanism may also work together. The first lift mechanism 502 drives the heating tray 3 to move down, and the second lift mechanism drives the support shaft 505 and the support ring 504 to move up, allowing the support ring 504 to be separated from the heating tray 3;

S5: The rotating mechanism 503 drives the first lift mechanism 502 to rotate again, and simultaneously drives the heating tray 3 to rotate by a second angle to a third angular position. After this step is completed, the relative position between the substrate w and the heating tray 3 only needs to change. Preferably, in this step, the heating tray 3 rotates to the initial position, and the heating tray 3 can directly rotate back to the initial position or continuously rotate to the initial position. As shown in FIG. 43C, the positions of the lift pins 501 return to the initial positions of the lift pins 501 shown in FIG. 41. At this time, the relative position between the substrate w and the heating tray 3 changes. In this step, the rotating mechanism 503 may also directly drive the heating tray 3 to rotate;

S6: The first lift mechanism 502 drives the heating tray 3 to move up until the

heating tray 3 contacts the substrate w. In this step, the first lift mechanism 502 may not work, and the second lift mechanism drives the support shaft 505 to move down until the substrate w contacts the heating tray 3. In this step, the first lift mechanism 502 and the second lift mechanism may also work together. The first lift mechanism 502 drives the heating tray 3 to move up, and the second lift mechanism drives the support shaft 505, thereby driving the support ring 504 and the substrate w to move down until the substrate w contacts the heating tray 3;

S7: Deposit a thin film of a second thickness on the substrate w;

S8: Repeat S3 to S7 until n times of thin-film deposition are completed;

S9: When the manipulator removes the substrate w from the processing chamber, the first lift mechanism 502 drives the lift pins 501 to move up in the vertical direction and extend out of the through-holes of the heating tray 3 to lift the substrate w off the heating tray 3, allowing the manipulator to remove the substrate w. Then the first lift mechanism 502 drives the lift pins 501 to move down in the vertical direction, and the lift pins 501 are retracted into the through-holes.

It should be noted that under the condition that the logics of the technical solutions are accurate, the plurality of embodiments described above can be combined with each other to form new solutions, that is, certain features, structures, or characteristics in one or more embodiments of the present application can be appropriately combined. The new solutions will not be repeated herein.

Through the above embodiments and related schematic diagrams, the present invention has disclosed relevant technologies in a specific and detailed manner, enabling those skilled in the art to implement the technologies accordingly. The embodiments described above are only used to illustrate the present invention, rather than limiting the present invention. The scope of the present invention shall be defined by the claims of the present invention. Changes in the number of elements described herein or replacement of equivalent elements shall still fall within the scope of the present invention.

Meanwhile, the present invention uses specific words to describe the

embodiments of the present invention. For example, "one embodiment," "an embodiment," and/or "some embodiments" refer to a certain feature, structure, or characteristic related to at least one embodiment of the present invention. Therefore, it should be emphasized and noted that "an embodiment" or "one embodiment" or "an alternative embodiment" mentioned two or more times in different positions in this specification do not necessarily refer to the same embodiment.

Similarly, it should be noted that in order to simplify the expression of the disclosure of the present invention and facilitate the understanding of one or more embodiments of the present invention, in the previous description of the embodiments of the present invention, various features are sometimes merged into one embodiment, accompanying drawing, or description thereof. However, this disclosure method does not mean that the object of the present invention requires more features than the features mentioned in the claims. In fact, the features of embodiments are fewer than all features of a single embodiment disclosed above.

What is claimed is:

1. A thin-film deposition apparatus, comprising:

a processing chamber, for performing thin-film deposition;

a heating tray, for supporting and heating a substrate, including a central raised substrate-support portion and a peripheral portion for placing a support ring;

a support mechanism, including a support ring arranged around the substrate-support portion and a support shaft for supporting the support ring;

a lift mechanism, for driving the support shaft to move up and down and/or driving the heating tray to move up and down;

a rotating mechanism, for driving the heating tray to rotate;

wherein, the thin-film deposition apparatus is configured as: after one thin-film deposition is completed, the rotating mechanism drives the heating tray to rotate the substrate from a first angular position to a second angular position; after the rotation is completed, the heating tray is separated from the substrate, and the substrate is supported by the support ring; the rotating mechanism drives the heating tray to rotate to a third angular position, while the support ring and the substrate remain at the second angular position; after the heating tray contacts the substrate, the next thin-film deposition is performed.

2. The thin-film deposition apparatus according to claim 1, wherein the third angular position is the same as the first angular position.

3. The thin-film deposition apparatus according to claim 1, wherein the inner diameter of the support ring is greater than the outer diameter of the substrate-support portion.

4. The thin-film deposition apparatus according to claim 1, wherein the support shaft is not fixedly connected to the support ring.

5. The thin-film deposition apparatus according to claim 4, wherein the surface

height difference between the substrate-support portion and the peripheral portion is the same as the thickness of the support ring.

6. The thin-film deposition apparatus according to claim 5, wherein the thickness of the support ring is between 0.3 mm and 0.7 mm.

7. The thin-film deposition apparatus according to claim 1, wherein the support ring is fixedly connected to the support shaft.

8. The thin-film deposition apparatus according to claim 7, wherein the surface height difference between the substrate-support portion and the peripheral portion is between 1.5 mm and 2.9 mm.

9. The thin-film deposition apparatus according to claim 8, wherein the thickness of the support ring is between 0.3 mm and 0.7 mm.

10. The thin-film deposition apparatus according to claim 7, wherein, when the rotating mechanism drives the heating tray to rotate together with the substrate, the support ring remains in a non-contact state with the heating tray and the substrate.

11. A thin-film deposition method, comprising:

placing a substrate into a processing chamber and depositing a thin film of a first thickness on the substrate;

a heating tray driving the substrate to rotate from a first angular position to a second angular position;

separating the heating tray from the substrate, supporting the substrate using a support ring, and the heating tray rotating from the second angular position to a third angular position;

bringing the heating tray into contact with the substrate, and depositing a thin film of a second thickness.

12. The thin-film deposition method according to claim 11, wherein the first angular position is the same as the third angular position.

13. The thin-film deposition method according to claim 11, wherein the separation of the heating tray from the substrate is achieved by a lift mechanism driving the heating tray to move down.

14. The thin-film deposition method according to claim 11, wherein the separation of the heating tray from the substrate is achieved by a lift mechanism driving the heating tray to move down and driving a support shaft to move up.

15. The thin-film deposition method according to claim 11, wherein the separation of the heating tray from the substrate is achieved by a lift mechanism driving a support shaft to move up.

16. The thin-film deposition method according to claim 11, wherein a support shaft is not fixedly connected to the support ring, and the support and separation between the support shaft and the support ring are achieved via relative movement.

17. The thin-film deposition method according to claim 16, wherein, when thin films are deposited on the substrate, the upper surface of the support ring is in contact with the substrate, and the lower surface of the support ring is in contact with the heating tray.

18. The thin-film deposition method according to claim 16, wherein, when the heating tray drives the substrate to rotate, the support ring is in a separated state from the support shaft, and the support ring is driven by the heating tray to rotate together.

19. The thin-film deposition method according to claim 11, wherein the support ring is fixedly connected to a support shaft, and the support shaft drives the support ring to move up and down.

20. The thin-film deposition method according to claim 19, wherein, after the support shaft drives the support ring to move down until the support ring loses contact with the substrate and the heating tray, the heating tray drives the substrate to rotate, and the support ring does not rotate.