THIN-FILM DEPOSITION DEVICE AND AUTOMATIC LEVELING METHOD FOR HEATING TRAY

TECHNICAL FIELD

The present invention relates to the field of semiconductor manufacturing equipment, and in particular to a thin-film deposition device and an automatic leveling method for a heating tray.

BACKGROUND

In thin-film deposition apparatuses, thin-film uniformity is related to many factors, such as temperature uniformity of a heating tray, parallelism between a showerhead and the heating tray, uniformity of a process gas, etc. Due to tolerance and installation error of each showerhead, it is difficult to ensure the parallelism between the showerhead and the heating tray, so the position of the heating tray needs to be adjusted. Usually, the heating tray is parallel to and rigidly connected to a support plate, and a leveling screw is provided at the bottom of the support plate. The heating tray is made parallel to the showerhead by manually adjusting the leveling screw. However, manual adjustment is time-consuming and laborious, and relies on the operator's manual perception, resulting in varying adjustment effects and low efficiency.

SUMMARY

The objective of the present invention is to provide a thin-film deposition device and an automatic leveling method for a heating tray, to solve the problem in the prior art of difficulty in accurately and quickly adjusting the parallelism between a heating tray and a showerhead.

To achieve the objective described above and other related objectives, the present invention provides a thin-film deposition device, comprising:

a heating tray, for placing at least three sensors, the at least three sensors being uniformly distributed around the center of the heating tray;

a showerhead, disposed above the heating tray, and located on a horizontal plane;

a leveling mechanism, connected to the heating tray, for automatically adjusting the pose of the heating tray based on the distance information fed back by the sensors, allowing the heating tray to be parallel to the showerhead.

Preferably, the leveling mechanism includes a fixed plate, a support plate, and at least three link rods; the at least three link rods are uniformly distributed around the center of the heating tray, the two ends of each link rod are respectively hinged to the fixed plate and the support plate, the fixed plate is fixedly connected to the bottom of a processing chamber, and the support plate is parallel to and rigidly connected to the heating tray.

Preferably, the number of the sensors and the number of the link rods are both three, the sensors and the link rods are in one-to-one correspondence, the hinge point between each link rod and the support plate has a projection point on the heating tray, the heating tray has a center point, and each sensor is disposed on a line connecting the projection point of a corresponding link rod to the center point.

Preferably, the distance information is a gap value between the heating tray and the showerhead.

The present invention further provides an automatic leveling method for the heating tray, comprising the following steps:

Step S1: determining whether the heating tray is parallel to the showerhead based on the distance information fed back by the sensors;

Step S2: when the heating tray is not parallel to the showerhead, calculating the current pose of the heating tray, and adjusting the pose of the heating tray to allow the heating tray to be parallel to the showerhead.

Preferably, in step S2, the step of calculating the current pose of the heating tray includes:

presetting an initial pose of the heating tray and initial coordinates of the sensors;

obtaining the height information of the sensors based on the distance information fed back by the sensors;

calculating the deviation angle and the tilt angle of the heating tray relative to the initial pose based on the height information, and then calculating current coordinates of the sensors;

calculating the coordinate transformation matrix based on the current coordinates and the initial coordinates of the sensors, the coordinate transformation matrix being a transformation matrix between the current pose and the initial pose of the heating tray, and obtaining the current pose of the heating tray according to the transformation matrix.

Preferably, in step S2, the step of adjusting the pose of the heating tray to allow the heating tray to be parallel to the showerhead includes:

calculating the current extension/retraction amount of the plurality of link rods in the leveling mechanism according to the inverse kinematics algorithm of parallel robots, calculating the adjustment amount for each link rod to move to a target position, and controlling the link rods to move according to the adjustment amount.

Preferably, the deviation angle is the angle between the line connecting the highest point and the lowest point of the heating tray and an xz plane, and the tilt angle is the angle between the line and an xy plane; wherein, a coordinate system $O\text{-}xyz$ is established based on the initial pose of the heating tray.

Preferably, the target position of each link rod is the position of a corresponding link rod when the heating tray is at the initial pose.

Preferably, in step S1, the distance information is a gap value between the heating tray and the showerhead.

As described above, the present invention provides a thin-film deposition device and an automatic leveling method for a heating tray, achieving the following beneficial effects: the parallelism between the heating tray and the showerhead can be quickly

adjusted; compared with manual leveling, the method is more convenient, faster, and has higher precision, thereby ensuring the uniformity of thin-film deposition. Moreover, during the process, the film thickness on a substrate can be adjusted by adjusting the parallelism between the heating tray and the showerhead, so as to improve the uniformity of thin-film deposition.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and performance of the present application are further described through the following embodiments and the accompanying drawings of the embodiments.

FIG. 1 is a schematic diagram of a thin-film deposition device according to an embodiment of the present invention;

FIG. 2 is a schematic diagram showing positions of three sensors on a heating tray according to an embodiment of the present invention;

FIG. 3 is a schematic diagram of three sensors on an initial plane according to an embodiment of the present invention;

FIG. 4 is a schematic diagram of projections of three current sensors on a vertical plane passing through a line L according to an embodiment of the present invention.

PREFERRED EMBODIMENTS OF THE APPLICATION

The embodiments of the present invention are described below through specific examples. 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. Various details of this specification can also be modified or changed based on different viewpoints and applications without departing from the spirit of the present invention.

It should be noted that the drawings provided in this embodiment are only for schematically illustrating the basic concept of the present invention. The drawings only

show components related to the present invention rather than being drawn according to the number, shape, and size of components in actual implementation. The form, quantity, and proportion of each component in actual implementation may be arbitrarily changed, and the component layout may be more complicated. In addition, the same reference numerals in the plurality of accompanying drawings represent the same or equivalent parts or components.

The present invention proposes a thin-film deposition device. As shown in FIG. 1, the device comprises: a showerhead 1, a heating tray 2, and a leveling mechanism 3. The showerhead 1 is disposed above the heating tray 2, and the showerhead 1 is always located on a horizontal plane. The leveling mechanism 3 is used to adjust the position of the heating tray 2 to allow the heating tray 2 to be parallel to the showerhead 1. The leveling mechanism 3 includes at least three link rods 31, a fixed plate 32, and a support plate 33. The plurality of link rods 31 are uniformly distributed around the center of the heating tray. One end of each link rod 31 is spherically hinged to the fixed plate 32, and the other end is connected to the support plate 33. The support plate 33 is parallel to and rigidly connected to the heating tray 2. The fixed plate 32 is fixedly disposed at the bottom of a processing chamber 4. The leveling mechanism 3 adopts a three-degree-of-freedom parallel robot mechanism with one translational motion and two rotational motions. At least three sensors uniformly distributed around the center of the heating tray 2 are placed on the heating tray 2 for obtaining distance information to determine whether the heating tray 2 is parallel to the showerhead 1.

In this embodiment, the link rods 31 are electric cylinders. When the electric cylinders are controlled to extend and retract, the support plate 33 drives the heating tray 2 to move, causing the position and orientation of the heating tray 2 to change. The uniform arrangement of three electric cylinders better ensures the stability of the device. The material of the support plate 33 is a high-hardness material, such as stainless steel. Increasing the rigidity of the support plate 33 can prevent relatively large deformation of the support plate 33 after the processing chamber 4 is evacuated, ensuring the stability of the entire structure during the process. In this embodiment, the number of sensors is also three. As shown in FIG. 2, the three sensors A, B, and C are respectively disposed on lines connecting the three connection points D, E, and F between the three link rods 31 and the heating tray 2 to the center of the heating tray 2. Wherein, the connection points between the three link rods 31 and the heating tray

are the projection points of the hinge points between the link rods 31 and the support plate 33 on the heating tray 2.

The present invention further proposes an automatic leveling method for a heating tray, which uses the thin-film deposition device described above. Therefore, the above description can be used to explain the automatic leveling method. Specifically, the automatic leveling method comprises the following steps:

Step S1: Determine whether the heating tray is parallel to the showerhead based on the distance information fed back by the sensors.

In this embodiment, three air gap sensors are used to measure the gap between the heating tray and the showerhead. The differences between the three gap values and a preset target value, or the differences between each pair of the three gap values, are calculated. When the maximum of the three differences is greater than or equal to a preset threshold, it is determined that the heating tray is not parallel to the showerhead; otherwise, it is determined that the heating tray is parallel to the showerhead.

In some embodiments, three position sensors may also be used. The differences between the positions of the three sensors and a preset target position, or the differences between each pair of the three sensor positions, are calculated. When the maximum of the three differences is smaller than a preset threshold, it is determined that the heating tray is not parallel to the showerhead; otherwise, it is determined that the heating tray is parallel to the showerhead.

Step S2: When the heating tray is not parallel to the showerhead, calculate the deviation angle and the tilt angle of the heating tray, obtain the coordinates of the sensors in a coordinate axis, then calculate the current pose of the heating tray, and adjust the pose of the heating tray to allow the heating tray to be parallel to the showerhead.

Specifically, step S2 includes the following steps:

Step S21: obtaining the height information of the three sensors;

Step S22: calculating the deviation angle and the tilt angle of the heating tray relative to the initial pose, and then calculating the current coordinates of the three sensors;

Step S23: calculating the transformation matrix between the current pose and the initial pose of the heating tray, and then obtaining the rotation angle of the heating tray around the coordinate axis;

Step S24: calculating the current extension/retraction amount of the three link rods in the leveling mechanism according to the inverse kinematics algorithm of parallel robots, calculating the adjustment amount for each link rod to move to a target position, and controlling the link rods to move.

FIG. 3 shows a schematic diagram of the three sensors on an initial plane. The three sensors on the initial plane are denoted as A_0, B_0, and C_0. FIG. 4 shows projections of the three current sensors on a vertical plane passing through a line L. The three sensors at the current positions are denoted as A_1, B_1, and C_1. In this embodiment, since the three sensors are uniformly distributed on the circumference of the heating tray, the three sensors form an equilateral triangle. An initial plane is set, i.e., the heating tray is at the initial pose. A spatial rectangular coordinate system $O\text{-}xyz$ is established with the center of the equilateral triangle formed by the three sensors on the initial plane as the origin O, one median line as the y axis, and the vertical upward direction as the z axis, according to the right-hand rule.

In step S21, since the showerhead is located on a horizontal plane and is parallel to the xy plane, the z coordinates of the three sensors can be calculated based on the gap values between the heating tray and the showerhead measured by the sensors.

As shown in FIG. 3 and FIG. 4, in step S22, when the heating tray tilts, due to the circular shape, a highest point and a lowest point are generated. The line connecting the highest point and the lowest point is defined as line L. Based on the z coordinates of the three sensors, the angle α between the line L and the xz plane and the angle β between the line L and the xy plane are calculated. Then, the coordinates of the

three sensors in the current coordinate system $O\text{-}xyz$ are calculated based on the two angles.

The specific calculation process is as follows:

$$\delta h_2 = z_2 - z_1$$
$$\delta h_3 = z_3 - z_1$$
$$l_1 = R\cos(90 - \alpha) = R\sin\alpha$$
$$l_2 = R\cos(\alpha + 30)$$
$$l_3 = R\cos(\alpha - 30)$$
$$L_2 = l_1 - l_2$$
$$L_3 = l_1 + l_3$$
$$\sin\beta = \frac{\delta h_2}{L_2} = \frac{\delta h_3}{L_3}$$
$$\frac{\delta h_2}{\delta h_3} = \frac{L_2}{L_3} = \frac{R\sin\alpha + R\cos(\alpha + 30)}{R\sin\alpha + R\cos(\alpha - 30)}$$

Wherein, z_1, z_2, and z_3 are the z coordinates of the three sensors respectively, and R is the distance from the three sensors to the center of the heating tray. According to the formulas described above, α and β can be obtained, and then the current coordinates of the three sensors can be calculated.

In step S23, based on the current positions and the initial positions of the three sensors, the coordinate transformation matrix is calculated, which is the transformation matrix between the current pose and the initial pose of the heating tray, and then the current pose of the heating tray is calculated.

In step S24, based on the current pose of the heating tray, combined with the inverse kinematics algorithm of parallel robots, the current extension/retraction amount of the three link rods is calculated, and then the adjustment amount for each link rod to move to the target position is obtained. Specifically, a horizontal plane is taken as the initial pose of the heating tray, and correspondingly, each link rod has an initial position. After the current extension/retraction amount of the three link rods is calculated, the adjustment amount for each link rod to move to the initial position is calculated, and the link rods are controlled to move.

In step S24, the target positions of the link rods can also be set based on the non-uniformity of thin-film deposition on a substrate, to adjust the parallelism between the

heating tray and the showerhead, thereby improving the uniformity of thin-film deposition. Specifically, during the process, when the thin film in a certain region on the substrate is relatively thick, the target positions of the link rods are reset to change the tilt angle of the heating tray. After the link rods move, the gap values between the heating tray and the showerhead corresponding to the region are reduced, thereby improving the film thickness uniformity.

After step S2, step S1 is repeated to adjust the position of the heating tray in real time, so that the heating tray always remains parallel to the showerhead.

The embodiments described above are only illustrative of the principles and effects of the present invention, and are not intended to limit the present invention. Anyone skilled in the art can modify or change the embodiments described above without departing from the spirit and scope of the present invention. Therefore, all equivalent modifications or changes made by those having ordinary knowledge in the art without departing from the spirit and technical idea disclosed in the present invention shall still be covered by the claims of the present invention.

What is claimed is:

1. A thin-film deposition device, comprising:

a heating tray, for placing at least three sensors, the at least three sensors being uniformly distributed around the center of the heating tray;

a showerhead, disposed above the heating tray, and located on a horizontal plane;

a leveling mechanism, connected to the heating tray, for automatically adjusting the pose of the heating tray based on the distance information fed back by the sensors, allowing the heating tray to be parallel to the showerhead.

2. The thin-film deposition device according to claim 1, wherein the leveling mechanism includes a fixed plate, a support plate, and at least three link rods, the at least three link rods are uniformly distributed around the center of the heating tray, the two ends of each link rod are respectively hinged to the fixed plate and the support plate, the fixed plate is fixedly connected to the bottom of a processing chamber, and the support plate is parallel to and rigidly connected to the heating tray.

3. The thin-film deposition device according to claim 2, wherein the number of the sensors and the number of the link rods are both three, the sensors and the link rods are in one-to-one correspondence, the hinge point between each link rod and the support plate has a projection point on the heating tray, the heating tray has a center point, and each sensor is disposed on a line connecting the projection point of a corresponding link rod to the center point.

4. The thin-film deposition device according to claim 1, wherein the distance information is a gap value between the heating tray and the showerhead.

5. An automatic leveling method for a heating tray, using the thin-film deposition device according to any one of claims 1 to 4, comprising the following steps:

Step S1: determining whether the heating tray is parallel to the showerhead based on the distance information fed back by the sensors;

Step S2: when the heating tray is not parallel to the showerhead, calculating the current pose of the heating tray, and adjusting the pose of the heating tray to allow the heating tray to be parallel to the showerhead.

6. The automatic leveling method for a heating tray according to claim 5, wherein in step S2, the step of calculating the current pose of the heating tray includes:

presetting an initial pose of the heating tray and initial coordinates of the sensors;

obtaining the height information of the sensors based on the distance information fed back by the sensors;

calculating the deviation angle and the tilt angle of the heating tray relative to the initial pose based on the height information, and then calculating current coordinates of the sensors;

calculating the coordinate transformation matrix based on the current coordinates and the initial coordinates of the sensors, the coordinate transformation matrix being a transformation matrix between the current pose and the initial pose of the heating tray, and obtaining the current pose of the heating tray according to the transformation matrix.

7. The automatic leveling method for a heating tray according to claim 5, wherein in step S2, the step of adjusting the pose of the heating tray to allow the heating tray to be parallel to the showerhead includes:

calculating the current extension/retraction amount of the plurality of link rods in the leveling mechanism according to the inverse kinematics algorithm of parallel robots, calculating the adjustment amount for each link rod to move to a target position, and controlling the link rods to move according to the adjustment amount.

8. The automatic leveling method for a heating tray according to claim 6, wherein the deviation angle is the angle between the line connecting the highest point and the lowest point of the heating tray and an xz plane, and the tilt angle is the angle between

the line and an xy plane; wherein, a coordinate system $O\text{-}xyz$ is established based on the initial pose of the heating tray.

9. The automatic leveling method for a heating tray according to claim 7, wherein the target position of each link rod is the position of a corresponding link rod when the heating tray is at the initial pose.

10. The automatic leveling method for a heating tray according to claim 5, wherein in step S1, the distance information is a gap value between the heating tray and the showerhead.