

ELECTROPLATING METHOD AND ELECTROPLATING APPARATUS

TECHNICAL FIELD

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

BACKGROUND

In the electroplating field, a seed layer is a thin metal layer formed on the surface of a substrate through chemical or physical methods. The seed layer is critical in the electroplating process, and the seed layer is used to guide and promote metal deposition. To increase the area of the effective electroplating region, the electrical contact points between an existing electroplating apparatus and the seed layer on the substrate are all located at the edge region of the substrate, with no direct contact at the central region of the substrate.

The higher the resistivity of the seed layer material and the thinner the thickness, the greater the resistance and the larger the difference in current density distribution. Since the electrical contact points are at the edge region of the substrate, the current density at the edge region of the substrate will be much higher than the current density at the central region of the substrate. Such uneven distribution of current density will result in thick plating layer at the edge of the substrate and thin plating layer at the center of the substrate, leading to a serious non-uniformity phenomenon.

In response to this situation, the current solution is to adopt an electroplating apparatus with multiple anodes, where each anode is controlled independently. According to the thickness difference in the plating layer obtained from preliminary experiments, the power of each anode during the electroplating process is controlled through a preset program. However, this solution has poor adaptability and can only be applied to specific seed layers. After the seed layer is replaced, the program needs to be reset.

SUMMARY

In view of the above defect of the prior art, the present invention provides an

electroplating method and an electroplating apparatus.

The present invention solves the technical problem described above through the following technical solution:

an electroplating method, comprising providing an electroplating apparatus, wherein the electroplating apparatus comprises a central anode and an edge electrode, the central anode corresponds to the central region of a substrate, and the edge electrode corresponds to the edge region of the substrate, the electroplating method further comprising:

S10: applying a positive voltage to the central anode, the edge electrode being inactive;

S20: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S30: comparing the magnitudes of v_1 and v_2 ;

S40: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, and outputting current I ;

S50: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, and outputting current I ;

S60: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged.

In the above method, a positive voltage is first applied to the central anode while the edge electrode is inactive. By separately obtaining the deposition rates of the plating layer on the central region and the plating layer on the edge region, the difference in the deposition rate between the edge region and the central region can be obtained. Based on this difference, the voltage and the output current of the edge electrode are controlled to bring the plating thickness on the central region of the substrate and on the edge region of the substrate closer together, thereby improving the electroplating uniformity.

The present invention further provides an electroplating apparatus, comprising an electroplating tank for containing an electroplating solution, and further comprising:

a central anode, arranged in the electroplating solution, and corresponding to the central region of the substrate;

a central power supply, connected to the edge region of the substrate and the central anode, for applying a positive voltage to the central anode and applying a negative voltage to the substrate;

an edge electrode, arranged around the periphery of the central anode, and corresponding to the edge region of the substrate;

an edge power supply, connected to the clamping region of the substrate and the edge electrode;

a central rate measurement module, for acquiring the deposition rate v_1 of the plating layer on the central region of the substrate;

an edge rate measurement module, for acquiring the deposition rate v_2 of the plating layer on the edge region of the substrate;

a control module, for comparing the magnitudes of v_1 and v_2 , and controlling the voltage polarity and the current magnitude applied by the edge power supply to the edge electrode according to the comparison result.

The above electroplating apparatus is provided with a central power supply and an edge power supply. The central power supply can independently supply power to the central anode, and the edge power supply can independently supply power to the edge electrode; the control of the central anode and the edge electrode is relatively independent. By providing a central rate measurement module and an edge rate measurement module, the deposition rates of the plating layer on the central region and on the edge region of the substrate can be obtained in real time. Under the action of the control module, the output of the edge power supply can be intelligently controlled based on the magnitudes of v_1 and v_2 , allowing v_2 to always approach v_1 until v_2 is equal to v_1 . This apparatus can make the plating layer thickness of the substrate more

uniform, and can establish closed-loop control. The apparatus remains applicable after the resistance of the seed layer changes, featuring broader adaptability.

The present invention further provides an electroplating method, comprising providing an electroplating apparatus, wherein the electroplating apparatus comprises a central anode and an edge electrode, the central anode corresponds to the central region of a substrate, and the edge electrode corresponds to the edge region of the substrate, the electroplating method further comprising:

S1000: applying a positive voltage to the central anode, applying a positive voltage to the edge electrode, and outputting current I ;

S1100: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S1200: comparing the magnitudes of v_1 and v_2 ;

S1300: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, increasing the output current I , and returning to step S1100;

S1400: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S1500: if v_1 is smaller than v_2 , applying a positive voltage to the edge electrode, and reducing the output current I .

In the initial step S1000 of the above method, a positive voltage is applied to the edge electrode, and current I is output. For cases where the resistance of the substrate's seed layer is relatively low, if only the central anode is set to be active, v_1 will be greater than v_2 . Therefore, by adopting this method, v_2 can be adjusted rapidly, allowing v_2 to approach v_1 more quickly, thereby accelerating the adjustment speed.

The present invention further provides an electroplating method, comprising providing an electroplating apparatus, wherein the electroplating apparatus comprises a central anode and an edge electrode, the central anode corresponds to the central region of a substrate, and the edge electrode corresponds to the edge region of the

substrate, the electroplating method further comprising:

S2000: applying a positive voltage to the central anode, applying a negative voltage to the edge electrode, and outputting current I;

S2100: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S2200: comparing the magnitudes of v_1 and v_2 ;

S2300: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, increasing the output current I, and returning to step S2100;

S2400: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S2500: if v_1 is greater than v_2 , applying a negative voltage to the edge electrode, and reducing the output current I.

In the initial step S2000 of the above method, a negative voltage is applied to the edge electrode, and current I is output. For cases where the resistance of the substrate's seed layer is relatively high, if only the central anode is set to be active, v_2 will be greater than v_1 . Therefore, by adopting this method, v_2 can be adjusted rapidly, allowing v_2 to approach v_1 more quickly, thereby accelerating the adjustment speed.

BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1A is a schematic diagram of the electroplating apparatus according to embodiment 1 of the present invention;

FIG. 1B is a schematic diagram of wafer region division according to embodiment 1 of the present invention;

FIG. 2 is a schematic diagram of the electric field when a positive voltage is

applied to the edge electrode according to embodiment 1 of the present invention;

FIG. 3 is a schematic diagram of the electric field when the edge electrode is deactivated according to embodiment 1 of the present invention;

FIG. 4 is a schematic diagram of the electric field when a negative voltage is applied to the edge electrode according to embodiment 1 of the present invention;

FIG. 5 is a schematic diagram of the central rate measurement module according to embodiment 1 of the present invention;

FIG. 6 is a schematic diagram of the central thickness measurement device according to embodiment 1 of the present invention;

FIG. 7 is a schematic diagram of the edge rate measurement module according to embodiment 1 of the present invention;

FIG. 8 is a schematic diagram of the edge thickness measurement device according to embodiment 1 of the present invention;

FIG. 9 is a schematic diagram of distribution of central eddy current sensors and edge eddy current sensors according to embodiment 1 of the present invention;

FIG. 10 is a flow chart of the electroplating method according to embodiment 2 of the present invention;

FIG. 11 is a flow chart of the electroplating method according to embodiment 3 of the present invention;

FIG. 12 is a flow chart of the electroplating method according to embodiment 4 of the present invention.

PREFERRED EMBODIMENTS OF THE PRESENT INVENTION

To describe the technical content, structural features, and achieved objectives and effects of the present invention in detail, the following embodiments and accompanying drawings will be used for detailed description, but the present invention

is not therefore limited to the scope of the described embodiments.

Embodiment 1

In an electroplating apparatus having multiple anodes, independent or joint control can be performed on different anodes. Current control methods are all open-loop control, provide no feedback mechanism, and are unable to adjust the output power of different anodes in real time according to the state of the plating layer thickness, thereby failing to establish closed-loop control. Therefore, when a seed layer is changed, the control program needs to be adjusted to adapt to the new seed layer, exhibiting poor adaptability. In addition, during the electroplating process, changes in the plating layer thickness cannot be monitored in real time, and the uniformity of the plating layer is uncontrollable.

As shown in FIG. 1A, FIG. 1B, and FIG. 2, this embodiment provides an electroplating apparatus capable of adjusting the output power of an edge electrode 400 in real time according to the deposition rate of the plating layer, comprising: an electroplating tank 150, a cathode clamp 100, a central anode 200, a central power supply 300, the edge electrode 400, an edge power supply 500, a central rate measurement module 600, an edge rate measurement module 700, and a control module 800. The electroplating tank 150 is configured to accommodate an electroplating solution. The cathode clamp 100 is configured to clamp a substrate 910. The substrate 910 includes a central region 913, an edge region 912, and a clamping region 911. The central anode 200 is disposed within the electroplating solution and corresponds to the central region 913 of the substrate 910. The negative terminal of the central power supply 300 is connected to the clamping region 911 of the substrate 910 via the cathode clamp 100, and configured to apply a negative voltage to the substrate 910. The positive terminal of the central power supply 300 is connected to the central anode 200, and configured to apply a positive voltage to the central anode 200. The edge electrode 400 is arranged surrounding the periphery of the central anode 200 and corresponds to the edge region 912 of the substrate 910. The edge power supply 500 is connected to the clamping region 911 of the substrate 910 via the cathode clamp 100. Furthermore, the edge power supply 500 is also connected to the edge electrode 400, and configured to apply a positive voltage or a negative voltage to the edge electrode 400. The central rate measurement module 600 is configured to acquire the deposition

rate v_1 of the plating layer on the central region 913 of the substrate 910. The edge rate measurement module 700 is configured to acquire the deposition rate v_2 of the plating layer on the edge region 912 of the substrate 910. The control module 800 is configured to compare the magnitudes of v_1 and v_2 , and based on the comparison result, control the voltage polarity and the current magnitude applied by the edge power supply 500 to the edge electrode 400.

In other embodiments, the central power supply 300 and the edge power supply 500 may also be directly connected to the clamping region 911 of the substrate 910.

The electroplating apparatus is provided with the central power supply 300 and the edge power supply 500; the central power supply 300 can independently supply power to the central anode 200, and the edge power supply 500 can independently supply power to the edge electrode 400, allowing the control of the central anode 200 and the edge electrode 400 to be relatively independent. By providing the central rate measurement module 600 and the edge rate measurement module 700, the deposition rates of the plating layer on the central region 913 and on the edge region 912 can be acquired in real time. Under the action of the control module 800, the output of the edge power supply 500 can be intelligently controlled according to the magnitudes of v_1 and v_2 , thereby allowing v_2 to always approach v_1 until v_2 is equal to v_1 . Through this control method, the electroplating apparatus makes the plating layer thickness of the substrate 910 more uniform and can establish closed-loop control, which remains applicable even after the resistance of the seed layer changes, featuring wider adaptability.

According to FIG. 1B and FIG. 2, to increase the area of the effective electroplating region, the central power supply 300 and the edge power supply 500 of the electroplating apparatus supply power to a seed layer 920 on the substrate 910 via contact pins 930 of the cathode clamp 100. The contact positions between the contact pins 930 and the seed layer 920 are located on the clamping region 911 of the substrate 910. The greater the resistance of the seed layer 920, the more severe the edge effect of the substrate 910. For example, when the seed layer employs cobalt material, due to the poor conductivity of cobalt, the electric field intensity on the edge region 912 of the substrate 910 is much higher than the electric field intensity on the central region 913, thereby causing the current density on the edge region 912 of the substrate 910 to

be much higher than the current density on the central region 913, and resulting in greater plating layer thickness on the edge region 912 of the substrate 910 than on the central region 913 of the substrate 910.

A positive voltage is typically applied to the edge electrode 400, and by supplying appropriate current, the edge effect problem is improved. However, as shown in FIG. 3, when the resistance of the seed layer 920 is particularly high, even when the edge electrode 400 corresponding to the edge region 912 of the substrate 910 is inactive, i.e., the output current of the edge power supply 500 is reduced to zero, the electric field intensity on the edge region 912 of the substrate 910 still remains higher than the electric field intensity on the central region 913 of the substrate 910, and the plating layer on the edge region 912 of the substrate 910 still remains thicker than the plating layer on the central region 913 of the substrate 910. In this case, the edge power supply 500 in this embodiment can further apply a negative voltage to the edge electrode 400. The voltages of the edge electrode 400 and the central anode 200 are both referenced to the substrate potential, for example, the substrate potential is taken as zero potential.

The edge power supply 500 is capable of applying both positive and negative voltages to the edge electrode 400, adapting to seed layers having different resistance values. When the resistance of the seed layer 920 of the substrate 910 is relatively small, the edge power supply 500 applies a positive voltage to the edge electrode 400, and the distribution of electric field lines on the edge region 912 and the central region 913 of the substrate 910 is relatively uniform. Specifically, the electric field line density (i.e., electric field intensity) on the edge region 912 of the substrate 910 is slightly higher than the electric field line density on the central region 913. In this case, if only the output current of the edge power supply 500 is reduced, the electric field line densities on the edge region 912 and on the central region 913 of the substrate 910 can be regulated, achieving identical deposition rates of the plating layer on the two regions. The greater the resistance of the seed layer 920 of the substrate 910, the greater the difference in the distribution of electric field lines between the central region 913 and the edge region 912 of the substrate 910. When the resistance of the seed layer 920 of the substrate 910 is sufficiently large, under the condition that the edge power supply 500 applies a positive voltage to the edge electrode 400, even if current output is stopped, the difference in the deposition rate of the plating layer between the edge

region 912 and the central region 913 still cannot be balanced. In this case, as shown in FIG. 4, the edge power supply 500 can apply a negative voltage to the edge electrode 400 to absorb a portion of the electric field lines emitted from the central anode 200 toward the edge region 912 of the substrate 910, which further reduces the deposition rate of the plating layer on the edge region 912, thereby making the plating layer on the central region 913 and on the edge region 912 of the substrate 910 more uniform.

It should be noted that FIG. 2, FIG. 3, and FIG. 4 are used only to illustrate the distribution of electric field lines when the edge electrode 400 is in different states and do not represent actual electric field distribution.

As shown in FIG. 5, the central rate measurement module 600 includes a central thickness measurement device 610 and a central rate calculation module 620. The central thickness measurement device 610 is configured to acquire the thickness value of the plating layer on the central region of the substrate 910. The central rate calculation module 620 is configured to calculate the deposition rate of the plating layer on the central region of the substrate 910 based on the thickness value of the plating layer on the central region of the substrate 910 and the sampling frequency of the central thickness measurement device 610.

Further, as shown in FIG. 6 and FIG. 9, the central thickness measurement device 610 includes a plurality of central eddy current sensors 611 and a central thickness calculation module 612. The central eddy current sensors 611 are distributed at intervals on the non-electroplated surface of the central region 913 of the substrate 910. The central thickness calculation module 612 is connected to the central eddy current sensors 611 and is configured to receive electrical signals from the central eddy current sensors 611 and output the average thickness value of the plating layer on the central region 913 of the substrate 910.

As shown in FIG. 7, the edge rate measurement module 700 includes an edge thickness measurement device 710 and an edge rate calculation module 720. The edge thickness measurement device 710 is configured to acquire the thickness value of the plating layer on the edge region of the substrate 910. The edge rate calculation module 720 is configured to calculate the deposition rate of the plating layer on the edge region of the substrate 910 based on the thickness value of the plating layer on the edge region

of the substrate 910 and the sampling frequency of the edge thickness measurement device 710.

Further, as shown in FIG. 8 and FIG. 9, the edge thickness measurement device 710 includes a plurality of edge eddy current sensors 711 and an edge thickness calculation module 712. The edge eddy current sensors 711 are distributed at intervals on the non-electroplated surface of the edge region 912 of the substrate 910. The edge thickness calculation module 712 is connected to the edge eddy current sensors 711 and is configured to receive electrical signals from the edge eddy current sensors 711 and output the average thickness value of the plating layer on the edge region 912 of the substrate 910.

Specifically, both the central thickness measurement device 610 and the edge thickness measurement device 710 are connected to a power supply via slip rings. The power supply is configured to supply power to the central thickness measurement device 610 and the edge thickness measurement device 710, thereby maintaining synchronous rotation with the substrate 910.

The control module 800, the central thickness calculation module 612, and the edge thickness calculation module 712 may be implemented using software, hardware, or a combination of software and hardware.

Furthermore, the specific implementation methods of the central rate measurement module 600 and the edge rate measurement module 700 are not limited to the solution in this embodiment and may also employ relatively mature solutions in the prior art.

Embodiment 2

This embodiment further provides an electroplating method. The electroplating apparatus used comprises a central anode and an edge electrode, wherein the central anode corresponds to the central region of a substrate, and the edge electrode corresponds to the edge region of the substrate. An exemplary electroplating apparatus is shown in FIG. 1, though the implementation environment of the electroplating method of this embodiment is not limited thereto.

According to FIG. 10, the electroplating method of this embodiment specifically comprises:

S10: applying a positive voltage to the central anode, the edge electrode being inactive;

S20: acquiring the deposition rate v_1 of the plating layer on the central region of the substrate, and acquiring the deposition rate v_2 of the plating layer on the edge region of the substrate;

S30: comparing the magnitudes of v_1 and v_2 ;

S40: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, and outputting current I ;

S50: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, and outputting current I ;

S60: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged, that is, no adjustment being made to the voltage and the output current I of the edge electrode.

The output current I in step S40 and the output current I in step S50 are initial preset values; the two values may be the same or different. The output current I in subsequent steps is a current value changed based on the initial preset values.

Through the central anode and the edge electrode, the deposition rates of the plating layer on the central region and on the edge region of the substrate can be controlled separately. In this method, first, a positive voltage is applied to the central anode, and the edge electrode is inactive. By separately acquiring the deposition rates of the plating layer on the central region and on the edge region, the difference in the deposition rate between the edge region and the central region can be obtained. Based on this difference, the voltage and the output current of the edge electrode are controlled, bringing the plating layer thicknesses on the central region and on the edge region of the substrate closer together, thereby improving the uniformity of electroplating.

Wherein, v_1 and v_2 may be substantially equal, with a permissible deviation based on actual use, that is, when the difference value between v_1 and v_2 is within a preset range, v_1 and v_2 may be considered equal.

After step S40, the following steps are further included:

S41: acquiring v_1 and v_2 ;

S42: comparing the magnitudes of v_1 and v_2 ;

S43: if v_1 is smaller than v_2 , applying a positive voltage to the edge electrode, and reducing the output current I ;

S45: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S46: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, increasing the output current I , and returning to step S41.

After step S43, the following step is further included:

S44: determining whether the output current I is 0; if I is not equal to 0, returning to step S41; if I is equal to 0, returning to step S30.

By adopting the closed-loop control method, the voltage and the output current I of the edge electrode can be continuously adjusted dynamically according to the magnitudes of v_1 and v_2 until v_1 is equal to v_2 , thereby further improving the uniformity of substrate electroplating. In step S43, by reducing the output current I , v_2 can be reduced. In step S44, if the output current I is not equal to 0, return to step S41; under the condition of applying a positive voltage to the edge electrode, the magnitude of v_2 is changed by controlling the magnitude of the output current I until v_1 is equal to v_2 . If the output current I is equal to 0, it indicates that the edge electrode has been deactivated, and v_1 may still be smaller than v_2 ; in this case, it is necessary to return to step S30, and v_2 can be further adjusted by changing the voltage polarity of the edge electrode.

After step S50, the following steps are further included:

S51: acquiring v_1 and v_2 ;

S52: comparing the magnitudes of v_1 and v_2 ;

S53: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, and increasing the output current I ;

S54: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S55: if v_1 is greater than v_2 , applying a negative voltage to the edge electrode, and reducing the output current I .

In this embodiment, after step S55, the following step is further included:

S56: determining whether the output current I is 0; if I is not equal to 0, returning to step S51; if I is equal to 0, returning to step S30.

In step S50, by applying a negative voltage to the edge electrode, a portion of the electric field of the central anode can be transferred, thereby reducing v_2 . After step S50, by acquiring the magnitudes of v_1 and v_2 again, and according to the magnitudes of v_1 and v_2 , the magnitude of the output current I is adjusted, and v_2 can be dynamically adjusted to make v_1 equal to v_2 . Furthermore, in step S56, if I is not equal to 0, return to step S51 for dynamic adjustment again; if I is equal to 0, it indicates that the edge electrode has been deactivated, and v_1 may still be greater than v_2 ; in this case, it is necessary to return to step S30, thereby enabling control of the edge electrode to switch from negative voltage to positive voltage to further adjust v_2 .

In this embodiment, the step of acquiring the deposition rate v_1 of the plating layer on the central region in step S20 specifically includes:

S21: arranging a central thickness measurement device on the non-electroplated surface of the central region;

S22: calculating v_1 through the thickness value output by the central thickness

measurement device and the sampling frequency of the central thickness measurement device.

Specifically, the sampling frequency refers to the number of thickness measurements performed by the central thickness measurement device per second. For example, if the sampling frequency is 10 Hz, it means the device can perform 10 thickness measurements per second. By multiplying the difference between two output thickness values by the sampling frequency, v_1 can be calculated.

Further, the central thickness measurement device includes a plurality of central eddy current sensors and a central thickness calculation module. The correspondence relationship between the electrical signals output by the central eddy current sensors and the plating layer thickness is obtained through a standard sample. The central thickness calculation module receives the electrical signals output by the plurality of central eddy current sensors, and outputs the thickness value by the method of averaging according to the correspondence relationship between the electrical signals output by the central eddy current sensors and the plating layer thickness.

In this embodiment, the step of acquiring the deposition rate v_2 of the plating layer on the edge region in step S20 specifically includes:

S23: arranging an edge thickness measurement device on the non-electroplated surface of the edge region;

S24: calculating v_2 through the thickness value output by the edge thickness measurement device and the sampling frequency of the edge thickness measurement device.

Wherein, the calculation principle of v_2 is the same as the calculation principle of v_1 .

Further, the edge thickness measurement device includes a plurality of edge eddy current sensors and an edge thickness calculation module. The correspondence relationship between the electrical signals output by the edge eddy current sensors and the plating layer thickness is obtained through a standard sample. The edge thickness calculation module receives the electrical signals output by the plurality of edge eddy

current sensors, and outputs the thickness value by the method of averaging according to this correspondence relationship.

The methods for acquiring the deposition rate v_1 of the plating layer on the central region and acquiring the deposition rate v_2 of the plating layer on the edge region are not limited thereto, and may also adopt relatively mature electroplating deposition rate measurement technologies in the prior art.

Embodiment 3

According to FIG. 11, this embodiment provides an electroplating method, comprising:

S1000: applying a positive voltage to the central anode, applying a positive voltage to the edge electrode, and outputting current I ;

S1100: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S1200: comparing the magnitudes of v_1 and v_2 ;

S1300: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, increasing the output current I , and returning to step S1100;

S1400: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S1500: if v_1 is smaller than v_2 , applying a positive voltage to the edge electrode, and reducing the output current I .

Different from embodiment 2, in this embodiment, in the initial step S1000, a positive voltage is applied to the edge electrode, and current I is output. For cases where the resistance of the substrate's seed layer is relatively low, if only the central anode is set to be active, v_1 will be greater than v_2 . Therefore, by adopting this method, v_2 can be adjusted rapidly, allowing v_2 to approach v_1 more quickly, thereby accelerating the adjustment speed.

The subsequent control logic is similar to the control logic in embodiment 2, and will not be repeatedly explained herein.

After step S1500, the following steps are further included:

S1600: determining whether the output current I is 0; if I is not equal to 0, returning to step S1100; if I is equal to 0, executing step S1700: applying a negative voltage to the edge electrode and outputting current I .

After step S1700, the following steps are further included:

S1710: acquiring v_1 and v_2 ;

S1720: comparing the magnitudes of v_1 and v_2 ;

S1730: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, increasing the output current I , and returning to step S1710;

S1740: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S1750: if v_1 is greater than v_2 , applying a negative voltage to the edge electrode, and reducing the output current I .

After step S1750, the following step is further included:

S1760: determining whether the output current I is 0; if I is not equal to 0, returning to step S1710; if I is equal to 0, returning to step S1000.

Embodiment 4

As shown in FIG. 12, this embodiment provides an electroplating method, comprising:

S2000: applying a positive voltage to the central anode, applying a negative voltage to the edge electrode, and outputting current I ;

S2100: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S2200: comparing the magnitudes of v_1 and v_2 ;

S2300: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, increasing the output current I , and returning to step S2100;

S2400: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S2500: if v_1 is greater than v_2 , applying a negative voltage to the edge electrode, and reducing the output current I .

Different from embodiment 2, in this embodiment, in the initial step S2000, a negative voltage is applied to the edge electrode, and current I is output. For cases where the resistance of the substrate's seed layer is relatively high, if only the central anode is set to be active, v_2 will be greater than v_1 . Therefore, by adopting this method, v_2 can be adjusted rapidly, allowing v_2 to approach v_1 more quickly, thereby accelerating the adjustment speed.

The subsequent control logic is similar to the control logic in embodiment 2, and will not be repeatedly explained herein.

After step S2500, the following steps are further included:

S2600: determining whether the output current I is 0; if I is not equal to 0, returning to step S2100; if I is equal to 0, executing step S2700: applying a positive voltage to the central anode, applying a positive voltage to the edge electrode, and output current I .

After step S2700, the following steps are further included:

S2710: acquiring v_1 and v_2 ;

S2720: comparing the magnitudes of v_1 and v_2 ;

S2730: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, increasing the output current I , and returning to step S2710;

S2740: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S2750: if v_1 is smaller than v_2 , applying a positive voltage to the edge electrode, and reducing the output current I .

After step S2750, the following step is further included:

S2760: determining whether the output current I is 0; if I is equal to 0, returning to step S2000; if I is not equal to 0, returning to step S2710.

Although specific embodiments of the present invention have been described above, those skilled in the art should understand that these embodiments are merely illustrative examples. Without departing from the principle and essence of the present invention, various changes or modifications can be made to these embodiments. Therefore, the protection scope of the present invention shall be defined by the appended claims.

What is claimed is:

1. An electroplating method, wherein the electroplating method comprises providing an electroplating apparatus, the electroplating apparatus comprises a central anode and an edge electrode, the central anode corresponds to the central region of a substrate, and the edge electrode corresponds to the edge region of the substrate, further comprising:

S10: applying a positive voltage to the central anode, the edge electrode being inactive;

S20: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S30: comparing the magnitudes of v_1 and v_2 ;

S40: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, and outputting current I ;

S50: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, and outputting current I ;

S60: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged.

2. The electroplating method according to claim 1, wherein after step S40, the electroplating method further comprises:

S41: acquiring v_1 and v_2 ;

S42: comparing the magnitudes of v_1 and v_2 ;

S43: if v_1 is smaller than v_2 , applying a positive voltage to the edge electrode, and reducing the output current I ;

S45: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S46: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, increasing the output current I , and returning to step S41.

3. The electroplating method according to claim 2, wherein after step S43, the electroplating method further comprises:

S44: determining whether the output current I is 0; if I is not equal to 0, returning to step S41; if I is equal to 0, returning to step S30.

4. The electroplating method according to claim 1, wherein after step S50, the electroplating method further comprises:

S51: acquiring v_1 and v_2 ;

S52: comparing the magnitudes of v_1 and v_2 ;

S53: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, and increasing the output current I ;

S54: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S55: if v_1 is greater than v_2 , applying a negative voltage to the edge electrode, and reducing the output current I .

5. The electroplating method according to claim 4, wherein after step S55, the electroplating method further comprises:

S56: determining whether the output current I is 0; if I is not equal to 0, returning to step S51; if I is equal to 0, returning to step S30.

6. The electroplating method according to claim 1, wherein step S20 specifically includes: arranging a central thickness measurement device on the non-electroplated surface of the central region; calculating v_1 through the thickness value output by the central thickness measurement device and the sampling frequency of the central thickness measurement device; arranging an edge thickness measurement device on the non-electroplated surface of the edge region; calculating v_2 through the thickness

value output by the edge thickness measurement device and the sampling frequency of the edge thickness measurement device.

7. The electroplating method according to claim 6, wherein the central thickness measurement device includes a plurality of central eddy current sensors and a central thickness calculation module, and the method comprises: obtaining the correspondence relationship between the electrical signals output by the central eddy current sensors and the plating layer thickness through a standard sample, and the central thickness calculation module receiving the electrical signals output by the plurality of central eddy current sensors and outputting the thickness value by the method of averaging according to the correspondence relationship; the edge thickness measurement device includes a plurality of edge eddy current sensors and an edge thickness calculation module, and the method comprises: obtaining the correspondence relationship between the electrical signals output by the edge eddy current sensors and the plating layer thickness through a standard sample, and the edge thickness calculation module receiving the electrical signals output by the plurality of edge eddy current sensors and outputting the thickness value by the method of averaging according to the correspondence relationship.

8. An electroplating apparatus, wherein the electroplating apparatus comprises an electroplating tank for containing an electroplating solution, further comprising:

a central anode, arranged in the electroplating solution, and corresponding to the central region of the substrate;

a central power supply, connected to the edge region of the substrate and the central anode, for applying a positive voltage to the central anode and applying a negative voltage to the substrate;

an edge electrode, arranged around the periphery of the central anode, and corresponding to the edge region of the substrate;

an edge power supply, connected to the clamping region of the substrate and the edge electrode;

a central rate measurement module, for acquiring the deposition rate v_1 of the

plating layer on the central region of the substrate;

an edge rate measurement module, for acquiring the deposition rate v_2 of the plating layer on the edge region of the substrate;

a control module, for comparing the magnitudes of v_1 and v_2 , and controlling the voltage polarity and the current magnitude applied by the edge power supply to the edge electrode according to the comparison result.

9. The electroplating apparatus according to claim 8, wherein the central rate measurement module includes: a central thickness measurement device, for acquiring the thickness value of the plating layer; a central rate calculation module, for calculating the deposition rate of the plating layer on the central region based on the thickness value and the sampling frequency of the central thickness measurement device.

10. The electroplating apparatus according to claim 9, wherein the central thickness measurement device includes: a plurality of central eddy current sensors, distributed at intervals on the non-electroplated surface of the central region of the substrate; a central thickness calculation module, connected to the plurality of central eddy current sensors, for receiving electrical signals from the plurality of central eddy current sensors, and outputting the average thickness value on the central region.

11. The electroplating apparatus according to claim 8, wherein the edge rate measurement module includes: an edge thickness measurement device, for acquiring the thickness value of the plating layer; an edge rate calculation module, for calculating the deposition rate of the plating layer on the edge region based on the thickness value and the sampling frequency of the edge thickness measurement device.

12. The electroplating apparatus according to claim 11, wherein the edge thickness measurement device includes: a plurality of edge eddy current sensors, distributed at intervals on the non-electroplated surface of the edge region of the substrate; an edge thickness calculation module, connected to the plurality of edge eddy current sensors, for receiving electrical signals from the plurality of edge eddy current sensors, and outputting the average thickness value on the edge region.

13. An electroplating method, wherein the electroplating method comprises providing an electroplating apparatus, the electroplating apparatus comprises a central anode and an edge electrode, the central anode corresponds to the central region of a substrate, and the edge electrode corresponds to the edge region of the substrate, further comprising:

S1000: applying a positive voltage to the central anode, applying a positive voltage to the edge electrode, and outputting current I;

S1100: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S1200: comparing the magnitudes of v_1 and v_2 ;

S1300: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, increasing the output current I, and returning to step S1100;

S1400: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S1500: if v_1 is smaller than v_2 , applying a positive voltage to the edge electrode, and reducing the output current I.

14. The electroplating method according to claim 13, wherein after step S1500, the electroplating method further comprises:

S1600: determining whether the applied current I is 0; if I is not equal to 0, returning to step S1100; if I is equal to 0, executing step S1700: applying a negative voltage to the edge electrode and outputting current I.

15. The electroplating method according to claim 14, wherein after step S1700, the electroplating method further comprises:

S1710: acquiring v_1 and v_2 ;

S1720: comparing the magnitudes of v_1 and v_2 ;

S1730: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, increasing the output current I , and returning to step S1710;

S1740: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S1750: if v_1 is greater than v_2 , applying a negative voltage to the edge electrode, and reducing the output current I .

16. The electroplating method according to claim 15, wherein after step S1750, the electroplating method further comprises:

S1760: determining whether the output current I is 0; if I is not equal to 0, returning to step S1710; if I is equal to 0, returning to step S1000.

17. An electroplating method, wherein the electroplating method comprises providing an electroplating apparatus, the electroplating apparatus comprises a central anode and an edge electrode, the central anode corresponds to the central region of a substrate, and the edge electrode corresponds to the edge region of the substrate, further comprising:

S2000: applying a positive voltage to the central anode, applying a negative voltage to the edge electrode, and outputting current I ;

S2100: acquiring the deposition rate v_1 of the plating layer on the central region, and acquiring the deposition rate v_2 of the plating layer on the edge region;

S2200: comparing the magnitudes of v_1 and v_2 ;

S2300: if v_1 is smaller than v_2 , applying a negative voltage to the edge electrode, increasing the output current I , and returning to step S2100;

S2400: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S2500: if v_1 is greater than v_2 , applying a negative voltage to the edge electrode, and reducing the output current I .

18. The electroplating method according to claim 17, wherein after S2500, the electroplating method further comprises:

S2600: determining whether the output current I is 0; if I is not equal to 0, returning to step S2100; if I is equal to 0, executing step S2700: applying a positive voltage to the central anode, applying a positive voltage to the edge electrode, and outputting current I .

19. The electroplating method according to claim 18, wherein after step S2700, the electroplating method further comprises:

S2710: acquiring v_1 and v_2 ;

S2720: comparing the magnitudes of v_1 and v_2 ;

S2730: if v_1 is greater than v_2 , applying a positive voltage to the edge electrode, increasing the output current I , and returning to step S2710;

S2740: if v_1 is equal to v_2 , maintaining the active/inactive state of the edge electrode unchanged;

S2750: if v_1 is smaller than v_2 , applying a positive voltage to the edge electrode, and reducing the output current I .

20. The electroplating method according to claim 19, wherein after step S2750, the electroplating method further comprises:

S2760: determining whether the output current I is 0; if I is equal to 0, returning to step S2000; if I is not equal to 0, returning to step S2710.