

ELECTROPLATING APPARATUS

FIELD OF THE INVENTION

The present invention relates to the technical field of semiconductor manufacturing, and in particular to an electroplating apparatus.

BACKGROUND

As shown in FIGS. 1 to 4, a conventional electroplating apparatus comprises an electroplating chamber, a substrate holding device (not shown in the figure), a membrane frame 100', an ionic membrane 200', and the like. The interior of the electroplating chamber comprises a cathode chamber 300' and an anode chamber 400'. The cathode chamber 300' is formed on the membrane frame 100'. The anode chamber 400' is located below the cathode chamber 300' and includes an anode 410'. The ionic membrane 200' is disposed at the bottom of the membrane frame 100' for separating the anode chamber 400' and the cathode chamber 300'. The metal ions in the anode liquid in the anode chamber 400' enter the cathode liquid in the cathode chamber 300' through the ionic membrane 200'. When the substrate 500' is electroplated, the substrate holding device clamps the substrate 500' so that the substrate 500' is immersed in the cathode liquid in the cathode chamber 300' with the front surface downward. During the electroplating process, an electric field is formed between the anode 410' and the substrate 500'. The metal ions such as Cu^{2+} in the anode liquid and cathode liquid migrate to the surface of the substrate 500', and the substrate 500' acquires electrons. The metal ions are electroplated on the surface of the substrate 500' to form an electroplating layer.

The membrane frame 100' has a middle channel 110' penetrating the center of the membrane frame 100'. The middle channel 110' is used for supplying an electroplating liquid to the middle region of the substrate. The middle channel 110' is formed by a middle blocking wall 120', and the middle blocking wall 120' is circular in shape and solid. In conjunction with FIGS. 2 and 3, FIG. 2 shows a schematic top view of the membrane frame 100', and FIG. 3 shows a schematic view of orthographic projection of the middle blocking wall 120' of the membrane frame 100' projected on the plane F' where the substrate is located. As can be seen from FIG. 3, the middle blocking wall

120' has a circle with the center O' of the substrate as a center in the orthographic projection region P' on the plane F' where the substrate is located. The inventors of the present application realize that during the rotation of the substrate 500', the rotation trajectory of any point on the substrate 500' corresponding to the blocked region of the middle blocking wall 120', such as point A' (the dashed circle where point A' is located in FIG. 3) will be completely included in the range of the orthographic projection region P'. Therefore, the electric field between any point in the blocked region on the substrate and the anode will always be shielded by the middle blocking wall 120'. Secondly, because the middle blocking wall 120' is located at the center of the membrane frame 100', and is circular and has no cathode liquid ejection holes at the top, the upward flow velocity of the electroplating liquid at the position of the middle blocking wall 120' is the weakest, which will significantly reduce the flow field of the electroplating liquid in the blocked region on the substrate, thereby resulting in a sudden change of the electroplating thickness in the middle region on the substrate 500', and forming a circular annular special pattern distribution in the blocked region. FIG. 4 shows an electroplating thickness curve of a 12-inch substrate measured after an electroplating process is performed by the conventional electroplating apparatus. The region of the 12-inch substrate having a substantial radius of 20mm to 50mm is the blocked region corresponding to the middle blocking wall 120'. As can be seen from FIG. 4, there is a significant fluctuation in the electroplating thickness on the substrate 500' in the blocked region, and the sudden change in thickness will form the aforementioned circular annular special pattern on the substrate.

SUMMARY

An object of the present invention is to provide an electroplating apparatus to solve the problem of the sudden change in the electroplating thickness on the substrate in the prior art.

In order to solve the above problem, an embodiment of the present invention provides an electroplating apparatus, comprising a membrane frame, the membrane frame comprising a middle channel penetrating the membrane frame and a middle blocking wall defining the middle channel, the middle blocking wall having no circle with the center of a substrate as the center in the orthographic projection region on the plane where the substrate is located.

In the present invention, the middle blocking wall of the membrane frame used in the electroplating apparatus is designed so that there is no circle with the center of the substrate as the center in the orthographic projection region on the plane where the substrate is located. In this way, when the substrate is rotated around the center of the substrate in the cathode chamber formed on the membrane frame to perform the electroplating process, the trajectory of any point in the blocked region corresponding to the middle blocking wall on the substrate is not completely included in the range of the orthographic projection region. Therefore, the electric field between any point on the substrate in the blocked region corresponding to the middle blocking wall and the anode will not be shielded by the middle blocking wall all the time, and the flow field of the electroplating liquid in the blocked region on the substrate will not be obviously reduced at the same time. Finally, the sudden change of the electroplating thickness of the blocked region on the substrate is greatly weakened, and the change of the electroplating thickness is basically smooth.

Other features and corresponding benefits of the present invention are set forth later in the specification, and it is to be understood that at least some of the benefits will become apparent from the description in the specification of the present invention.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a schematic cross-sectional view of a conventional electroplating apparatus;

FIG. 2 is a schematic top view of a conventional membrane frame;

FIG. 3 is a schematic view of the orthographic projection of a conventional middle blocking wall projected on the plane where a substrate is located;

FIG. 4 is a graph showing an electroplating thickness of a substrate measured after a conventional electroplating apparatus uses a conventional membrane frame;

FIG. 5 is a schematic cross-sectional view of an electroplating apparatus

according to the first embodiment provided by embodiment 1 of the present invention;

FIG. 6 is a schematic perspective view of a membrane frame according to the first embodiment provided by embodiment 1 of the present invention;

FIG. 7 is a schematic top view of a membrane frame according to the first embodiment provided by embodiment 1 of the present invention;

FIG. 8 is a schematic cross-sectional view of a membrane frame according to the first embodiment provided by embodiment 1 of the present invention;

FIG. 9 is a schematic view of the orthographic projection of a middle blocking wall on the plane where a substrate is located according to the first embodiment provided by embodiment 1 of the present invention;

FIG. 10 is a graph showing an electroplating thickness on a substrate measured after the substrate is respectively electroplated by a conventional electroplating apparatus using a conventional membrane frame and by the electroplating apparatus of the present invention using the membrane frame according to the first embodiment of embodiment 1;

FIG. 11 is a schematic top view of a membrane frame according to the second embodiment provided by embodiment 1 of the present invention;

FIG. 12 is a schematic view of a middle blocking wall according to the second embodiment provided by embodiment 1 of the present invention;

FIG. 13 is a graph showing an electroplating thickness on a substrate measured after the substrate is respectively electroplated by a conventional electroplating apparatus using a conventional membrane frame and by the electroplating apparatus of the present invention using the membrane frame according to the second embodiment of embodiment 1;

FIG. 14 is a schematic view of a middle blocking wall according to the first embodiment provided by embodiment 2 of the present invention;

FIG. 15 is a view of the orthographic projection of a middle blocking wall on the plane where a substrate is located according to the first embodiment provided by embodiment 2 of the present invention;

FIG. 16 is a schematic view of a middle blocking wall according to the second embodiment provided by embodiment 2 of the present invention;

FIG. 17 is a schematic view of the orthographic projection of an outer peripheral blocking wall on the plane where a substrate is located provided by embodiment 3 of the present invention;

FIGS. 18 and 19 are schematic top views of a membrane frame provided by embodiment 3 of the present invention;

FIG. 20 is a schematic perspective view of a membrane frame provided by embodiment 4 of the present invention;

FIG. 21 is a schematic view of the orthographic projection of the second end of each branch pipe projected on the plane where a substrate is located provided by embodiment 4 of the present invention; and

FIG. 22 is a schematic top view of a membrane frame provided by embodiment 4 of the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

The embodiments of the present invention are described below by specific embodiments, and other advantages and benefits of the present invention can be easily understood by those skilled in the art by the content disclosed in the specification. Although the description of the present invention will be described in conjunction with the preferred embodiments, this does not mean that the features of the present invention are limited to these embodiments. On the contrary, the purpose of the description of the invention in conjunction with the embodiments is to cover other alternatives or modifications that may be extended based on the claims of the present invention. In order to provide an in-depth understanding of the present invention, many specific details will be included in the following description. The present invention may also

be practiced without these details. Furthermore, in order to avoid confusion or obscuring the focus of the present invention, some specific details will be omitted in the description. It should be noted that the embodiments of the present invention and the features of the embodiments may be combined with each other as long as there is no conflict.

It should be noted that in the present specification, similar reference numerals and letters represent similar items in the following drawings, and therefore, once an item is defined in one drawing, it is not necessary to further define and explain the item in the following drawings.

Hereinafter, the technical solutions of the present invention will be clearly and completely described with reference to the accompanying drawings, and it is obvious that the described embodiments are some embodiments of the present invention, but not all embodiments. Based on the embodiments in the present invention, all other embodiments obtained by those of ordinary skill in the art without making creative efforts belong to the scope of protection of the present invention.

In the description of the present invention, it should be noted that the orientation or positional relationship indicated by the terms “center”, “upper”, “lower”, “left”, “right”, “vertical”, “horizontal”, “inner”, “outer”, etc., is based on the orientation or positional relationship shown in the accompanying drawings, and is only for convenience and simplification of the description of the present invention, and does not indicate or imply that the referred device or element must have a specific orientation, be constructed and operate in a specific orientation, and therefore cannot be understood as a limitation of the present invention. Furthermore, the terms “first”, “second”, and “third” are for descriptive purposes only and cannot be understood to indicate or imply relative importance.

In the description of the present invention, it should be noted that unless otherwise explicitly specified and defined, the terms “installation”, “communication” and “connection” should be understood in a broad sense. For example, the connection can be a fixed connection, a detachable connection, or an integral connection; the connection can be a mechanical connection, or an electrical connection; the connection can be a direct connection, an indirectly connected through an intermediate medium,

or an internal communication of two elements. The specific meanings of the above terms in the present invention will be understood by those of ordinary skill in the art.

In order to clarify the objects, technical solutions, and advantages of the present invention, the embodiments of the present invention will be described in further details below with reference to the accompanying drawings.

According to FIGS. 5 to 7, FIG. 5 shows a schematic cross-sectional view of an electroplating apparatus, FIG. 6 shows a schematic perspective view of a membrane frame, and FIG. 7 shows a schematic top view of a membrane frame. The electroplating apparatus provided in embodiment 1 comprises an electroplating chamber, an anode 410, an ionic membrane 200, a membrane frame 100 and a substrate holding device (not shown in the figure). The electroplating chamber comprises an anode chamber 400 and a cathode chamber 300. The cathode chamber 300 is formed on the membrane frame 100 and the anode chamber 400 is located below the cathode chamber 300. The anode chamber 400 includes the anode 410. The ionic membrane 200 is disposed at the bottom of the membrane frame 100 for separating the cathode chamber 300 and the anode chamber 400, so that metal ions in the anode liquid in the anode chamber 400 enter the cathode liquid in the cathode chamber 300 through the ionic membrane 200, so as to replenish the cathode chamber 300 with metal ions, such as Cu^{2+} . The substrate holding device clamps the substrate 500 and the substrate 500 is electroplated in the cathode chamber 300. It should be pointed out that the anode liquid and cathode liquid are collectively referred to as the electroplating liquid.

The membrane frame 100 comprises a middle channel 110 penetrating the membrane frame 100 and a middle blocking wall 120 defining the middle channel 110. The membrane frame 100 also comprises a side wall 130 and a plurality of branch pipes 140. The side wall 130 of the membrane frame 100 extends upwardly to form the cathode chamber 300, and the side wall 130 is provided with cathode liquid inlets 131 (referred to in conjunction with FIG. 8). Each branch pipe 140 is provided with a liquid supply channel 141 and an injection hole 1423. The liquid supply channel 141 is in communication with the cathode liquid inlets 131 and the injection holes 1423. Each branch pipe 140 supplies cathode liquid to the cathode chamber 300 through the injection hole 1423.

Wherein, the first ends of the plurality of branch pipes 140 are arranged at intervals along the circumferential direction of the side wall 130 of the membrane frame 100, the second ends of the plurality of branch pipes 140 are connected to the middle blocking wall 120. The middle blocking wall 120 is provided with a plurality of liquid outlet holes 121, and the plurality of liquid outlet holes 121 are in communication with the middle channel 110 and the liquid supply channel 141 of each branch pipe 140. The top of the middle blocking wall 120 is also mounted with a central cap 180 (referred to in conjunction with FIG. 5) covering the middle channel 110. The central cap comprises a plurality of dispersion holes (not shown in the figure), for the cathode liquid of the middle channel 110 to pass through.

When the cathode liquid is supplied to the cathode chamber 300, the cathode liquid passes through the cathode liquid inlets 131 through the cathode liquid pipelines 310 (referred to in conjunction with FIG. 5) into the liquid supply channel 141 of each branch pipe 140, and enters the cathode chamber 300 through the injection holes 1423 and the liquid outlet holes 121. Then, the electroplating liquid in the cathode chamber 300 (the electroplating liquid includes the cathode liquid and the metal ions supplied from the anode liquid) is supplied from the bottom to the top to the surface of the substrate 500. Wherein, the cathode liquid in the liquid supply channel 141 is supplied to the middle region of the substrate 500 through the central cap 180 after entering the middle channel 110 through the liquid outlet holes 121.

In the present embodiment, there are six branch pipes 140 for uniformly distributing the flow rate of the cathode liquid. In other embodiments, the number of branch pipes 140 may be increased or decreased according to actual process requirements.

As shown in FIG. 6, the membrane frame 100 further comprises an outer peripheral blocking wall 150 that surrounds between the middle blocking wall 120 and the side wall 130. Exemplarily, the top of the outer peripheral blocking wall 150 is sealingly connected to the bottom of a diffuser plate 190 (referred to in conjunction with FIG. 5) to divide the cathode chamber 300 into at least two independent cathode regions. In this embodiment, the membrane frame 100 comprises an outer peripheral blocking wall 150 that divides the cathode chamber 300 into two cathode regions. The region surrounded by the outer peripheral blocking wall 150 is the first cathode region,

and the region between the outer peripheral blocking wall 150 and the side wall 130 of the membrane frame 100 is the second cathode region. In other embodiments, the number of outer peripheral blocking walls 150 may be increased or decreased according to actual process requirements.

The electroplating apparatus further comprises an anode blocking wall 420 disposed in the anode chamber 400 and below the outer peripheral blocking wall 150, and the anode blocking wall 420 is used to divide the anode chamber 400 into a plurality of anode regions, and the plurality of anode regions correspond to the plurality of cathode regions respectively. As shown in FIG. 5, in this embodiment, the electroplating apparatus comprises an anode blocking wall 420 that divides the anode chamber 400 into a central first anode region and a peripheral second anode region. The first anode region corresponds to the first cathode region, and the second anode region corresponds to the second cathode region.

In this application, in order to avoid the electric field between any point of the blocked region corresponding to the middle blocking wall 120 on the substrate 500 and the anode 410 being always blocked by the middle blocking wall 120, a related improvement is made to the middle blocking wall 120 of the membrane frame 100, that is, there is no circle with the center of the substrate as the center in the orthographic projection region of the middle blocking wall 120 of the membrane frame 100 on the plane where the substrate is located. When the substrate 500 is rotated around the center of the substrate in the cathode chamber 300 to perform the electroplating process, any point in the blocked region corresponding to the middle blocking wall 120 on the substrate 500 rotates around the center of the substrate, and the rotation trajectory formed thereby is a circle with the center of the substrate as the center. In the present application, since the middle blocking wall 120 is designed so that there is no circle with the center of the substrate as the center in the orthographic projection region on the plane where the substrate is located, the rotation trajectory of any point in the blocked region corresponding to the middle blocking wall 120 on the substrate 500 will not be completely included in the range of the orthographic projection region. This design makes the electric field between any point in the blocked region corresponding to the middle blocking wall 120 on the substrate 500 and the anode 410 not always shielded by the middle blocking wall 120, so that the flow field of electroplating liquid

in the blocked region on the substrate 500 is not significantly reduced. Finally, the sudden change of the electroplating thickness of the blocked region on the substrate 500 weakens significantly or even disappears. That is to say, the change of electroplating thickness is basically smooth, and the purpose of improving the uniformity of the electroplating thickness is achieved. It should be noted that the orthographic projection region of the middle blocking wall 120 on the plane where the substrate is located is, the blocked region of the substrate by the middle blocking wall 120.

Embodiment 1:

In this embodiment, the middle blocking wall 120 of the membrane frame 100 comprises an inner contour 1201 and an outer contour 1202, and there is no circular annular region between the outer contour 1202 and the inner contour 1201 on the cross section of the middle blocking wall 120, so that there is no circle with the center of the substrate as the center in the orthographic projection region of the middle blocking wall 120 on the plane where the substrate is located.

FIG. 9 shows a schematic view of an orthographic projection of the middle blocking wall on the plane where the substrate is located in the first embodiment of the present embodiment. The diagonal portion in FIG. 9 is the orthographic projection region P1 of the middle blocking wall, and the middle blocking wall 120 is labeled in FIG. 9 for convenience. Specifically, in the first embodiment, as shown in FIG. 9, the shape of the inner contour 1201 and the shape of the outer contour 1202 of the middle blocking wall 120 are consistent, for example, both are regular hexagons, and the inscribed circle 12022 of the outer contour 1202 is smaller than the circumscribed circle 12011 of the inner contour 1201 of the middle blocking wall 120. In this case, between the inscribed circle 12022 of the outer contour 1202 and the circumscribed circle 12011 of the inner contour 1201, there is no circular annular region on the cross section of the middle blocking wall 120, so whether the middle blocking wall 120 is disposed eccentrically or centrally with respect to the center O1 of the substrate, the middle blocking wall 120 does not have a circle with the center O1 of the substrate as the center in the orthographic projection region P1 on the plane where the substrate is located. Hereinafter, with reference to FIG. 9, a case where the middle blocking wall 120 shields the substrate according to the first embodiment will be described. Firstly,

an arbitrary point, e.g., a point A1, in the blocked region of the middle blocking wall 120 corresponding to the hexagon on the substrate (between the inscribed circle of the inner contour 1201 and the circumscribed circle of the outer contour 1202) is taken. When the substrate is rotated around the center O1 of the substrate in the cathode chamber to perform the electroplating process, the rotation trajectory of the point A1 is the circle with the center O1 of the substrate as the center (the dotted circle where the point A1 is located in FIG. 9). Since the middle blocking wall 120 does not have a circle with the center O1 of the substrate as the center in the orthographic projection region P1 on the plane where the substrate is located, the rotation trajectory of the point A1 is not completely included in the range of the orthographic projection region P1, and is partially included in the range of the orthographic projection region P1 and partially outside the range of the orthographic projection region P1. Therefore, the electric field between any point in the blocked region on the substrate and the anode will not be shielded by the regular hexagonal middle blocking wall 120 all the time. And at the same time, the flow field of the electroplating liquid in the blocked region will not be significantly reduced, finally, so that the electroplating thickness change of the blocked region on the substrate after electroplating is basically smooth.

In the embodiments not shown, the shape of the inner contour 1201 and the shape of the outer contour 1202 of the middle blocking wall 120 may also be other polygons, such as regular pentagons, squares, regular triangles, and the like.

FIG. 10 is a graph showing the electroplating thickness of the substrate measured after the substrate is respectively electroplated by the conventional electroplating apparatus using the membrane frame 100' having a circular shape of the middle blocking wall 120' and by the electroplating apparatus of the present application using the membrane frame 100 having a regular hexagonal shape of the middle blocking wall 120. In FIG. 10, the abscissa represents the radius of the substrate 500, and the ordinate represents the electroplating thickness. As can be seen from FIG. 10, under the same process parameters, after the conventional electroplating apparatus performs the electroplating process on the 12-inch substrate, the blocked region corresponding to the middle blocking wall 120' on the 12-inch substrate is roughly located in the region with a radius range of 20mm to 50mm on the substrate, and the electroplating thickness in this blocked region fluctuates obviously. After the electroplating apparatus of the

present application performs the electroplating process on the 12-inch substrate, the blocked region of the middle blocking wall 120 corresponding to the regular hexagon on the 12-inch substrate is also roughly located in the region with the radius range of 20mm to 50mm on the substrate, and the electroplating thickness in the blocked region does not fluctuate significantly, and is more uniform. Therefore, setting the middle blocking wall 120 in a regular hexagonal shape can effectively improve the uniformity of the electroplating thickness.

As shown in FIGS. 11 and 12, FIG. 11 shows a schematic top view of the membrane frame in the second embodiment of the present embodiment, and FIG. 12 shows a schematic view of the middle blocking wall in the second embodiment of the present embodiment. In the second embodiment, as shown in FIGS. 11 and 12, the shape of the inner contour 1201 of the middle blocking wall 120 is consistent with the shape of the outer contour 1202, and both are oval shapes. In addition, in the second embodiment, the ratio of the long axis to the short axis of the oval is greater than or equal to 1.5, and the difference between the long axis and the short axis of the oval is greater than twice the thickness d_1 of the middle blocking wall 120. In this case, as shown in FIG. 12, there is no circular annular region between the outer contour 1202 and the inner contour 1201 of the oval middle blocking wall 120 on the cross section of the middle blocking wall 120. And whether the middle blocking wall 120 is disposed eccentrically or centrally with respect to the center O_1 of the substrate, the oval middle blocking wall 120 has no circle with the center O_1 of the substrate as the center in the orthographic projection region on the plane where the substrate is located. In this way, when the substrate is rotated, the electric field between any point in the blocked region corresponding to the oval middle blocking wall 120 on the substrate and the anode is not always shielded by the oval middle blocking wall 120, so that the flow field of electroplating liquid in the blocked region is not significantly reduced, and finally, the electroplating thickness change in the blocked region on the substrate after electroplating is basically smooth. In the present embodiment, the outer contour 1202 and the inner contour 1201 of the oval middle blocking wall 120 are concentric and have the same shape, so the both are parallel, and the thickness d_1 of the middle blocking wall 120 is the distance between the inner contour 1201 and the outer contour 1202 of the middle blocking wall 120.

FIG. 13 is a graph showing the electroplating thickness on the substrate after the substrate is respectively electroplated by the conventional electroplating apparatus using the membrane frame having a circular middle blocking wall and by the electroplating apparatus of the present application using the membrane frame having an oval middle blocking wall. In FIG. 13, the abscissa represents the radius of the substrate, and the ordinate represents the electroplating thickness. As can be seen from FIG. 13, under the same process parameters, after the conventional electroplating apparatus performs the electroplating process on the 12-inch substrate, the blocked region corresponding to the middle blocking wall on the 12-inch substrate is roughly located in the region with a radius range of 20mm to 50mm on the substrate, and the electroplating thickness in the blocked region fluctuates obviously. After the electroplating apparatus of the present application performs the electroplating process on the 12-inch substrate, the blocked region corresponding to the oval middle blocking wall on the 12-inch substrate is approximately located in the region with the radius range of 30mm to 60mm on the substrate, and the electroplating thickness in the blocked region does not fluctuate significantly, and is more uniform. Therefore, setting the middle blocking wall as an oval shape can effectively improve the uniformity of the electroplating thickness.

Embodiment 2:

As shown in FIGS. 14 and 15, FIG. 14 shows a schematic view of a middle blocking wall provided by embodiment 2, and FIG. 15 shows a schematic view of an orthographic projection of the middle blocking wall on the plane where the substrate is located provided by embodiment 2. In FIG. 15, the shaded portion is the orthographic projection region when the reference middle blocking wall coincides with the center of the substrate, and the diagonal portion is the actual orthographic projection region P2 of the middle blocking wall, and the middle blocking wall 120 is labeled in FIG. 15 for convenience. The middle blocking wall 120 of the membrane frame provided in embodiment 2 is disposed eccentrically with respect to the center O1 of the substrate. There is a first circular annular region on the cross section of the middle blocking wall 120 between the outer contour 1202 and the inner contour 1201 of the middle blocking wall 120, and the eccentricity of the middle blocking wall 120 is greater than one-half of the thickness d2 of the first circular annular region. Wherein, the center of the middle

blocking wall 120 is represented by O2. Specifically, in the first embodiment of the present embodiment, as shown in FIG. 15, the shapes of the inner contour 1201 and the outer contour 1202 of the middle blocking wall 120 are consistent, for example, both are circular shapes, and the outer contour 1202 and the inner contour 1201 of the middle blocking wall 120 constitute the first circular annular region. The eccentricity of the middle blocking wall 120 is greater than one-half of the thickness d_2 of the first circular annular region, so that the middle blocking wall 120 has no circle with the center O1 of the substrate as the center in the orthographic projection region P2 on the plane where the substrate is located. Hereinafter, with reference to FIG. 15, a case where the middle blocking wall 120 shields the substrate according to the first embodiment of the present embodiment will be described. Take any point on the substrate corresponding to the blocked region of the middle blocking wall 120 (the region between the small circle formed around O1 by the point of the middle blocking wall 120 closest to the substrate center O1 and the large circle formed around O1 by the point of the middle blocking wall 120 farthest from the substrate center O1), such as point A2. When the substrate is rotated around the center of the substrate in the cathode chamber to perform the electroplating process, the rotation trajectory of the point A2 is a circle with the center O1 of the substrate as the center (the dotted circle where point A2 is located in FIG. 15). Since the middle blocking wall 120 has no circle with the center O1 of the substrate as the center in the orthographic projection region P2 on the plane where the substrate is located, the rotation trajectory of the point A2 is not completely included in the range of the orthographic projection region P2, and is partially included in the range of the orthographic projection region P2 and partially outside the range of the orthographic projection region P2. This makes the electric field between the point A2 and the anode not always shielded by the eccentric middle blocking wall 120, and finally makes the sudden change of the electroplating thickness in the blocked region where the rotation trajectory of the point A2 on the substrate is located to be greatly weakened or even disappear, so as to achieve the purpose of improving the uniformity of the electroplating thickness.

FIG. 16 is a schematic view of the middle blocking wall according to the second embodiment of the present embodiment. Specifically, in the second embodiment of the present embodiment, the shapes of the inner contour 1201 and the outer contour 1202 of the middle blocking wall 120 are inconsistent, for example, the inner contour 1201

of the middle blocking wall 120 is square, the outer contour 1202 of the middle blocking wall 120 is hexagonal. There is a first circular annular region between the inner contour 1201 and the outer contour 1202 of the middle blocking wall 120, and the inscribed circle 12022 of the outer contour 1202 and the circumscribed circle 12011 of the inner contour 1201 constitute the first circular annular region. The eccentricity of the middle blocking wall 120 is greater than one-half of the thickness d_2 of the first circular annular region, so that the middle blocking wall 120 has no circle with the center of the substrate as the center in the orthographic projection region on the plane where the substrate is located.

It should be noted that the eccentricity of the middle blocking wall 120 described above is the distance between the center O2 of the middle blocking wall 120 in the orthographic projection region on the plane where the substrate is located and the center O1 of the substrate.

Embodiment 3:

In this embodiment, in order to prevent the electric field between any point in the blocked region corresponding to an outer peripheral blocking wall on a substrate and an anode from being shielded by the outer peripheral blocking wall all the time, the outer peripheral blocking wall of a membrane frame is improved, that is, the outer peripheral blocking wall of the membrane frame does not have a circle with the center of the substrate as the center in the orthographic projection region on the plane where the substrate is located. FIG. 17 is a schematic view of the outer peripheral blocking wall according to an embodiment of embodiment 3. The contour setting of the outer peripheral blocking wall 150 shown in FIG. 17 is similar to the contour setting of the middle blocking wall provided in the first embodiment of embodiment 1. As shown in FIG. 17, the shape of the inner contour 1501 and the shape of the outer contour 1502 of the outer peripheral blocking wall 150 are consistent, for example, both are regular hexagons, and the inscribed circle 15022 of the outer contour 1502 is smaller than the circumscribed circle 15011 of the inner contour 1501 of the outer peripheral blocking wall 150. In this case, there is no circular annular region between the inscribed circle 15022 of the outer contour 1502 of the outer peripheral blocking wall 150 and the circumscribed circle 15011 of the inner contour 1501 of the outer peripheral blocking wall 150 on the cross section of the outer peripheral blocking wall 150. Then,

regardless of whether the outer peripheral blocking wall 150 is set eccentrically or centrally with respect to the center O1 of the substrate, the outer peripheral blocking wall 150 does not have a circle with the center O1 of the substrate as the center in the orthographic projection region on the plane where the substrate is located. Hence, the electric field between any point in the blocked region corresponding to the outer peripheral blocking wall 150 on the substrate and the anode is not always shielded by the outer peripheral blocking wall 150, so that the purpose of improving the uniformity of the electroplating thickness in the blocked region can be achieved.

Specifically, for example, in the specific embodiment shown in FIG. 18, there are intervals between the six corners of the outer peripheral blocking wall 150 and the side wall 130 of the membrane frame 100. Correspondingly, at this time, the structure of an anode blocking wall can be consistent with the structure of the outer peripheral blocking wall 150. There are intervals between the six corners of the anode blocking wall and the side wall of the anode chamber, and the anode blocking wall and the outer peripheral blocking wall 150 are vertically aligned. Also, as in the specific embodiment shown in FIG. 19, the structure of the outer peripheral blocking wall 150 is similar to the inscribed hexagon of the side wall 130 of the membrane frame 100, and accordingly, the structure of the anode blocking wall may be similar to the inscribed hexagon of the side wall of the anode chamber at this time, and the anode blocking wall and the outer peripheral blocking wall 150 are vertically aligned.

It should be noted that FIGS. 18 and 19 are merely embodiments, and are not used to define a specific arrangement form of the outer peripheral blocking wall 150. In addition, the specific form of the contour of the outer peripheral blocking wall 150 may be similar to the specific form of the contour of the middle blocking wall involved in the above-described embodiments 1 and 2, and the related description of the contour arrangement of the middle blocking wall and the shielding situation of the substrate by the middle blocking wall in the above-described embodiments 1 and 2 may be applied to the outer peripheral blocking wall 150. For example, the outer peripheral blocking wall 150 may also be arranged in the form of the middle blocking wall according to embodiment 2, specifically, there is a second circular annular region on the cross section of the outer peripheral blocking wall 150 between the outer contour 1502 and the inner contour 1501 of the outer peripheral blocking wall 150. And the outer

peripheral blocking wall 150 is disposed eccentrically with respect to the center O1 of the substrate, wherein, the eccentricity of the outer peripheral blocking wall 150 is greater than one-half of the thickness of the second circular annular region.

Embodiment 4:

As shown in FIGS. 20 to 22, FIG. 20 shows a schematic perspective view of a membrane frame provided in embodiment 4, and FIG. 21 shows a schematic view of the orthographic projection of the second end of each branch pipe on the plane where a substrate is located provided in embodiment 4, and FIG. 22 shows a schematic perspective view of a membrane frame provided in embodiment 4. A middle blocking wall of the membrane frame 100 of an electroplating apparatus provided in embodiment 4 is discontinuous along the circumferential direction. In contrast, the middle blocking wall of embodiments 1 – 3 is continuous along the circumferential direction.

In the specific embodiment shown in FIG. 20, the second ends of all branch pipes 140 are set at intervals along the circumferential direction of a middle channel 110, and the second ends of all branch pipes 140 collectively define as the middle blocking wall to be discontinuous along the circumferential direction. The second end of each branch pipe 140 (i.e., the middle blocking wall discontinuous along the circumferential direction) is provided with a liquid outlet hole 121 facing the middle channel 110 to supply the cathode liquid to the middle channel 110. In the present embodiment, the cross section of the middle channel 110 defined by the second end of each branch pipe 140 is similar to a circle, and in other embodiments, the cross section of the defined middle channel 110 may also be hexagonal, oval, triangular, etc., depending on the different arrangements of each branch pipe 140 and the different shapes of the second end of each branch pipe 140.

As shown in FIG. 21, there is no circle with the center O1 of the substrate as the center in the orthographic projection of the second end of each branch pipe 140, that is, the middle blocking wall projected on the plane where the substrate is located. Hereinafter, with reference to FIG. 21, a case where the middle blocking wall shields the substrate provided in the present embodiment will be described. Take any point on the substrate in the blocked region corresponding to the middle blocking wall, such as

point A3, when the substrate is rotated around the center of the substrate in the cathode chamber to perform the electroplating process, the rotation trajectory of the point A3 is a circle with the center O1 of the substrate as the center (the dotted circle where the point A3 is located in FIG. 21). Since the middle blocking wall has no circle with the center O1 of the substrate as the center in the orthographic projection region on the plane where the substrate is located, the rotation trajectory of the point A3 is not completely included on the orthographic projection region. Therefore, the electric field between any point in the blocked region on the substrate and the anode is not always shielded by the second end of each branch pipe 140. At the same time, the flow field of the electroplating liquid in the blocked region corresponding to the second end of each branch pipe 140 on the substrate will not be obviously reduced, and finally the electroplating thickness of the blocked region on the substrate is greatly weakened. The sudden change of the electroplating thickness is weakened or even disappear, and the electroplating thickness change is basically smooth, so as to achieve the purpose of improving the uniformity of the electroplating thickness of the substrate.

Specifically, as shown in FIG. 22, the ratio of the sum of the distance d3 between the second ends of each two branch pipes 140 to the sum of the thickness d4 of all branch pipes 140 is not less than a critical minimum value. The critical minimum value refers to the ratio of the sum of the distance between the second ends of each two branch pipes 140 to the sum of the thickness of all branch pipes 140 that at least ensures that the uniformity of the electroplating thickness of the substrate meets the requirements of the electroplating process. Preferably, the critical minimum value is 50%, i.e., $d3/d4 \times 100\% > 50\%$.

Finally, it should be noted that the above embodiments are only used to illustrate the technical solutions of the present invention, and are not used to limit the technical solutions of the present invention. Although the present invention has been described in detail with reference to the above-described embodiments, those of ordinary skill in the art should understand that the technical solutions described in the above-described embodiments can still be modified, or some or all of the technical features thereof can be equivalently replaced. However, these modifications or substitutions do not make the essence of the corresponding technical solutions deviate from the scope of the technical solution of each embodiment of the present invention.

What is claimed is:

1. An electroplating apparatus, comprising:

a membrane frame, comprising a middle channel penetrating the membrane frame and a middle blocking wall defining the middle channel, the middle blocking wall having no circle with the center of a substrate as the center in the orthographic projection region on the plane where the substrate is located.

2. The electroplating apparatus according to claim 1, wherein the middle blocking wall comprises an inner contour and an outer contour, and on the cross section of the middle blocking wall, no circular annular region exists in the region between the outer contour and the inner contour of the middle blocking wall.

3. The electroplating apparatus according to claim 2, wherein the shape of the inner contour and the shape of the outer contour of the middle blocking wall are consistent and polygonal, and the inscribed circle of the outer contour is smaller than the circumscribed circle of the inner contour of the middle blocking wall.

4. The electroplating apparatus according to claim 2, wherein the shape of the inner contour and the shape of the outer contour of the middle blocking wall are consistent and oval, and the ratio of the long axis to the short axis of the oval is greater than or equal to 1.5.

5. The electroplating apparatus according to claim 4, wherein the difference between the long axis and the short axis of the oval is greater than twice the thickness of the middle blocking wall.

6. The electroplating apparatus according to claim 1, wherein the middle blocking wall comprises an inner contour and an outer contour, and on the cross section of the middle blocking wall, a first circular annular region exists in the region between the outer contour and the inner contour of the middle blocking wall; wherein, the middle blocking wall is disposed eccentrically with respect to the center of the substrate, and the eccentricity of the middle blocking wall is greater than one-half of the thickness of the first circular annular region.

7. The electroplating apparatus according to claim 1, wherein the membrane frame further comprises a side wall and an outer peripheral blocking wall, the side wall extends upwardly to form a cathode chamber, the outer peripheral blocking wall is disposed around the middle channel of the membrane frame and the side wall of the membrane frame for separating the cathode chamber into at least two independent cathode regions.

8. The electroplating apparatus according to claim 7, wherein the outer peripheral blocking wall has no circle with the center of the substrate as the center in the orthographic projection region on the plane where the substrate is located.

9. The electroplating apparatus according to claim 8, wherein the outer peripheral blocking wall comprises an inner contour and an outer contour, and on the cross section of the outer peripheral blocking wall, no circular annular region exists in the region between the outer contour and the inner contour of the outer peripheral blocking wall.

10. The electroplating apparatus according to claim 8, wherein the outer peripheral blocking wall comprises an inner contour and an outer contour, and on the cross section of the outer peripheral blocking wall, a second circular annular region exists in the region between the outer contour and the inner contour of the outer peripheral blocking wall; wherein, the outer peripheral blocking wall is disposed eccentrically with respect to the center of the substrate, and the eccentricity of the outer peripheral blocking wall is greater than one-half of the thickness of the second circular annular region.

11. The electroplating apparatus according to claim 1, wherein the middle blocking wall of the membrane frame along the circumferential direction is discontinuous.

12. The electroplating apparatus according to claim 11, wherein the membrane frame further comprises a plurality of branch pipes, the second ends of all branch pipes are arranged at intervals along the circumferential direction of the middle channel, and the second ends of all branch pipes collectively define as the middle blocking wall to be discontinuous along the circumferential direction.

13. The electroplating apparatus according to claim 12, wherein the ratio of the sum of the distance between the second ends of each two branch pipes to the sum of the thickness of all branch pipes is not less than a critical minimum value, the critical minimum value refers to the ratio of the sum of the distance between the second ends of each two branch pipes to the sum of the thickness of all branch pipes that at least ensures that the uniformity of the electroplating thickness of the substrate meets the requirements of the electroplating process.

14. The electroplating apparatus according to claim 13, wherein the critical minimum value is 50%.