

ELECTROPLATING APPARATUS AND ELECTROPLATING METHOD FOR NON-CIRCULAR SUBSTRATE

FIELD OF THE INVENTION

[0001] The present invention relates to the technical field of semiconductor manufacturing, and more specifically, relates to an electroplating process in the semiconductor manufacturing technology.

BACKGROUND

[0002] Most of the traditional substrates are circle, and most of the chips are square. When multiple square chips are formed on a circular substrate, due to the shape mismatch, the edge area of the substrate will inevitably be discarded because it cannot be used. Therefore, the area utilization rate of producing square chips on a circular substrate is not high, and the production efficiency of the chips is also affected to a certain extent.

[0003] With the gradual popularization of fan-out advanced packaging technology and changes in substrate materials, the application of the square substrate is increasing. The shape of the square substrate matches the shape of the square chip better. On the different substrates of the same area, the square substrate can accommodate more chips than the circle substrate, and the edge area of the square substrate can also arrange chips. The area utilization of the square substrate is improved, so the production efficiency of the chip is improved.

[0004] However, the problem of the mismatching equipment followed. The current mainstream semiconductor equipment is designed based on the circular substrate. For electroplating equipment, the electrode is designed to be circular or ring-shaped, and the substrate is rotated to complete the plating process. The circular or ring-shaped electrode matches the circular substrate, and the substrate can cover all the electrode areas. For the square substrate, the shape does not match the circular or ring-shaped electrode, and the substrate can't cover all the electrode areas. During the rotation of the square substrate, the top corner of the substrate will sweep the electrode area, and only part of electrode area will be covered at the same time. If the electrodes remain fully turned on, a cutting electric field at the edge of the substrate will be formed, which will cause non-uniformity in plating and greatly increase the height of the copper pillars at the edge of the substrate.

SUMMARY

[0100] The present invention provides electroplating apparatus and electroplating method for non-circular substrate.

5 **[0101]** According to an embodiment of the present invention, an electroplating apparatus for non-circular substrate is proposed. The apparatus includes a central electrode area, a peripheral electrode area, a power supply unit and a control device. The central electrode area is circular, and the size of the central electrode area is the inscribed circle of the non-circular substrate. The central electrode is arranged in the central electrode area, and the central electrode fills the central electrode area. The peripheral electrode area surrounds the central electrode area. The peripheral
10 size of the peripheral electrode area is the circumscribed circle of the non-circular substrate. The peripheral electrode area is provided with closely arranged point electrodes, and the point electrodes fill the peripheral electrode area. The power supply unit is connected to the central electrode and the point electrodes to supply power to the central electrode and the point electrodes. The control device is connected between the power supply unit, the central electrode and the point
15 electrodes. The control device controls the on-off of the central electrode and the point electrodes, and the control device tracks the rotating position of the substrate, so that the electrodes in the central electrode area and the peripheral electrode area covered by the substrate will be turned on. The electrodes not covered by the substrate will be turned off. The electrodes are turned on or off following the rotation of the substrate.

20 **[0102]** In one embodiment, the central electrode is always covered by the substrate, and the point electrodes in the peripheral electrode area covered by the substrate are determined as follows:

[0103] Determine the position of each vertex angle of the non-circular substrate relative to the center of the circle;

25 **[0104]** For each vertex angle, determine the opening angle according to the two sides that make up the vertex angle;

[0105] Detect the rotating position of the substrate, and determine the position of each vertex angle of the substrate according to the rotating position of the substrate. The vertex angles are located on the outer circumference of the peripheral electrode area;

30 **[0106]** Taking each vertex angle as the origin, the projection area in the peripheral electrode area is determined according to the opening angle of each vertex angle. The point electrodes falling in the projection area are the point electrodes covered by the substrate.

[0107] In one embodiment, the control device includes an angel sensor, a projection simulator

and a switching device. The angle sensor is used to track the rotation angle of the substrate. The projection simulator determines the position of each vertex angle according to the rotation angle of the substrate, and the projection area in the peripheral electrode area is determined according to the vertex angle and the opening angle. The switching device is connected between the point electrodes in the peripheral and the power supply unit. The switching device turns on the point electrodes currently in the projection area, and turns off the point electrodes currently not in the projection area.

[0108] In one embodiment, the central electrode can be one of the following:

[0109] A single circular electrode that fills the central electrode area; or

[0110] Several block electrodes, which are combined to form a circle and fill the central electrode area.

[0111] Several ring electrodes, which are combined to form a circle and fill the central electrode area.

[0112] In one embodiment, there are several peripheral electrode areas, and the several peripheral electrode areas are concentric rings. The several peripheral electrode areas start from the central electrode area and circle outward in turn, wherein the size of the outermost peripheral electrode area is the circumscribed circle of the non-circular substrate.

[0113] In one embodiment, power supply unit comprises a central power supply and several peripheral power supplies. The central power supply supplies power to the central electrode, and each peripheral power supply supplies power to the point electrodes in the corresponding peripheral electrode area respectively. Each peripheral electrode area has its own peripheral power supply and switching device.

[0114] In one embodiment, power supply unit comprises a central power supply for a central electrode and a peripheral power supply for the point electrodes in all peripheral electrode areas. Each peripheral electrode area has its own switching device, but all the peripheral electrode areas share the same peripheral power supply.

[0115] In one embodiment, a power supply supplies power to the central electrode and the point electrodes in all peripheral electrode areas at the same time. Each peripheral electrode area has its own switching device, but the central electrode and all the peripheral electrode areas share the same power supply.

[0116] In one embodiment, there peripheral electrode areas are sequentially arranged around the central electrode area. The point electrode can be circular, square, hexagonal or arc-shaped.

[0117] In one embodiment, the non-circular substrate is square substrate, and the four vertex angles of the square substrate are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each vertex angle is 90 degrees, and the opening angle of each vertex angle is symmetrical to the diameter of circle. Or the non-circular substrate is a rectangular substrate, and the four vertex angles of the rectangular substrate are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each vertex angle is 90 degrees, and the opening angle of each vertex angle is asymmetrical with respect to the diameter of the circle.

[0118] According to an embodiment of the present invention, a method for electroplating a non-circular substrate is proposed, including:

[0119] Divide the electrode area. Divide the electrode area into a central electrode area and a peripheral electrode area. The central electrode area is circular, and the size of the central electrode is the inscribed circle of the non-circular substrate. The central electrode is set in the central electrode area, the central electrode is filled the central electrode area. The peripheral electrode area surrounds the central electrode area. The peripheral size of the peripheral electrode area is the circumscribed circle of the non-circular substrate. A close arrangement of point electrodes is arranged in the peripheral electrode area, and the point electrodes fill the peripheral electrode area.

[0120] Track the rotation of the substrate and track the rotating position of the substrate.

[0121] Control the on-off of the electrodes. The power supply unit is connected to the central electrode and the point electrodes through the control device to supply power to the central electrode and the point electrodes. The control device controls the on-off of the central electrode and the point electrodes. According to the rotating position of the substrate, the control device turns on the electrodes in the area covered by the substrate in the central electrode area and the peripheral electrode area, and the electrodes in the area not covered by the substrate are turned off. The electrodes are turned on or off following the rotation of the substrate.

[0122] In one embodiment, the central electrode is always covered by the substrate, and the point electrodes covered by the substrate in the peripheral electrode area are determined as follows:

[0123] Determine the position of each vertex angle of the non-circular substrate relative to the center of the circle.

[0124] For each vertex angle, determine the opening angle according to the two sides that make up the vertex angle.

[0125] Detecting the rotating position of the substrate, and determining the position of each

vertex angle of the substrate according to the rotating position. All the vertex angles are located on the outer circumference of the peripheral electrode area.

[0126] Taking each vertex angle as the origin, the projection area in the peripheral electrode area is determined according to the opening angle of each vertex angle. The point electrodes falling in the projection area are the point electrodes covered by the substrate.

[0127] In one embodiment, control device means:

[0128] Track the rotating angle of the substrate through an angle sensor;

[0129] Use a projection simulator to determine the position of each vertex angle according to the rotating angle of the substrate, and determine the projection area in the peripheral electrode area according to the position and opening angle of the vertex angles.

[0130] Control the on-off of the point electrodes through the switching device connected between the point electrodes in the peripheral electrode area and the power supply unit. The switching device turns on the point electrodes currently in the projection area and turns off the point electrodes currently not in the projection area.

[0131] In one embodiment, the central electrode can be one of the following:

[0132] A single circular electrode that fills the central electrode area; or

[0133] Several block electrodes, which are combined to form a circle and fill the central electrode area.

[0134] Several ring electrodes, which are combined to form a circle and fill the central electrode area.

[0135] In one embodiment, there are several peripheral electrode areas, and the several peripheral electrode areas are concentric rings. The several peripheral electrode areas begin from the central electrode area and circle outward in turn, wherein the size of the outermost peripheral electrode area is the circumscribed circle of the non-circular substrate.

[0136] In one embodiment, power supply unit comprises a central power supply and several peripheral power supplies. The central power supply supplies power to the central electrode, and each peripheral power supply supplies power to the point electrodes in the corresponding peripheral electrode area respectively. Each peripheral electrode area has its own peripheral power supply and switching device.

[0137] In one embodiment, power supply unit comprises a central power supply for a central electrode and a peripheral power supply for the point electrodes in all peripheral electrode areas. Each peripheral electrode area has its own switching device, but all the peripheral electrode areas share the same peripheral power supply.

5 **[0138]** In one embodiment, a power supply supplies power to the central electrode and the point electrodes in all peripheral electrode areas at the same time. Each peripheral electrode area has its own switching device, but the central electrode and all the peripheral electrode areas share the same power supply.

10 **[0139]** In one embodiment, there peripheral electrode areas are sequentially arranged around the central electrode area. The point electrode can be circular, square, hexagonal or arc-shaped.

15 **[0140]** In one embodiment, the non-circular substrate is square, the four vertex angles of the square substrate are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each vertex angle is 90 degrees, and the opening angle of each vertex angle is symmetrical to the diameter of circle. Or the non-circular substrate is a rectangular substrate, and the four vertex angles of the rectangular substrate are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each vertex angle is 90 degrees, and the opening angle of each vertex angle is asymmetrical with respect to the diameter of the circle.

20 **[0141]** The electroplating apparatus and electroplating method for non-circular substrate of the present invention can be used for electroplating the substrate whose shape is square, rectangle, etc. Following the rotation of the substrate, the electrodes in the area covered by the substrate will be turned on, and the electrodes in the uncovered area will be turned off. The whole substrate can be under the uniform electric field intensity, and the situation of substrate cutting electric field will be avoided to ensure the uniformity of the electroplating on the substrate, especially in the
25 edge area of the substrate.

BRIEF DESCRIPTION OF DRAWINGS

[0142] FIG. 1a illustrates a structural view of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention.

30 **[0143]** FIG. 1b and 1c illustrate the different forms of the central electrode in an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention.

[0144] FIG. 2a and 2b illustrate a schematic diagram of the change of coverage area when a square substrate is rotated on the electroplating apparatus of the present invention.

[0145] FIG. 3 illustrates a schematic diagram of the determine method of the point electrodes covered by the substrate in the peripheral electrode area when the square substrate is rotated on the electroplating apparatus of the present invention.

[0146] FIG. 4 illustrates a schematic diagram of the determine method of the point electrodes covered by the substrate in the peripheral electrode area when the rectangular substrate is rotated on the electroplating apparatus of the present invention.

[0147] FIG. 5a illustrates a schematic diagram of a first arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention.

[0148] FIG. 5b illustrates a schematic diagram of a second arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention.

[0149] FIG. 5c illustrates a schematic diagram of a third arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention.

[0150] FIG. 5d illustrates a schematic diagram of a fourth arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention .

[0151] FIG. 6 illustrates the flowchart of an electroplating method for a non-circular substrate according to an embodiment of the present invention.

DETAILED DESCRIPTION

[0152] Refer to FIG.1a as shown, FIG. 1a illustrates a structural view of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention. The electroplating apparatus for non-circular substrate includes a central electrode area101, several peripheral electrode areas, a power supply unit103 and a control device104.

[0153] The central electrode area101 is circular, and the size of the central electrode area101 is the inscribed circle of the non-circular substrate. A common shape of the non-circular substrate is square or rectangular. The central electrode area101 is an inscribed circle of the square or rectangle. If the non-circular substrate is other shape, the central electrode area101 is also an inscribed circle of the non-circular substrate. A central electrode is disposed in the central electrode area101 and fills the central electrode area101. Because the central electrode fills the entire central electrode area, in this paper and the accompanying drawings, reference symbol 101

represents both the central electrode area and the central electrode. Although the central electrode fills the entire central electrode area, the central electrode also has a variety of configurations. In the embodiment shown in Figure 1a, the central electrode is a single circular electrode that fills the central electrode area. In the following detailed description, all the description is mainly based on the embodiment illustrated in FIG.1a that the central electrode configured as a single circular electrode. In other embodiments, the central electrode also has other configurations. For example, it is configured as several block electrodes, and the combination of several block electrodes forms a circle and fills the central electrode area. FIG. 1b and 1c illustrate the different forms of the central electrode in an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention. In the embodiment illustrated in FIG.3b, several fan-shaped block electrodes are combined to form the central electrode101. In the embodiment illustrated in FIG.3c, several concentric annular electrodes are combined to form the central electrode101. Configuring the central electrode in the forms of a combination of several block electrodes can make the control of the central electrode more flexible.

[0154] The peripheral electrode area surrounds the central electrode area, and the peripheral size of the peripheral electrode area is the circumscribed circle of the non-circular substrate. Closely arranged point electrodes are arranged in the peripheral electrode area, and the point electrodes fill the peripheral electrode area. In the embodiment shown in FIG.1a, there are several peripheral electrode areas, and the several peripheral electrode areas are in a concentric-ring shape. The several peripheral electrode areas start from the central electrode area101 and circle outward in turn, wherein the size of the outermost peripheral electrode area is the circumscribed circle of the non-circular substrate. Similarly, a common shape of a non-circular substrate is square or rectangular, and the outermost peripheral electrode area is the circumscribed circle of the square or rectangle. If the non-circular substrate is other shape, the outermost peripheral electrode area is also the circumscribed circle of the non-circular substrate. In the illustrated embodiment, three peripheral electrode areas are arranged around the central electrode area in turn, namely, a first peripheral electrode area121, a second peripheral electrode area122 and a third peripheral electrode area123. The outermost peripheral electrode area is the third peripheral electrode area 123, which is the circumscribed circle of the non-circular substrate. In the illustrated embodiment, the widths of the three peripheral electrode areas121, 122 and 123 are equal. In other embodiments, the widths of the first peripheral electrode area121, the second peripheral electrode area122 and the third peripheral electrode area123 can be unequal. Closely arranged point electrodes102 are arranged in the peripheral electrode area. The point electrodes102 are evenly distributed and fill the peripheral electrode area. The three peripheral electrode areas are all arranged with closely arranged point electrodes102. The point electrodes102 are evenly distributed and fill the three peripheral electrode areas. The point electrodes102 can be circular, square, hexagonal or arc-shaped. In the illustrated embodiment, the point electrodes102 are circular electrodes arranged closely next to each other and fill the entire peripheral electrode area. If the point electrodes are round, square or arc-shaped, there will be gaps between the point

electrodes due to the shape. If the point electrodes are hexagonal and arranged in a honeycomb pattern, the gap between the point electrodes can be small or no gap. The peripheral electrode area can also be divided into other numbers or only a single annular peripheral electrode area can be arranged around the central electrode area. Because the peripheral electrode area is filled with point electrodes, whether the peripheral electrode area is divided or how many areas it is divided into does not affect the working process of the point electrodes. For the convenience of control and expression, the peripheral electrode area is usually divided into three annular areas in this embodiment, and subsequent descriptions in this paper will use this configuration as an example for illustration.

[0155] The power supply unit103 is connected to the central electrode101 and the point electrodes102 to supply power to the central electrode101 and the point electrodes102.

[0156] The control device 104 is connected between the power supply unit103, the center electrode101 and the point electrodes102 and controls the on-off of the center electrode101 and the point electrodes102. The control device 104 tracks the rotating position of the substrate such that the electrodes in the central electrode area and the peripheral electrode area covered by the substrate are turned on and the electrodes uncovered by the substrate are turned off. The electrodes are turned on or off following the rotation of the substrate.

[0157] FIG. 2a and 2b illustrate a schematic diagram of the change of coverage area when a square substrate is rotated on the electroplating apparatus of the present invention. FIG.2a shows the state of the square substrate in the electroplating device at time t1, and FIG.2b shows the state of the square substrate in the electroplating device at time t2 after the square substrate is rotated. Refer to FIG. 2a and 2b as shown, the central electrode 101 is always covered by the substrate 200 because the central electrode101 is an internal circle of the square substrate 200. The first peripheral electrode area121, the second peripheral electrode area122 and the third peripheral electrode area123 are only covered by the four vertex angles of the substrate 200, wherein the outermost third peripheral electrode area123 is the circumscribed circle of the square substrate 200, so the square substrate200 will not exceed the range of the electroplating apparatus. As shown in FIG.2a and FIG.2b, the point electrodes102 marked by textured stripes in the three peripheral electrode areas are the point electrodes not covered by the substrate200, and the point electrodes102 represented by solid black are the point electrodes102 covered by the substrate 200. At different times t1 and t2, due to the rotation of the substrate, the point electrodes covered by the substrate are different. In one embodiment, the following method is used to determine which point electrodes in several peripheral electrode areas are currently covered by the substrate. The process can be referred to as FIG.3, which illustrates a schematic diagram of the determine method of the point electrodes covered by the substrate in the peripheral electrode area when the square substrate is rotated on the electroplating apparatus of the present invention.

[0158] As shown in FIG.3, taking square substrate200 as an example, the point electrodes covered by the substrate in the peripheral electrode area are determined as follows:

[0159] For the square substrate200, the diameter of the central electrode area101 is equal to the side length of the square, so the central electrode area101 is an inscribed circle of the square substrate 200. The diameter of the outermost third peripheral electrode area123 is equal to the length of the diagonal of the square, so the third peripheral electrode area is a circumscribed circle of the square substrate200.

[0160] Determine the position of each vertex angle of the non-circular substrate relative to the center of the circle at first. The center of the circle here is the common center of the concentric central electrode area101, the first peripheral electrode area121, the second peripheral electrode area122 and the third peripheral electrode area123. The square substrate 200 has four vertex angles.

[0161] For each vertex angle, the opening angle is determined from the two sides that make up the angle. For the square substrate200, the two sides that make up each vertex angle are two sides perpendicular to each other, so the opening angle of each vertex angle is 90 degrees. The four vertex angles of the square substrate200 are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each vertex angle is 90 degrees, and the opening angle of each vertex angle is symmetrical with respect to the diameter of the circle.

[0162] Detect the rotating position of the substrate, and the position of each vertex angle of the substrate is determined by the rotation position. The vertex angles are located on the outer circumference of the outermost peripheral electrode area. According to the rotation angle of the substrate, the angular position of the four angles of the substrate can be calculated. Take FIG.3 as an example to illustrate. The upward direction of each circular electrode area can be determined as the initial position, that is, the position of 0 degrees. The positive angle can be set in a clockwise direction along the circumference. After one week of cycling, 360 degrees coincide with 0 degrees. A certain vertex angle of the square substrate200 is determined as the reference vertex angle, and the angle difference between the other three angles and the reference vertex angle is 90 degrees, 180 degrees and 270 degrees. The detection of the rotation position of the substrate is to detect the deviation between the reference vertex angle and the 0 degrees position. For example, the reference vertex angle is 0 degrees in the initial position, and the remaining three angles can be calculated to be 90 degrees, 180 degrees, and 270 degrees. During the rotation of the substrate, if the reference vertex angle is detected to turn to 30 degrees, then the positions of remaining three angles can be calculated in turn that at the position of 120 degrees, 210 degrees and 300 degrees.

[0163] Taking each vertex angle as a starting point, the projection area in each peripheral electrode area is determined according to the opening angle of each vertex angle, and the point

electrodes falling in the projection area are the point electrodes covered by the substrate. After the position of each vertex angle is determined, the two sides are extended with the opening angle of each vertex angle is 90 degrees, and the projected area covered by the substrate can be delimited in the three peripheral electrode areas. The point electrodes located in the projected area are the point electrodes covered by the substrate. For the identification of point electrodes, a numbering method can be used to determine which point electrodes located in the projection area covered by the substrate.

[0164] FIG.4 illustrates a schematic diagram of the determine method of the point electrodes covered by the substrate in the peripheral electrode area when the rectangular substrate is rotated on the electroplating apparatus of the present invention. As shown in FIG.4, taking rectangular substrate 300 as an example, the point electrodes covered by the substrate in the peripheral electrode area are determined as follows:

[0165] For the rectangular substrate 300, the diameter of the central electrode area 101 is equal to the length of the short side of the rectangle, so the central electrode area 101 is an inscribed circle of the rectangular substrate 300. The diameter of the outermost third peripheral electrode area 123 is equal to the length of the diagonal of the rectangle, so the third peripheral electrode area is a circumscribed circle of the rectangular substrate 300.

[0166] Determine the position of each vertex angle of the non-circular substrate relative to the center of the circle at first. The center of the circle here is the common center of the concentric central electrode area 101, the first peripheral electrode area 121, the second peripheral electrode area 122 and the third peripheral electrode area 123. The rectangular substrate 300 has four vertex angles.

[0167] For each vertex angle, the opening angle is determined from the two sides that make up the angle. For the rectangular substrate 300, the two sides that make up each vertex angle are two sides perpendicular to each other, so the opening angle of each vertex angle is 90 degrees. The four vertex angles of the rectangular substrate 300 are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each vertex angle is 90 degrees, and the opening angle of each vertex angle is asymmetrical with respect to the diameter of the circle. If each vertex angle is connected to the center of the circle, it will be found that the opening angle of the vertex angle is smaller near the long side and larger near the short side, which is not symmetrical distributed with respect to the diameter.

[0168] Detect the rotating position of the substrate, and the position of each vertex angle of the substrate is determined by the rotation position. The vertex angles are located on the outer circumference of the outermost peripheral electrode area. According to the rotation angle of the substrate, the angular position of the four angles of the substrate can be calculated. Take FIG.4 as

an example to illustrate. The upward direction of each circular electrode area can be determined as the initial position, that is, the position of 0 degrees. The positive angle can be set in a clockwise direction along the circumference. After one week of cycling, 360 degrees coincide with 0 degrees. A certain vertex angle of the rectangular substrate 300 is determined as the reference vertex angle, and there are angle differences between the other three angles and the reference vertex angle. The angle differences between the remaining three angles of the rectangular substrate and the reference vertex angle is not equidistant. For example, the second vertex angle differs from the reference vertex angle by 60 degrees, the third vertex angle differs from the reference vertex angle by 180 degrees, and the fourth vertex angle differs from the reference vertex angle by 240 degrees. The detection of the rotation position of the substrate is to detect the deviation between the reference vertex angle and the 0 degrees position. For example, the reference vertex angle is 0 degrees in the initial position, and the remaining three angles can be calculated to be 60 degrees, 180 degrees, and 240 degrees. During the rotation of the substrate, if the reference vertex angle is detected to turn to 30 degrees, then the positions of remaining three angles can be calculated in turn that at the position of 90 degrees, 210 degrees and 270 degrees.

[0169] Taking each vertex angle as a starting point, the projection area in each peripheral electrode area is determined according to the opening angle of each vertex angle, and the point electrodes falling in the projection area are the point electrodes covered by the substrate. After the position of each vertex angle is determined, the two sides are extended with the opening angle of each vertex angle is 90 degrees, and the projected area covered by the substrate can be delimited in the three peripheral electrode areas. The point electrodes located in the projected area are the point electrodes covered by the substrate. For the identification of point electrodes, a numbering method can be used to determine which point electrodes located in the projection area covered by the substrate. Comparing FIG.4 and FIG.3, it can be seen that the position of the projection area is also different under the same substrate angle due to the different shapes of the substrate.

[0170] Referring back to FIG.1, in order to implement the above process, the control device 104 includes an angle sensor141, a projection simulator142 and a switching device143. The angle sensor141 tracks the rotation angle of the substrate. According to the rotation angle of the substrate determined by the angle sensor141, the angle of the reference vertex angle can be determined and the angles of the remaining three angles can be calculated accordingly. The projection simulator142 determines the position of each vertex angle according to the rotation angle of the substrate, and determines the projection area in each peripheral electrode area according to each vertex angle and its opening angle. The projection simulator142 determines the projection area in each peripheral electrode area according to the position and opening angle of each vertex and determines which point electrodes are in the projection area and covered by the substrate sequentially. The switching device 143 is connected between the point electrodes102 in the peripheral electrode area and the power supply unit103. The switching device143 turns on the point electrodes 102 currently in the projection area, and turns off the point electrodes102 not in

the projection area.

[0171] In different embodiments, the power supply unit and the control device, mainly the switching device in the control device, have different configuration modes. FIG.5a to FIG.5c reveal three different configuration modes.

5 **[0172]** First reference Figure5a, which illustrates a schematic diagram of a first arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention. In the first configuration mode, the power supply unit103 comprises a central area power supply131 and several peripheral area power supplies including a first peripheral area power supply132, a second peripheral area power supply133 and a third peripheral area power supply134 in the illustrated embodiment. The central area power supply131 supplies power to the central electrode101, and the power supply in each peripheral area supplies power to the point electrodes in its corresponding peripheral electrode area. Specifically, the first peripheral area power supply132 supplies power to the point electrodes in the first peripheral electrode area121, the second peripheral area power supply133 supplies power to the point electrodes in the second peripheral electrode area122, and the third peripheral area power supply134 supplies power to the point electrodes in the third peripheral electrode area123. The switching device143 is respectively connected to the first peripheral area power supply132, the second peripheral area power supply133 and the third peripheral area power supply134. There are several switching components in the switching device 143, and the relation between the switching components and the point electrodes is one-to-one correspondence. In the illustrated embodiment, the switching components of the switching device143 are divided into three parts corresponding to the point electrodes in the first peripheral electrode area121, the second peripheral electrode area122 and the third peripheral electrode area123 respectively. In this way, each peripheral electrode area has its own peripheral area power supply and switching device. In the first configuration mode, the central electrode area and the peripheral electrode area have independent power supply and switch. In the illustrated embodiment, the central electrode is directly connected to the central area power supply without switching device. Since the center electrode is always covered by the substrate that it is always in the conduction state during the electroplating process, so it can be controlled directly by the main power supply. There is no need to add a separate power supply.

35 **[0173]** FIG. 5b illustrates a schematic diagram of a second arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention. In the second configuration mode, the power supply unit 103 includes a central area power supply131 and a peripheral area power supply135. The central area power supply131 supplies power to the central electrode101, and the peripheral area power supply135 supplies power to all point electrodes in the peripheral electrode area. In other words, the first peripheral electrode area121, the second peripheral electrode area122 and the third

peripheral electrode area123 are all powered by the peripheral area power supply135. The switching device143 is connected to the peripheral area power supply135. There are several switching components in the switching device143, and the relation between the switching components and the point electrodes is one-to-one correspondence. In the illustrated embodiment, the switching components of the switching device143 are divided into three parts corresponding to the point electrodes in the first peripheral electrode area121, the second peripheral electrode area122 and the third peripheral electrode area123 respectively. In the second configuration mode, each peripheral electrode area has its own switching device and shares the same peripheral area power supply. Similar to FIG.5a, the center electrode is directly connected to the central area power supply without a switching device in the embodiment illustrated in FIG.5b.

[0174] FIG. 5c illustrates a schematic diagram of a third arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention. In the third configuration mode, the power supply unit103 supplies power to the central electrode and all point electrodes in the peripheral electrode area at the same time. The central electrode area101, the first peripheral electrode area121, the second peripheral electrode area122 and the third peripheral electrode area123 are powered by the same power supply. The switching device143 is connected to the power supply unit103. There are several switching components in the switching device143, and the relation between the switching components and the point electrodes is one-to-one correspondence. In the illustrated embodiment, the switching components of the switching device143 are divided into three parts corresponding to the point electrodes in the first peripheral electrode area121, the second peripheral electrode area122 and the third peripheral electrode area123 respectively. In the third configuration mode, each peripheral electrode area has its own switching device and shares the same peripheral area power supply. Similar to the previous illustration, the center electrode is directly connected to the central area power supply without a switching device in the embodiment illustrated in FIG.5c.

[0175] The three different configuration modes revealed in FIG.5a to FIG.5c mainly focus on the control relationship between the central area and peripheral electrode area. As described above, the central electrode area can be configured not only as a single circular electrode, but also as several block electrodes. When the central electrode area is configured as several block electrodes, the block electrodes are combined to form the central electrode area, and a group of switching components will also be added to the central electrode area. FIG. 5d illustrates a schematic diagram of a fourth arrangement of a power supply unit and a control device of an electroplating apparatus for a non-circular substrate according to an embodiment of the present invention. The fourth configuration mode is mainly for the central electrode area. The different between the fourth configuration mode shown in FIG.5d and the first configuration mode shown in Figure 5a is that the central electrode is composed of two concentric annular electrodes in the fourth configuration mode. Therefore, the central area power supply also includes two parts that 131a and 131b, and two groups of switching components that 143a and 143b are added between the

central area power supply and the central electrode. The two parts of the central area power supply and the two groups of switching components respectively control the two electrodes that make up the central electrode. In the illustrated embodiment, one of the parts 131a of the central area power supply and the switching components 143a control the electrode of the inner ring which is a circular electrode. Another part 131b of the central power supply and the switching component 143b control the electrode of the outer circle which is a ring electrode. The circular electrode and the ring electrode form the central electrode. The switching components 143a and 143b for controlling the central electrode are part of the switching device 143 and are also included in the switching device. In the embodiment shown in FIG.5b and FIG.5c, the central electrode can also be configured with a number of block electrodes and added a switching component to the central electrode area. Separate central area power supply and switching components for different areas of the central electrode can better control the working state of the central electrode.

[0176] The present invention also discloses an electroplating method for a non-circular substrate, which can also be understood as the working process of the above-mentioned electroplating apparatus for a non-circular substrate. FIG. 6 illustrates the flowchart of an electroplating method for a non-circular substrate according to an embodiment of the present invention. As shown in FIG.6, the electroplating method for a non-circular substrate comprises the following steps:

[0177] S1: Divide the electrode area. The electrode area is divided into a central electrode area and a peripheral electrode area. The central electrode area is circular, and the size of the central electrode area is the inscribed circle of the non-circular substrate. A central electrode is arranged in the central electrode area, and the central electrode fills the central electrode area. The peripheral electrode area surrounds the central electrode area, and the peripheral size of the peripheral electrode area is the circumscribed circle of the non-circular substrate. Closely arranged point electrodes are arranged in the peripheral electrode area, and the point electrodes fill the peripheral electrode area. The central electrode can be configured as a single circular electrode, several block electrodes or several ring electrodes. A single circular electrode alone fills the central electrode area. Several block electrodes are combined to form a circle and fill the central electrode area. Several ring electrodes are combined to form a circle and fill the central electrode area. In one embodiment, there are several peripheral electrode areas, and the several peripheral electrode areas are concentric rings. The several peripheral electrode areas start from the central electrode area and surround outwards sequentially, wherein the size of the outermost peripheral electrode area is the circumscribed circle of the non-circular substrate. Closely arranged point electrodes are arranged in the peripheral electrode area, and the point electrodes evenly distributed and fill the peripheral electrode area. In one embodiment, three peripheral electrode areas are sequentially arranged around the central electrode area, and the widths of the three peripheral electrode areas are equal. The point electrode can be circular, square, hexagonal or arc-shaped.

[0178] S2: Track the rotation of the substrate and track the rotating position of the substrate.

[0179] S3: Control the on-off of the electrodes. The power supply unit is connected to the central electrode and the point electrodes through the control device to supply power to the central electrode and the point electrodes. The control device controls the on-off of the central electrode and the point electrodes. According to the rotating position of the substrate, the control device turns on the electrodes in the area covered by the substrate in the central electrode area and the peripheral electrode area, and the electrodes in the area not covered by the substrate are turned off. The electrodes are turned on or off following the rotation of the substrate.

[0180] Wherein, the central electrode is always covered by the substrate, and the point electrodes covered by the substrate in the peripheral electrode area are determined as follows:

[0181] Determine the position of each vertex angle of the non-circular substrate relative to the center of the circle.

[0182] For each vertex angle, determine the opening angle according to the two sides that make up the vertex angle. In one embodiment, the non-circular substrate is a square substrate, and the four angles of the square substrate are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each angle is 90 degrees, and the opening angle of each vertex angle is symmetrical with respect to the diameter of the circle. In another embodiment, the non-circular substrate is a rectangular substrate, and the four angles of the rectangular substrate are located on the outer circumference of the outermost peripheral electrode area. The opening angle of each angle is 90 degrees, and the opening angle of each vertex angle is asymmetrical with respect to the diameter of the circle.

[0183] Detect the rotating position of the substrate, and determine the position of each vertex angle of the substrate according to the rotating position of the substrate. The vertex angles are located on the outer circumference of the peripheral electrode area.

[0184] Taking each vertex angle as the origin, the projection area in the peripheral electrode area is determined according to the opening angle of each vertex angle. The point electrodes falling in the projection area are the point electrodes covered by the substrate.

[0185] The control device determines the point electrodes covered by the substrate in the peripheral electrode area through the following components:

[0186] Track the rotation angle of the substrate through the angle sensor;

[0187] Use a projection simulator to determine the position of each vertex angle according to the rotating angle of the substrate, and determine the projection area in the peripheral electrode

area according to the position and opening angle of the vertex angles;

5 [0188] Control the on-off of the point electrodes through the switching device connected between the point electrodes in the peripheral electrode area and the power supply unit. The switching device turns on the point electrodes currently in the projection area and turns off the point electrodes currently not in the projection area.

[0189] The power supply unit and control device can be configured in the following three configurations:

10 [0190] The power supply unit comprises a central power supply and several peripheral power supplies. The central power supply supplies power to the central electrode, and each peripheral power supply supplies power to the point electrodes in the corresponding peripheral electrode area respectively. Each peripheral electrode area has its own peripheral power supply and switching device; or

15 [0191] The power supply unit comprises a central power supply for a central electrode and a peripheral power supply for the point electrodes in all peripheral electrode areas. Each peripheral electrode area has its own switching device, but all the peripheral electrode areas share the same peripheral power supply; or

[0192] A power supply supplies power to the central electrode and the point electrodes in all peripheral electrode areas at the same time. Each peripheral electrode area has its own switching device, but the central electrode and all the peripheral electrode areas share the same power supply.

20 [0193] The implementation details of the electroplating method for non-circular substrates correspond to the electroplating apparatus for non-circular substrates mentioned above. For details, please refer to the above description of the electroplating apparatus for the non-circular substrate.

25 [0194] The electroplating apparatus and electroplating method for non-circular substrates of the present invention can electroplate substrates with shapes such as square, rectangular, etc. Following the rotation of the substrates, the electrodes in the areas covered by the substrates are turned on, and the electrodes in the uncovered areas are turned off. It can make the whole substrate under the uniform electric field intensity and avoid the occurrence of substrate cutting electric field, so as to ensure the uniformity of electroplating on the substrate, especially the edge area of
30 the substrate.

[0195] It should also be noted that the above-mentioned embodiments are only specific embodiments of the present invention. Obviously, the present invention is not limited to the above embodiments. The subsequent similar changes or deformations that can be directly derived or

easily associated by those of skill in the art from the contents disclosed in the invention shall fall within the scope of protection of the invention. The embodiments are provided to those of skill in the art to realize or use the invention, and those of skill in the art may make various modifications or changes to the embodiments without deviating from the invention idea of the invention.

- 5 Therefore, the scope of protection of the invention is not limited by the said embodiments, but should be in line with the maximum scope of innovative features mentioned in the claims.

What is claimed is:

1. An electroplating apparatus for non-circular substrate, comprising:

A circular central electrode area configured with a central electrode filling the entire center electrode area which size is an inscribed circle of the non-circular substrate;

5 A peripheral electrode area configured with a close arrangement of point electrodes filling the peripheral electrode area which peripheral size is the circumscribed circle of the non-circular substrate surrounding the central electrode area;

A power supply unit being connected to the central electrode and the point electrodes to supply power to the central electrode and the point electrodes; and

10 A control device being connected between the power supply unit, the central electrode and the point electrodes for controlling the on-off of the central electrode and the point electrodes, wherein the control device tracks the rotating position of the substrate so that the electrodes in the central electrode area and the peripheral electrode area covered by the substrate will be turned on and the electrodes not covered by the substrate will be turned off.

15 2. An electroplating apparatus for non-circular substrate as claimed in claim 1, wherein the central electrode is always covered by the substrate, the point electrodes in the peripheral electrode area covered by the substrate being determined as follows:

Determining the position of each vertex angle of the non-circular substrate relative to the center of the circle;

20 Determining the opening angle of each vertex angle according to the two sides that make up the vertex angle;

Detecting the rotating position of the substrate, determining the position of each vertex angle of the substrate according to the rotating position of the substrate, wherein the vertex angles are located on the outer circumference of the peripheral electrode area;

25 Taking each vertex angle as the origin, determining the projection area in the peripheral electrode area according to the opening angle of each vertex angle, the point electrodes falling in the projection area being the point electrodes covered by the substrate.

3. An electroplating apparatus for non-circular substrate as claimed in claim 2, wherein the controlling device includes:

An angle sensor configured to track the rotation angle of the substrate;

A projection simulator configured to determine the position of each vertex angle according to the rotation angle of the substrate and determine the projection area according to the opening angle of each vertex angle;

5 A switching device connected between the point electrodes in the peripheral area and the power supply unit configured to turn on the point electrodes currently in the projection area and turn off the point electrodes currently not in the projection area.

4. An electroplating apparatus for non-circular substrate as claimed in claim 1, wherein the central electrode is:

10 A single circular electrode filling the central electrode area; or

Several block electrodes combined to form a circle and filling the central electrode area; or

Several ring electrodes combined to form a circle and filling the central electrode area.

5. An electroplating apparatus for non-circular substrate as claimed in claim 4, wherein there are several concentric-ring shape peripheral electrode areas starting from the central electrode area and circling outward in turn, the outermost peripheral electrode area size of which is the circumscribed circle of the non-circular substrate.

6. An electroplating apparatus for non-circular substrate as claimed in claim 5, wherein the power supply unit comprises a central power supply supplies power to the central electrode and several peripheral power supplies supply power to the point electrodes in the corresponding peripheral electrode area respectively, each peripheral electrode area configured with its own peripheral power supply and switching device.

7. An electroplating apparatus for non-circular substrate as claimed in claim 5, wherein the power supply unit comprises a central power supply supplies power to the central electrode and a peripheral power supply supplies power to the point electrodes in all peripheral electrode areas, each peripheral electrode area configured with its own peripheral power supply and sharing the same switching device.

8. An electroplating apparatus for non-circular substrate as claimed in claim 5, wherein the power supply unit supplies power to the central electrode and the point electrodes in all peripheral electrode areas, each peripheral electrode area configured with its own switching device, all peripheral electrode areas and the central electrode sharing the same power supply unit.

9. An electroplating apparatus for non-circular substrate as claimed in claim 5, wherein three peripheral electrode areas are arranged sequentially around the central electrode area, the shape of the point electrode configured to circular, square, hexagonal or arc-shaped.

5 10. An electroplating apparatus for non-circular substrate as claimed in claim 9, wherein the non-circular substrate is:

a square substrate which four vertex angles are located on the outer circumference of the outermost peripheral electrode area that the opening angle of each vertex angle is 90 degrees and the opening angle of each vertex angle is symmetrical to the diameter of circle; or

10 a rectangle substrate four vertex angles are located on the outer circumference of the outermost peripheral electrode area that the opening angle of each vertex angle is 90 degrees and the opening angle of each vertex angle is asymmetrical to the diameter of circle.

11. An electroplating method for non-circular substrate, including:

15 Dividing the electrode area into a circular central electrode area configured with a central electrode filling the central electrode area which size is the inscribed circle of the non-circular substrate and a peripheral electrode area configured with a close arrangement of point electrodes filling the peripheral electrode area which peripheral size is the circumscribed circle of the non-circular substrate surrounding the central electrode area.

Tracking the rotation of the substrate and tracking the rotating position of the substrate.

20 Controlling the on-off of the electrodes, the power supply unit connected to the central electrode and the point electrodes through the control device configured to control the on-off of the central electrode and the point electrodes to supply power to the central electrode and the point electrodes, wherein the control device turns on the electrodes in the area covered by the substrate and turns off the electrodes in the area not covered by the substrate in the central electrode area and the peripheral electrode area according to the rotating position of the substrate so that the
25 electrodes are turned on or off following the rotation of the substrate.

12. An electroplating method for non-circular substrate as claimed in claim 11, wherein the central electrode is always covered by the substrate, the point electrodes in the peripheral electrode area covered by the substrate being determined as follows:

30 Determining the position of each vertex angle of the non-circular substrate relative to the center of the circle;

Determining the opening angle of each vertex angle according to the two sides that make up

the vertex angle;

Detecting the rotating position of the substrate, determining the position of each vertex angle of the substrate according to the rotating position of the substrate, wherein the vertex angles are located on the outer circumference of the peripheral electrode area;

- 5 Taking each vertex angle as the origin, determining the projection area in the peripheral electrode area according to the opening angle of each vertex angle, the point electrodes falling in the projection area being the point electrodes covered by the substrate.

13. An electroplating method for non-circular substrate as claimed in claim 12, wherein the controlling device configured as following:

- 10 Tracking the rotation angle of the substrate through an angle sensor;

Determining the position of each vertex angle according to the rotation angle of the substrate through a projection simulator and determining the projection area according to the opening angle of each vertex angle;

- 15 Controlling the on-off of the point electrodes that turn on the point electrodes currently in the projection area and turn off the point electrodes currently not in the projection area through a switching device connected between the point electrodes in the peripheral area and the power supply unit.

14. An electroplating method for non-circular substrate as claimed in claim 11, wherein the central electrode is:

- 20 A single circular electrode filling the central electrode area; or

Several block electrodes combined to form a circle and filling the central electrode area; or

Several ring electrodes combined to form a circle and filling the central electrode area.

- 25 15. An electroplating method for non-circular substrate as claimed in claim 11, wherein there are several concentric-ring shape peripheral electrode areas starting from the central electrode area and circling outward in turn, the outermost peripheral electrode area size of which is the circumscribed circle of the non-circular substrate.

16. An electroplating method for non-circular substrate as claimed in claim 15, wherein the power supply unit comprises a central power supply supplies power to the central electrode and several peripheral power supplies supply power to the point electrodes in the corresponding

peripheral electrode area respectively, each peripheral electrode area configured with its own peripheral power supply and switching device.

5 17. An electroplating method for non-circular substrate as claimed in claim 15, wherein the power supply unit comprises a central power supply supplies power to the central electrode and a peripheral power supply supplies power to the point electrodes in all peripheral electrode areas, each peripheral electrode area configured with its own peripheral power supply and sharing the same switching device.

10 18. An electroplating method for non-circular substrate as claimed in claim 15, wherein the power supply unit supplies power to the central electrode and the point electrodes in all peripheral electrode areas, each peripheral electrode area configured with its own switching device, all peripheral electrode areas and the central electrode sharing the same power supply unit.

19. An electroplating method for non-circular substrate as claimed in claim 15, wherein three peripheral electrode areas are arranged sequentially around the central electrode area, the shape of the point electrode configured to circular, square, hexagonal or arc-shaped.

15 20. An electroplating method for non-circular substrate as claimed in claim 19, wherein the non-circular substrate is:

a square substrate which four vertex angles are located on the outer circumference of the outermost peripheral electrode area that the opening angle of each vertex angle is 90 degrees and the opening angle of each vertex angle is symmetrical to the diameter of circle; or

20 a rectangle substrate four vertex angles are located on the outer circumference of the outermost peripheral electrode area that the opening angle of each vertex angle is 90 degrees and the opening angle of each vertex angle is asymmetrical to the diameter of circle.