SUBSTRATE ELECTROPLATING METHOD AND DEVICE AND DEFORMABLE DIFFUSION PLATE

TECHNICAL FIELD

The present invention relates to the field of semiconductor manufacturing equipment, and in particular to a substrate electroplating method and device and a deformable diffusion plate.

BACKGROUND

In the electroplating process, an edge effect is present, that is, due to the direct contact between the edge of a substrate and a chuck, the resistance in the edge region of the substrate is smaller than the resistance in the central region of the substrate, and current tends to pass through paths with lower resistance, therefore, the electric field strength in the edge region is greater than the electric field strength in the central region, resulting in a higher metal deposition rate in the edge region than in the central region, which in turn leads to a significantly high metal deposition thickness in the edge region of the substrate. The metal deposition rate distribution within the substrate sheet is positively correlated with the metal deposition thickness distribution. For different chip layers or different products, generally, a uniform metal deposition thickness distribution within the substrate sheet is desired. In some specific cases, a requirement that the metal deposition thickness in the edge region of the substrate is different from the metal deposition thickness in the central region may be present, such as for chemical mechanical polishing (CMP) removal of excess metal deposition.

Existing devices can control the deposition rate within the substrate sheet by providing a second anode and adjusting the current output of the second anode, or by replacing a diffusion plate with a different one.

For the solution of adjusting the current output of the second anode, an electroplating chamber requires a multi-anode design, with an independent electroplating power supply controlling the current output of the second anode at the outer ring, which results in a complex structure and increased equipment cost.

For the solution of replacing the diffusion plate with a different one of a different shape, the principle is to use a diffusion plate of a different shape to change the spacing between different regions of the substrate and the diffusion plate, thereby adjusting the electric field distribution. Therefore, depending on different product requirements, not only is the diffusion plate required to be manually replaced with the installation

position adjusted, but also post-replacement deposition thickness testing and monitoring shall be performed, which significantly affects the effective operating time of equipment.

Therefore, how to provide an efficient substrate electroplating method and device for controlling the deposition rate within the substrate sheet becomes a problem that needs to be solved.

SUMMARY

In view of the above-mentioned shortcomings of the prior art, the present invention aims to provide a substrate electroplating method and device, and a deformable diffusion plate, to solve the technical problem in existing substrate electroplating processes of difficulty in efficiently controlling the deposition rate within the substrate sheet.

To achieve the objective described above and other related objectives, the present invention proposes a substrate electroplating method, comprising the following steps: configuring a substrate in an electroplating bath, the substrate having a surface to be electroplated, the electroplating bath containing an electroplating solution and being provided with a deformable diffusion plate, wherein the deformable diffusion plate has a first surface, and the first surface faces the surface to be electroplated; adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated of the substrate; electroplating metal onto the surface to be electroplated of the substrate.

Optionally, the step of adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated of the substrate includes: pre-acquiring the correspondence between a preset deposition thickness from the central region to the edge region of the surface to be electroplated and the spacing, and automatically adjusting the shape of the deformable diffusion plate according to the preset deposition thickness and the correspondence, to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated, so that the actual deposition thickness from the central region to the edge region of the surface to be electroplated conforms to the preset deposition thickness.

The present invention further proposes a substrate electroplating device, comprising: an electroplating bath, for containing an electroplating solution; a chuck,

for configuring the substrate in the electroplating bath, the substrate having a surface to be electroplated; a deformable diffusion plate, disposed within the electroplating bath, wherein the deformable diffusion plate has a first surface, the first surface faces the surface to be electroplated, and the edge of the deformable diffusion plate is fixedly connected to the inner wall of the electroplating bath; a deformation regulating device, for adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated of the substrate.

Optionally, the deformable diffusion plate includes a first layer plate and a second layer plate superimposed on each other, the first layer plate and the second layer plate have different coefficients of thermal expansion, the deformation regulating device includes a temperature-varying element, and the temperature-varying element is used to change the temperature of the deformable diffusion plate to adjust the shape of the deformable diffusion plate.

Optionally, the temperature-varying element is disposed between the first layer plate and the second layer plate.

Optionally, the deformation regulating device further includes a temperature controller, the temperature-varying element is used to change the temperature of the deformable diffusion plate according to a temperature control signal from the temperature controller to adjust the shape of the deformable diffusion plate.

Optionally, the deformation regulating device further includes a deformation detector for detecting the deformation of the deformable diffusion plate and feeding the deformation back to the temperature controller; the temperature controller is also used to generate the temperature control signal based on the deformation.

Optionally, the deformation regulating device further includes a temperature detector for detecting the temperature of the deformable diffusion plate and feeding the temperature back to the temperature controller; the temperature controller is also used to generate the temperature control signal based on the temperature.

Optionally, the deformation regulating device includes an actuator and an actuation controller; the actuator is drivingly connected to the central region of the deformable diffusion plate, and is used to drive the deformable diffusion plate according to an actuation control signal from the actuation controller to adjust the shape of the deformable diffusion plate.

Another aspect of the present invention further proposes a deformable diffusion plate applied to a substrate processing device, and the deformable diffusion plate includes a first layer plate and a second layer plate superimposed on each other, wherein the first layer plate and the second layer plate have different coefficients of thermal expansion.

As described above, the present invention provides a substrate electroplating method and device, which at least have the following beneficial effects:

1. By providing a deformable diffusion plate and a deformation regulating device, the spacing between the deformable diffusion plate (from the central region to the edge region) and the surface to be electroplated of the substrate can be adjusted by adjusting the shape of the deformable diffusion plate, thereby adjusting the electric field distribution and thus meeting different deposition thickness distribution requirements;

2. The spacing between the deformable diffusion plate (from the central region to the edge region) and the surface to be electroplated of the substrate can be adjusted without the need to disassemble and replace the deformable diffusion plate;

3. Utilizing the difference in coefficients of thermal expansion of different materials, predictable deformation of the deformable diffusion plate is achieved through internal temperature variation, without the need for additional mechanisms, occupying no internal space of the electroplating bath, and not interfering with other components within the electroplating bath;

4. Utilizing the deformable property of the deformable diffusion plate, the actuator drives the deformable diffusion plate to undergo predictable deformation, and by adjusting the shape of the deformable diffusion plate, the spacing between the deformable diffusion plate (from the central region to the edge region) and the surface to be electroplated of the substrate can be adjusted to adjust the electric field distribution, thereby meeting different deposition thickness distribution requirements.

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 structural view of the substrate electroplating device according to Embodiment 1 of the present invention;

FIG. 2 is a schematic structural view of the deformable diffusion plate according

to Embodiment 1 of the present invention;

FIG. 3 is a schematic top view of the deformable diffusion plate according to Embodiment 1 of the present invention;

FIG. 4 is a schematic view of electric field line distribution when the deformable diffusion plate according to Embodiment 1 of the present invention is in a first form;

FIG. 5 is a schematic view of electric field line distribution when the deformable diffusion plate according to Embodiment 1 of the present invention is in a second form;

FIG. 6 is a schematic view of electric field line distribution when the deformable diffusion plate according to Embodiment 1 of the present invention is in a third form; and

FIG. 7 is a schematic structural view of the substrate electroplating device according to Embodiment 3 of the present invention.

PREFERRED EMBODIMENTS OF THE APPLICATION

The embodiments of the present invention are illustrated through the following 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 in this specification can also be modified or adjusted based on different viewpoints and applications without departing from the spirit of the present invention.

It should be noted that the accompanying drawings of the present disclosure only schematically illustrate the basic concept of the present invention. Although the accompanying 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 can be arbitrarily adjusted, and the layout of the components may also be more complex.

In the following description involving the accompanying drawings, unless otherwise indicated, the same numbers in different accompanying drawings represent the same or similar elements. The embodiments described in the following exemplary embodiments do not represent all embodiments consistent with the present invention. Rather, the embodiments are merely examples of devices consistent with some aspects

of the present invention as detailed in the appended claims.

The terms used in the present disclosure are for the purpose of describing particular embodiments only and are not intended to limit the present disclosure. The singular forms "a/an," "said," and "the" used in the present disclosure and the appended claims are also intended to include plural forms unless the context clearly indicates otherwise. It should also be understood that the term "and/or" used herein refers to and includes any or all possible combinations of one or more associated listed items.

In the description of the present disclosure, unless otherwise specified and defined, it should be noted that the terms "install," "interconnect," and "connect" should be understood in a broad sense. For example, the connection may be a mechanical connection or an electrical connection, or an internal communication between two elements, and the connection may be a direct connection or an indirect connection through an intermediate medium. For those skilled in the art, the specific meanings of the terms described above can be understood based on specific circumstances.

It should be understood that although the terms "first," "second," "third," and the like may be used in the present disclosure to describe various information, such information should not be limited to these terms. These terms are only used to distinguish the same type of information from each other.

In the description of the present disclosure, it should be understood that the terms "upper," "lower," "front," "back," "left," "right," "vertical," "horizontal," "top," " bottom," "inner," "outer," etc., that may be used indicate orientations or positional relationships based on the orientations or positional relationships shown in the accompanying drawings. The terms are only for convenience in describing the present invention and simplifying the description, and do not indicate or imply that the device or element referred to must have a specific orientation, be constructed and operated in a specific orientation, and therefore cannot be construed as limiting the present invention.

Embodiment 1

This embodiment provides a substrate electroplating device. As shown in FIG. 1, which shows a schematic structural view of the substrate electroplating device according to Embodiment 1 of the present invention, the substrate electroplating device comprises: an electroplating bath 1, for containing an electroplating solution 11; a chuck 2, for placing a substrate 3 in the electroplating bath 1, the substrate 3

having a surface to be electroplated 30; a deformable diffusion plate 4, disposed within the electroplating bath 1, wherein the deformable diffusion plate 4 has a first surface 40, the first surface 40 faces the surface to be electroplated 30, and the edge region of the deformable diffusion plate 4 is fixedly connected to the inner wall of the electroplating bath 1; a deformation regulating device 5, for adjusting the shape of the deformable diffusion plate 4 to adjust the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30.

As shown in FIG. 1, in this embodiment, the electroplating bath 1 is a bath body with an upward opening. The interior of the electroplating bath 1 is configured as a space for performing electroplating on the substrate 3. This space contains the electroplating solution 11 and is also provided with an electroplating anode 6 and an ion exchange membrane 7. The electroplating anode 6 is disposed at the bottom of the electroplating bath 1, and the ion exchange membrane 7 is disposed above the electroplating anode 6. The deformable diffusion plate 4 is located below the substrate 3, close to the surface to be electroplated 30 of the substrate 3. In this embodiment, the substrate 3 and the deformable diffusion plate 4 are located above the ion exchange membrane 7. Additionally, the plate surface of the substrate 3 faces downward, so the surface to be electroplated 30 of the substrate 3 is the lower surface of the substrate 3. The edge of the deformable diffusion plate 4 is mounted on the inner wall of the electroplating bath 1. The chuck 2 is located above the electroplating bath 1, used to clamp the substrate 3 and place the substrate 3 in the electroplating bath 1 during electroplating, so that the substrate 3 is immersed in the electroplating solution 11 in the electroplating bath 1. During electroplating, the substrate 3 is configured as an electroplating cathode and immersed in the electroplating solution 11 in the electroplating bath 1. Metal cations in the electroplating solution 11 pass through the ion exchange membrane 7 and the deformable diffusion plate 4 in sequence, and are then reduced to metal on the surface to be electroplated 30 of the substrate 3, depositing on the surface to be electroplated 30.

During the electroplating process, the electric field intensity in different regions of the substrate 3 affects the metal deposition rate, which in turn affects the metal deposition thickness. Since the edge of the substrate 3 is in direct contact with the chuck 2, the resistance in the edge region of the substrate 3 is lower than the resistance in the central region of the substrate 3. Current tends to flow through paths of lower resistance, so the electric field intensity in the edge region is greater than the electric field intensity in the central region, leading to a higher deposition rate at the edge than at the center. This results in a significantly high deposition thickness in the edge region of the substrate 3, i.e., the edge effect. Therefore, to better control the metal deposition

thickness in different regions of the substrate 3, it is necessary to control the electric field intensity in different regions of the substrate 3.

In this embodiment, a deformable diffusion plate 4 is disposed within the electroplating bath 1. When electroplating is performed on the substrate 3, the surface to be electroplated 30 of the substrate 3 is the lower surface of the substrate 3. The deformable diffusion plate 4 is located below the substrate 3 and has a first surface 40 facing the surface to be electroplated 30. The main body of the deformable diffusion plate 4 is made of an insulating material and is provided with a plurality of through holes, allowing the electroplating solution 13 to pass through the through holes, thereby uniformizing the flow field and consequently the electric field. By adjusting the spacing between the first surface 40 of the deformable diffusion plate 4 (from the central region to the edge region) and the surface to be electroplated 30, the uniformity of the electric field distribution can be further improved.

Once a traditional diffusion plate is fixedly installed in the electroplating bath 1, it is difficult to adjust the spacing between the diffusion plate and the substrate, especially to adjust the spacing between different regions of the diffusion plate (from the central region to the edge region) and the substrate with varying spacing variations (i.e., changing the shape of the diffusion plate itself). However, in this embodiment, a deformable diffusion plate 4 and a deformation regulating device 5 are included. The deformable diffusion plate 4 is made of a deformable material and has a deformable property. Therefore, even after the deformable diffusion plate 4 is installed in the electroplating bath 1, the shape of the deformable diffusion plate 4 can be adjusted by the deformation regulating device 5, thereby adjusting the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30, and consequently adjusting the electric field distribution between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30.

As shown in FIG. 2, which shows a schematic structural view of the diffusion plate according to Embodiment 1 of the present invention, exemplarily, the deformable diffusion plate 4 includes a first layer plate 41 and a second layer plate 42 superimposed on each other. The first layer plate 41 is located above the second layer plate 42, and the upper surface of the first layer plate 41 is the first surface 40. The coefficients of thermal expansion of the first layer plate 41 and the second layer plate 42 are different. As shown in FIG. 1, the deformation regulating device 5 includes a temperature-varying element 511, which is disposed between the first layer plate 41 and the second layer plate 42, and is used to change the temperature of the deformable

diffusion plate 4 to adjust the shape of the deformable diffusion plate 4.

Preferably, in this embodiment, the deformation regulating device 5 further includes a temperature controller 512. The temperature-varying element 511 is used to change the temperature of the deformable diffusion plate 4 according to a temperature control signal from the temperature controller 512, so as to adjust the shape of the deformable diffusion plate 4. Exemplarily, the temperature controller 512 can be a separately configured device with control functions such as a microcontroller, PLC, or computer, or the temperature controller 512 can be an original control device of the substrate electroplating device itself.

Since the coefficients of thermal expansion of the first layer plate 41 and the second layer plate 42 are different, when the temperature-varying element 511 changes the temperature, the degrees of deformation of the first layer plate 41 and the second layer plate 42 will also differ, causing the deformable diffusion plate 4 to undergo warped deformation in the normal direction of the substrate 3. Based on the difference in thermal expansion coefficients between the first layer plate 41 and the second layer plate 42, the output power of the temperature-varying element 511 can be adjusted to change the temperature of the deformable diffusion plate 4, causing the deformable diffusion plate 4 to undergo desired deformation. This adjusts the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30, thereby achieving the desired electric field distribution.

As shown in FIG. 3, which shows a schematic top view of the deformable diffusion plate according to Embodiment 1 of the present invention, the temperature-varying element 511 includes a plurality of heating wires 5111, distributed between the first layer plate 41 and the second layer plate 42 along the diameter of the deformable diffusion plate 4. Preferably, in this embodiment, the deformation regulating device 5 further includes a plurality of temperature detectors 513. As shown in FIG. 3, exemplarily, in this embodiment, four temperature detectors 513 are included, uniformly distributed on the deformable diffusion plate 4. Preferably, the temperature detectors 513 are disposed between the first layer plate 41 and the second layer plate 42, and are used to transmit the detected temperature of the deformable diffusion plate 4 to the temperature controller 512, enabling closed-loop control of the temperature-varying element 511. The deformable diffusion plate 4 is provided with a plurality of through holes (not shown), so the arrangement of the heating wires 5111 and temperature detectors 513 should avoid the through holes.

It should be understood that the number and arrangement of the heating wires

5111 and temperature detectors 513 shown in FIG. 3 are merely exemplary. In other possible embodiments, the heating wires 5111 could also be arranged, for example, in the form of a spiral line, and the number of temperature detectors 513 could be smaller than or more than four. If the deformation of the first layer plate 41 and the second layer plate 42 due to temperature changes can meet a desired deformation, optionally, the heating wires 5111 could also be distributed only in specific regions of the deformable diffusion plate 4, such as the edge region. Those skilled in the art can reasonably arrange the heating wires 5111 and temperature detectors 513 based on the teachings of this disclosure.

It should be understood that in other possible embodiments, the deformation regulating device 5 further includes a deformation detector, such as an image sensor or a displacement sensor, used to detect the deformation of the deformable diffusion plate 4 and feed the detected deformation back to the temperature controller 512. The temperature controller 512 is also used to generate a temperature control signal based on the detected deformation. For example, if the deformation detector detects that the deformation of the deformable diffusion plate 4 is small and does not meet expectations, this detection result is fed back to the temperature controller 512, which generates a temperature control signal to increase the heating power of the heating wires 5111 to increase the deformation of the deformable diffusion plate 4.

FIGS. 4 to 6 respectively show schematic views of the distribution of electric field lines 8 between the first surface 40 and the surface to be electroplated 30 when the deformable diffusion plate 4 according to Embodiment 1 of the present invention is in a first form, a second form, and a third form.

As shown in FIG. 4, in the first form, the deformable diffusion plate 4 presents a flat, non-warped plate shape. No difference is present in the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30. Due to the edge effect, the electric field in the edge region is more concentrated than the electric field in the central region, and the electric field lines 8 close to the edge region of the substrate 3 appear curved, bending toward the edge of the substrate 3.

As shown in FIG. 5, the dashed lines X indicate the position of the first surface 40 in the first form. When the coefficient of thermal expansion of the first layer plate 41 is smaller than the coefficient of thermal expansion of the second layer plate 42 (refer to the first layer plate 41 and second layer plate 42 in FIG. 2), after the deformable diffusion plate 4 is heated, the deformation of the second layer plate 42

located at the lower portion of the deformable diffusion plate 4 is greater than the deformation of the first layer plate 41 located at the upper portion of the deformable diffusion plate 4, causing the deformable diffusion plate 4 to warp as shown in FIG. 5. The spacing between the first surface 40 and the surface to be electroplated 30 gradually decreases from the central region to the edge region. Compared with the first form, although in the second form, the overall spacing between the first surface 40 and the surface to be electroplated 30 increases, the increase amount gradually decreases from the central region to the edge region. This suppresses the edge effect, making the distribution of the electric field lines 8 between the first surface 40 and the surface to be electroplated 30 more uniform, without concentration toward the edge region as in FIG. 4.

As shown in FIG. 6, the dashed lines X indicate the position of the first surface 40 in the first form. When the coefficient of thermal expansion of the first layer plate 41 is greater than the coefficient of thermal expansion of the second layer plate 42 (refer to the first layer plate 41 and second layer plate 42 in FIG. 2), after the deformable diffusion plate 4 is heated, the deformation of the first layer plate 41 located at the upper portion of the deformable diffusion plate 4 is greater than the deformation of the second layer plate 42 located at the lower portion of the deformable diffusion plate 4, causing the deformable diffusion plate 4 to warp as shown in FIG. 6. The spacing between the first surface 40 and the surface to be electroplated 30 gradually increases from the central region to the edge region. Compared with the first form, although in the third form, the overall spacing between the first surface 40 and the surface to be electroplated 30 decreases, the decrease amount gradually decreases from the central region to the edge region. This intensifies the edge effect, and compared with the electric field line distribution in FIGS. 4 and 5, the distribution of the electric field lines 8 between the first surface 40 and the surface to be electroplated 30 becomes more concentrated toward the edge region.

Therefore, based on actual electroplating requirements, suitable materials for the first layer plate 41 and the second layer plate 42 can be selected. According to the coefficients of thermal expansion of the first layer plate 41 and the second layer plate 42, the output power of the temperature-varying element 511 can be controlled to change the shape of the deformable diffusion plate 4, causing the deformable diffusion plate 4 to undergo desired deformation. This adjusts the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30, thereby achieving desired electric field distribution. Exemplarily, the materials of the first layer plate 41 and the second layer plate 42 include, but are not limited to, PET, PVDF, PFA, PTFE, PVC, PP, PEEK, HDPE, PPS, etc.

Furthermore, in other possible embodiments, the temperature-varying element 511 can also be a cooling element, or can integrate both a cooling element and a heating element, allowing flexible adjustment of the shape of the deformable diffusion plate 4. It should be understood that when the temperature-varying element 511 is a cooling element, the deformation trend of the deformable diffusion plate 4 is opposite to the deformation trend of the deformable diffusion plate 4 when the temperature-varying element 511 is a heating element.

Optionally, the correspondence between a preset deposition thickness from the central region to the edge region of the surface to be electroplated 30 and the spacing (i.e., several spacings between the first surface 40 and the surface to be electroplated 30 corresponding to different regions from the central region to the edge region) can be pre-acquired. This correspondence is stored in a control device 512 of the deformation regulating device 5. The control device 512 can automatically adjust the shape of the deformable diffusion plate 4 based on the preset deposition thickness and the correspondence, thereby adjusting the spacing between the first surface 40 of the deformable diffusion plate 4 (from the central region to the edge region) and the surface to be electroplated 30 of the substrate 3, so that the actual deposition thickness from the central region to the edge region of the surface to be electroplated 30 matches the preset deposition thickness. This enables automatic spacing adjustment by the deformation regulating device 5 without requiring an operator to manually input adjustment parameters into the deformation regulating device 5.

In this embodiment, utilizing the difference in thermal expansion coefficients of different materials, the deformable diffuser plate 4 achieves predictable deformation by changing temperature (heating or cooling), thereby adjusting the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30, thus obtaining a desired electric field distribution. No additional mechanisms are required, no internal space of the electroplating bath 1 is occupied, and no interference with other components in the electroplating bath 1 occurs. The spacing between the first surface 40 of the deformable diffuser plate 4 (from the central region to the edge region) and the surface to be electroplated 30 of the substrate 3 can be adjusted without disassembly and replacement, ensuring that the actual deposition thickness on the surface to be electroplated 30 from the central region to the edge region conforms to the preset deposition thickness.

Embodiment 2

This embodiment provides a deformable diffuser plate applied to a substrate

processing device. As shown in FIG. 1, exemplarily, the deformable diffuser plate 4 is applied to a substrate electroplating device. As shown in FIG. 2, the deformable diffuser plate 4 includes a first layer plate 41 and a second layer plate 42 superimposed on each other, wherein the thermal expansion coefficients of the first layer plate 41 and the second layer plate 42 are different. For a detailed description of the deformable diffuser plate 4, refer to Embodiment 1, which will not be repeated herein.

Embodiment 3

This embodiment provides a substrate electroplating device. As shown in FIG. 7, which shows a schematic structural view of the substrate electroplating device according to Embodiment 3 of the present invention, compared with Embodiment 1, Embodiment 3 is mainly different in that the implementation manner of the deformation regulating device 5 is different.

As shown in FIG. 7, in Embodiment 3, the deformation regulating device 5 includes an actuator 521 and an actuation controller 522; the end of the edge region of the deformable diffuser plate 4 is fixedly connected to the inner wall of the electroplating bath 1, and the actuator 521 is connected to the central region of the deformable diffuser plate 4, and is used to drive the deformable diffuser plate 4 according to an actuation control signal from the actuation controller, thereby adjusting the shape of the deformable diffuser plate 4.

It should be understood that the actuator 521 is a component that can push or pull the deformable diffuser plate 4. Exemplarily, in this embodiment, the actuator 521 includes an actuation transmission member 5211. One end of the actuation transmission member 5211 is connected to the central region of the deformable diffuser plate 4, and this end moves in the normal direction of the substrate 3 according to the actuation control signal sent by the actuation controller 522, thereby causing the deformable diffuser plate 4 to deform due to the tensile force or thrust force of the actuation transmission member 5211. As shown in FIG. 7, exemplarily, the normal direction of the substrate 3 is the vertical direction, and the actuation transmission member 5211 moves downward in the vertical direction, pulling the deformable diffuser plate 4 to adjust to the second form, which can make the metal deposition thickness on the substrate 3 uniformly distributed from the central region to the edge region, suppressing the edge effect.

It should be understood that the movement of the actuator 521 can also be controlled according to actual electroplating requirements, adjusting the shape of the deformable diffuser plate 4 to the first form or the third form. For example, when the

actuator 521 remains in the initial position, the shape of the deformable diffuser plate 4 can be maintained in the first form; or the actuator 521 pushes the deformable diffuser plate 4 upward to adjust the shape of the deformable diffuser plate 4 to the third form.

It should be understood that in other possible embodiments, the deformation regulating device 5 further includes a deformation detector, such as an image sensor or a displacement sensor, used to detect the deformation of the deformable diffuser plate 4 and feed the detected deformation back to the actuation controller 522; the actuation controller 522 is also used to generate an actuation control signal based on the detected deformation. For example, if the deformation detector detects that the deformation of the deformable diffuser plate 4 is small and does not meet expectations, the detection result is fed back to the actuation controller 522, which generates an actuation control signal to increase the tensile force or thrust force of the actuation transmission member 5211 to increase the deformation of the deformable diffuser plate 4.

This embodiment utilizes the deformable property of the deformable diffuser plate 4, driving the deformable diffuser plate 4 to undergo predictable deformation through the actuator 521. Without the need for disassembly and replacement of the deformable diffuser plate 4, the spacing between the deformable diffuser plate 4 and the substrate 3 can be adjusted by changing the shape of the deformable diffuser plate 4, thereby adjusting the electric field distribution to meet different deposition thickness distribution requirements.

Embodiment 4

This embodiment provides a substrate electroplating method, comprising the following steps:

S1, configuring a substrate 3 in an electroplating bath 1, the substrate 3 having a surface to be electroplated 30, the electroplating bath 1 containing an electroplating solution 11 and being provided with a deformable diffuser plate 4, wherein the deformable diffuser plate 11 has a first surface 40, and the first surface 40 faces the surface to be electroplated 30;

S2, adjusting the shape of the deformable diffuser plate 4 to adjust the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30 of the substrate 3;

S3, electroplating metal onto the surface to be electroplated 30 of the substrate 3.

Specifically, under process requirements where the edge effect does not need to be suppressed, step S2 includes: adjusting the shape of the deformable diffuser plate 4 to a first form, so that the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30 remains constant. As shown in FIG. 4, the deformable diffuser plate 4 appears as a flat, non-warped plate, with no difference in the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30. Due to the edge effect, the electric field in the edge region is more concentrated than in the central region, and electric field lines 8 close to the edge region of the substrate 3 will exhibit a curved shape bending toward the edge of the substrate 3.

Under process requirements where the edge effect needs to be suppressed, step S2 includes: adjusting the shape of the deformable diffuser plate 4 to a second form, so that the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30 gradually decreases. As shown in FIG. 5, the shape of the deformable diffuser plate 4 is adjusted to cause warping of the deformable diffuser plate 4 as shown in FIG. 5. The spacing between the first surface 40 and the surface to be electroplated 30 gradually decreases from the central region to the edge region. Compared with the first form, although in the second form, the overall spacing between the first surface 40 and the surface to be electroplated 30 increases, the increase amount from the central region to the edge region gradually decreases, which suppresses the edge effect, making the distribution of the electric field lines 8 between the first surface 40 and the surface to be electroplated 30 more uniform, without concentration toward the edge region as in FIG. 4.

Under process requirements where the edge effect needs to be intensified, step S2 includes: adjusting the shape of the deformable diffuser plate 4 to a third form, so that the spacing between the first surface 40 (from the central region to the edge region) and the surface to be electroplated 30 gradually increases. As shown in FIG. 6, the shape of the deformable diffuser plate 4 is adjusted to the third form to cause warping of the deformable diffuser plate 4 as shown in FIG. 6, and the spacing between the first surface 40 and the surface to be electroplated 30 gradually increases from the central region to the edge region. Compared with the first form, although in the third form, the overall spacing between the first surface 40 and the surface to be electroplated 30 decreases, the decrease amount from the central region to the edge region gradually decreases, which intensifies the edge effect. Compared with the electric field line distribution in FIG. 4 and FIG. 5, the distribution of the electric field

lines 8 between the first surface 40 and the surface to be electroplated 30 becomes more concentrated toward the edge region.

Optionally, step S2 further includes: pre-acquiring the correspondence between a preset deposition thickness from the central region to the edge region of the surface to be electroplated 30 and the spacing (i.e., several spacings between the first surface 40 and the surface to be electroplated 30 from the central region to the edge region corresponding to different regions), storing the correspondence in a control device 512 of a deformation regulating device 5, and the control device 512 can automatically adjust the shape of the deformable diffuser plate 4 according to the preset deposition thickness distribution and the correspondence, so as to adjust the spacing between the first surface 40 of the deformable diffuser plate 4 (from the central region to the edge region) and the surface to be electroplated 30 of the substrate 3, so that the actual deposition thickness from the central region to the edge region of the surface to be electroplated 30 conforms to the preset deposition thickness. In this way, automatic adjustment of the spacing by the deformation regulating device 5 can be achieved without requiring an operator to manually input adjustment parameters into the deformation regulating device 5.

The embodiments described above are merely illustrative of the principles and effects of the present invention, and are not intended to limit the present invention. Any person skilled in the art can modify or adjust the embodiments described above without departing from the spirit and scope of the present invention. Therefore, all equivalent modifications or adjustments made by those with ordinary knowledge in the art without departing from the spirit and technical ideas disclosed in the present invention shall still be covered by the claims of the present invention.

What is claimed is:

1. A substrate electroplating method, comprising the following steps:

configuring a substrate in an electroplating bath, the substrate having a surface to be electroplated, the electroplating bath containing an electroplating solution and being provided with a deformable diffusion plate, wherein the deformable diffusion plate has a first surface, and the first surface faces the surface to be electroplated;

adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated;

electroplating metal onto the surface to be electroplated.

2. The substrate electroplating method according to claim 1, wherein the step of adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated includes: adjusting the shape of the deformable diffusion plate to a first form, so that the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated remains constant.

3. The substrate electroplating method according to claim 1, wherein the step of adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated includes: adjusting the shape of the deformable diffusion plate to a second form, so that the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated gradually decreases.

4. The substrate electroplating method according to claim 1, wherein the step of adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated includes: adjusting the shape of the deformable diffusion plate to a third form, so that the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated gradually increases.

5. The substrate electroplating method according to claim 1, wherein the step of adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated includes: pre-acquiring the correspondence between a preset deposition thickness from the central region to the edge region of the surface to be electroplated

and the spacing, and automatically adjusting the shape of the deformable diffusion plate according to the preset deposition thickness and the correspondence, to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated, so that the actual deposition thickness from the central region to the edge region of the surface to be electroplated conforms to the preset deposition thickness.

6. A substrate electroplating device, comprising:

an electroplating bath, for containing an electroplating solution;

a chuck, for configuring a substrate in the electroplating bath, the substrate having a surface to be electroplated;

a deformable diffusion plate, disposed within the electroplating bath, wherein the deformable diffusion plate has a first surface, the first surface faces the surface to be electroplated, and the edge of the deformable diffusion plate is fixedly connected to the inner wall of the electroplating bath;

a deformation regulating device, for adjusting the shape of the deformable diffusion plate to adjust the spacing between the first surface (from the central region to the edge region) and the surface to be electroplated.

7. The substrate electroplating device according to claim 6, wherein the deformable diffusion plate includes a first layer plate and a second layer plate superimposed on each other, and the first layer plate and the second layer plate have different coefficients of thermal expansion; the deformation regulating device includes a temperature-varying element, used to change the temperature of the deformable diffusion plate to adjust the shape of the deformable diffusion plate.

8. The substrate electroplating device according to claim 7, wherein the temperature-varying element is disposed between the first layer plate and the second layer plate.

9. The substrate electroplating device according to claim 7, wherein the deformation regulating device further includes a temperature controller, and the temperature-varying element is used to change the temperature of the deformable diffusion plate according to a temperature control signal from the temperature controller to adjust the shape of the deformable diffusion plate.

10. The substrate electroplating device according to claim 9, wherein the

deformation regulating device further includes a deformation detector for detecting the deformation of the deformable diffusion plate and feeding the deformation back to the temperature controller; the temperature controller is further used to generate the temperature control signal based on the deformation.

11. The substrate electroplating device according to claim 9, wherein the deformation regulating device further includes a temperature detector for detecting the temperature of the deformable diffusion plate and feeding the temperature back to the temperature controller; the temperature controller is further used to generate the temperature control signal based on the temperature.

12. The substrate electroplating device according to claim 6, wherein the deformation regulating device includes an actuator and an actuation controller; the actuator is drivingly connected to the central region of the deformable diffusion plate, and is used to drive the deformable diffusion plate according to an actuation control signal of the actuation controller, so as to adjust the shape of the deformable diffusion plate.

13. The substrate electroplating device according to claim 12, wherein the deformation regulating device further includes a deformation detector for detecting the deformation of the deformable diffusion plate and feeding the deformation back to the actuation controller; the actuation controller is further used to generate the actuation control signal based on the deformation.

14. A deformable diffusion plate, applied to a substrate processing device, wherein the deformable diffusion plate includes a first layer plate and a second layer plate superimposed on each other, and the first layer plate and the second layer plate have different coefficients of thermal expansion.