

# **ELECTROPLATING APPARATUS AND ELECTROPLATING METHOD**

## **FIELD OF THE INVENTION**

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

## **BACKGROUND**

In the post-Moore era, advanced packaging technologies for integrating chips are playing an increasingly important role. Wherein, three-dimensional (3D) stacking technology, regional silicon interconnection technology, embedded multi-chip interconnection bridge technology, and the like all demand high-aspect-ratio hole filling electroplating. Currently, there are some well-known significant difficulties in high-aspect-ratio hole filling process: it is difficult for an electroplating solution to completely penetrate deep holes, once the electroplating solution fails to completely penetrate deep holes, electroplating defects such as virtual electroplating and voids will emerge in the electroplating process, reducing the yield of electroplated products; in addition, with the increase of aspect ratio, the proportion of areas controlled by diffusion in electroplating holes also increases, which will reduce the electroplating efficiency and electroplating quality. In order to solve the above problems, strengthening the stirring of the electroplating solution is a solution. For this reason, a stirring mechanism can be provided in the electroplating apparatus, and the stirring mechanism can swing horizontally in the electroplating solution or swing vertically in the electroplating solution. The swing direction of the stirring mechanism depends on the electroplating mode of the electroplating machine. When the electroplating machine is operated in a horizontal plating mode, the swing mode of the stirring mechanism in the electroplating solution is horizontal swing; when the electroplating machine is operated in a vertical rack-plating mode, the swing mode of the stirring mechanism in the electroplating solution is vertical swing. The stirring mechanism that swings in the electroplating solution is used to enhance the mass transfer of the electroplating solution and increase the relative speed between the electroplating solution and the surface of the workpiece. The stirring paddle, as an exemplary stirring mechanism, has a plurality of mutually parallel paddles with a certain gap between

adjacent paddles. When the stirring paddle moves, a liquid vortex is created. The liquid vortex creates a high-speed stirring flow on the lower surface (face down) of a wafer, thereby enhancing the mass transfer. In order to further enhance the mass transfer of the electroplating solution, the usual way is to simply increase the speed of the reciprocating motion of paddles. However, the high-speed reciprocating motion of the stirring paddle leads to a large difference in the flow rate of the electroplating solution in each area of the electroplating chamber, which leads to a large difference in the flow rate of the electroplating solution in each area of the workpiece. This results in a large difference in mass transfer in each area, resulting in the occurrence of non-uniform electroplating and reducing the electroplating quality.

## SUMMARY

In order to avoid simply increasing the speed of the reciprocating motion of paddles, which leads to a large difference in the flow rate of the electroplating solution in each area of the electroplating chamber and consequently causes the occurrence of non-uniform electroplating, the present invention regulates the motion mode of the stirring mechanism, improves the electroplating efficiency, enhances the ability of the electroplating solution to penetrate deep holes at the same time, and achieves the effect of uniform electroplating.

In a first aspect, the present application proposes an electroplating apparatus, comprising an electroplating chamber, a wafer holding device, a stirring mechanism, and a driving mechanism. Wherein, the electroplating chamber is used for accommodating an electroplating solution; the wafer holding device is configured to hold a wafer; the stirring mechanism is provided inside the electroplating chamber, when the wafer holding device holds the wafer, the stirring mechanism is provided parallel to the wafer; the driving mechanism is configured to drive the stirring mechanism to perform continuous main-periodic reciprocating motions parallel to the wafer to make the stirring mechanism stir the electroplating solution. Wherein, each main-periodic reciprocating motion includes N continuous sub-periodic reciprocating motions, N is an integer greater than or equal to 2, and the amplitudes and frequencies of adjacent sub-periodic reciprocating motions are equal. Within the same main period, the ending position of the stirring mechanism in the previous sub-period is the starting position of the stirring mechanism in the subsequent adjacent sub-period, and the sub-

stroke of the stirring mechanism in the same sub-period is a real number greater than 0, wherein the sub-stroke is the distance between the ending position and the starting position of the stirring mechanism in the same sub-period.

According to a specific implementation of the embodiment of the present application, the starting position of the main-periodic reciprocating motion is the origin position, the ending position of the main-periodic reciprocating motion is the reversal position, and the reversal position is the farthest position from the origin position that the stirring mechanism reaches during the main-periodic reciprocating motion. Each main-periodic reciprocating motion includes one main stroke, and the main stroke is the distance between the origin position and the reversal position.

According to a specific implementation of the embodiment of the present application, the main stroke is set within the range of 10 to 30 mm.

According to a specific implementation of the embodiment of the present application, in the same process, each sub-periodic reciprocating motion has identical amplitude.

According to a specific implementation of the embodiment of the present application, when  $N$  is greater than or equal to 3, each sub-stroke in the same main-periodic reciprocating motion may be either equal or different.

According to a specific implementation of the embodiment of the present application, the sub-stroke is set within the range of 1 to 10 mm.

According to a specific implementation of the embodiment of the present application, the stirring mechanism performs the sub-periodic reciprocating motion at a preset frequency, wherein the preset frequency is set within the range of 3 to 12 Hz.

According to a specific implementation of the embodiment of the present application, the stirring mechanism performs the sub-periodic reciprocating motion with a preset amplitude, wherein the preset amplitude is set within the range of 12 to 20 mm.

According to a specific implementation of the embodiment of the present

application, the duration of each sub-period is set within the range of 1 to 600 seconds.

In a second aspect, the present application proposes an electroplating method, comprising: holding a wafer in an electroplating chamber containing an electroplating solution; a driving mechanism driving a stirring mechanism to perform continuous main-periodic reciprocating motions parallel to the wafer to make the stirring mechanism stir the electroplating solution. Wherein, each main-periodic reciprocating motion includes  $N$  continuous sub-periodic reciprocating motions,  $N$  is an integer greater than or equal to 2, and the amplitudes and frequencies of adjacent sub-periodic reciprocating motions are equal. Within the same main period, the ending position of the stirring mechanism in the previous sub-period is the starting position of the stirring mechanism in the subsequent adjacent sub-period, and the sub-stroke of the stirring mechanism in the same sub-period is a real number greater than 0, wherein the sub-stroke is the distance between the ending position and the starting position of the stirring mechanism in the same sub-period.

According to a specific implementation of the embodiment of the present application, the starting position of the main-periodic reciprocating motion is the origin position, the ending position of the main-periodic reciprocating motion is the reversal position, and the reversal position is the farthest position from the origin position that the stirring mechanism reaches during the main-periodic reciprocating motion. Each main-periodic reciprocating motion includes one main stroke, and the main stroke is the distance between the origin position and the reversal position.

According to a specific implementation of the embodiment of the present application, in the same process, each sub-periodic reciprocating motion has identical amplitude.

According to a specific implementation of the embodiment of the present application, when  $N$  is greater than or equal to 3, each sub-stroke in the same main-periodic reciprocating motion may be either equal or different.

The electroplating apparatus and the electroplating method of the present invention regulate the motion mode of the stirring mechanism. Each continuous main-periodic reciprocating motion executed by the stirring mechanism inside the

electroplating chamber is subdivided into N continuous sub-periodic reciprocating motions of the same motion mode, wherein N is an integer greater than or equal to 2. The present invention not only improves the electroplating efficiency, but also enhances the ability of the electroplating solution to penetrate deep holes to achieve the effect of uniform electroplating. Other features and advantages of the present invention will be set forth in the following specification, and will, in part, become apparent from the specification, or will be learned by practicing the present invention. The objects and other advantages of the present invention can be achieved and obtained by the structures indicated in the specification and in the accompanying drawings.

## BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 shows a schematic view of the motion mode of a stirring mechanism driven by a driving mechanism in a prior-art electroplating apparatus;

FIG. 2 shows the result of the flow rate of an electroplating solution on the lower surface of a wafer under the motion mode of a stirring mechanism in FIG. 1;

FIG. 3 shows a schematic structural view of an electroplating apparatus according to an embodiment of the present invention;

FIG. 4 shows a schematic top view of a stirring mechanism according to an embodiment of the present invention;

FIG. 5 shows a schematic view of a motion mode of a stirring mechanism according to an embodiment of the present invention;

FIG. 6 shows a schematic view of another motion mode of a stirring mechanism according to an embodiment of the present invention; and

FIG. 7 shows the result of the flow rate of an electroplating solution on the lower surface of a wafer under the motion mode of a stirring mechanism according to an

embodiment of the present invention.

## PREFERRED EMBODIMENTS OF THE INVENTION

In order to further clarify the objects, technical solutions and advantages of the embodiments of the present invention, the technical solutions in the embodiments of the present invention will be clearly and completely described below with reference to the drawings in the embodiments of the present invention, and it is obvious that the described embodiments are part of the embodiments of the present invention, but not all the embodiments. Based on the embodiments in the present invention, all other embodiments obtained by those of ordinary skill in the art without creative efforts fall within the scope of protection of the present invention.

In the electroplating apparatus, in order to strengthen the stirring of an electroplating solution, a stirring mechanism can be arranged below a wafer at a position opposite to the wafer, and during electroplating, the stirring mechanism performs a reciprocating motion along a direction parallel to the wafer to strengthen the stirring of the electroplating solution. According to FIG. 1, FIG. 1 shows a schematic view of the motion mode of a stirring mechanism driven by a driving mechanism in a prior-art electroplating apparatus, wherein the horizontal axis represents the process time, with the unit being seconds (s), the vertical axis represents the change of the position of the stirring mechanism, with the unit being millimeters (mm). The figure shows the motion mode of the stirring mechanism driven by the driving mechanism, represented by the change in position of the stirring mechanism with time. The driving mechanism drives the stirring mechanism to vibrate at a predetermined frequency and a predetermined amplitude inside an electroplating chamber, and as shown in FIG. 1, the amplitude is approximately 20 mm, and the frequency is approximately 5 Hz. The flow rate of the electroplating solution on the lower surface of the wafer under this vibration mode is simulated and calculated, and the simulation result is shown in FIG. 2. The flow rate of the electroplating solution in each area on the lower surface of the wafer is quite different. It can be seen from the figure that the maximum flow rate of the electroplating solution across the area on the lower surface of the wafer is about 160 mm/s, the minimum flow rate is about 60 mm/s, and the difference is about 100 mm/s, which leads to a large difference in the amount of the electroplating solution contacting each area on the lower surface of the wafer,

thus affecting the uniformity of electroplating.

The present invention aims to improve the vibration mode of controlling the stirring mechanism, so as to better control the stirring effect of the electroplating solution and achieve the purpose of uniform electroplating.

According to FIGS. 3 and 4, an embodiment of the present invention discloses an electroplating apparatus for electroplating the wafer surface. The electroplating apparatus includes an electroplating chamber 100, a wafer holding device 200, a stirring mechanism 300, and a driving mechanism 400. The electroplating chamber 100 is used to accommodate an electroplating solution; the wafer holding device 200 is used to hold a wafer 500; the stirring mechanism 300 includes a plurality of strip-shaped paddles 301 arranged in parallel, and a gap 302 is formed between adjacent paddles 301. During the electroplating process, gaps 302 between adjacent paddles 301 provide pathways for liquid and electric fields to pass through. The paddles 301 are made of an insulating material, for example, plastics such as Polyvinyl Chloride (PVC), Polycarbonate (PC), Chlorinated Polyvinyl Chloride (CPVC), Polyphenylene Sulfide (PPS), Polyether Ether Ketone (PEEK), Polytetrafluoroethylene (PTFE), or the like. The stirring mechanism 300 is disposed in the electroplating chamber 100, and the stirring mechanism 300 is parallel to the wafer 500 when the wafer 500 is held on the wafer holding device 200.

The driving mechanism 400 is disposed outside the electroplating chamber 100, and the driving mechanism 400 is configured to drive the stirring mechanism 300 to perform continuous main-periodic reciprocating motions in the direction parallel to the wafer 500 held by the wafer holding device 200, so as to make the stirring mechanism 300 stir the electroplating solution. Each main-periodic reciprocating motion includes N continuous sub-periodic reciprocating motions, wherein N is an integer greater than or equal to 2, and the amplitudes and frequencies of adjacent sub-periodic reciprocating motions are equal. Within the same main period, the ending position of the stirring mechanism 300 in the previous sub-period is the starting position of the stirring mechanism in the subsequent adjacent sub-period, and the sub-stroke of the stirring mechanism 300 in the same sub-period is a real number greater than 0, wherein the sub-stroke is the distance between the ending position and the starting position of the stirring mechanism 300 in the same sub-period. In some embodiments, in the same

process, each sub-periodic reciprocating motion has the same amplitude and frequency, which can ensure strong stirring of the electroplating solution and make the difference in the flow rate of the electroplating solution in each area of the electroplating chamber relatively uniform at the same time. Specifically, after each area in the electroplating chamber has experienced the electroplating solution of each speed in one sub-period, the time-averaged speed of the electroplating solution is maintained within a relatively stable range, thereby improving the uniformity of the electroplating solution.

Furthermore, the driving mechanism 400 includes at least one driving member, and the selection range of the driving member includes, but is not limited to, a motor, an electric machine, and the like. When the number of driving members is greater than or equal to 2, the driving members are symmetrically arranged with respect to the electroplating chamber 100 to stabilize the stirring mechanism 300, keep the balance of the stirring mechanism 300, and further achieve the purpose of stably stirring the electroplating solution. As shown in FIG. 3, in this embodiment, the driving mechanism 400 includes two driving members, and the driving members are symmetrically arranged on both sides of the electroplating chamber 100.

As an example, according to FIG. 3, during the reciprocating motion of the stirring mechanism 300 inside the electroplating chamber 100, when the initial state is set, the stirring mechanism 300 is positioned at the motion-starting position, and the driving mechanism 400 drives the stirring mechanism 300 to perform continuous main-periodic reciprocating motions parallel to the wafer 500 in the wafer holding device 200. In order to facilitate understanding, the motion-starting position of the stirring mechanism 300 is the origin position in the present application; the motion-ending position of the stirring mechanism 300 is the reversal position, and the reversal position is the farthest position from the origin position that the stirring mechanism 300 reaches during the main-periodic reciprocating motion. Thus, one main-periodic reciprocating motion proceeds as follows: the stirring mechanism 300 starts from the motion-starting position (i.e., the origin position), moves toward the ending position, reaches the motion-ending position (i.e., the reversal position), then moves toward the origin position in the reversal direction, finally reaching the origin position to complete the period. A plurality of repeated main-periodic reciprocating motions can be included in the same process, so as to achieve the effect that the stirring mechanism 300

strengthens the stirring of the electroplating solution, thereby uniformly electroplating the wafer 500. As shown in FIG. 5, FIG. 5 shows two main periods, in this embodiment, the origin position of the stirring mechanism 300 is at 0 mm, and the reversal position is at 32 mm.

Furthermore, each main-periodic reciprocating motion performed by the stirring mechanism 300 specifically includes: the stirring mechanism 300 performs N sub-periodic reciprocating motions at a preset frequency  $f_1$  and a preset amplitude  $A_1$ . As shown in FIG. 5, each main period includes three sub-periods, and the motion frequency of the stirring mechanism 300 in each sub-period is  $f_1$ , and the motion amplitude is  $A_1$ . Within each main period, the stirring mechanism 300 gradually reaches the reversal position from the origin position through three sub-periodic reciprocating motions, returns to the origin position when reaching the ending position of the main period, and starts the next main-periodic reciprocating motion.

Wherein, one main-periodic reciprocating motion includes one main stroke L and at least one sub-stroke M. The main stroke is the maximum distance the stirring mechanism 300 reaches away from the origin position, that is, the distance between the origin position and the reversal position. The sub-stroke is the distance between the ending position and the starting position of the stirring mechanism 300 in the same sub-period. It should be understood that the main stroke L is a value determined according to the size of the electroplating chamber 100. Generally, the size of the electroplating chamber 100 is determined, and the value of the main stroke L is a fixed value. For example, according to the size of the electroplating chamber 100, the main stroke L is generally fixed at a certain value within the range of 10 to 30 mm, for example, may be 10 mm, 20 mm, 30 mm, and the like. The number N of sub-periods included in each main-periodic reciprocating motion is set manually, and N is an integer greater than or equal to 2, indicating that one main-periodic reciprocating motion includes N continuous sub-periodic reciprocating motions. The frequency  $f_1$  and the amplitude  $A_1$  of each sub-periodic reciprocating motion are manually set values, for example, the frequency  $f_1$  is generally preset within the range of 3 to 12 Hz, may be 3 Hz, 5 Hz, 10 Hz, 12 Hz, and the like; the amplitude  $A_1$  is generally preset within the range of 12 to 20 mm, may be 12 mm, 15 mm, 18 mm, 20 mm, and the like. Besides, the sub-stroke M of one sub-period is also a manually set value before the

start of the process, and the number of sub-strokes is  $N - 1$ . It should be noted that the duration  $t$  of each sub-period in each main-periodic reciprocating motion is generally preset within the range of 1 to 600 s, may be 1 s, 60 s, 100 s, 300 s, 600 s, and the like.

Furthermore, when  $N$  is greater than or equal to 3, that is, when the number of sub-strokes is greater than or equal to 2, all sub-strokes may be equal or unequal, and the sub-strokes are set according to actual process conditions during operation. Specifically, when  $N$  is greater than or equal to 3, it means that one main-periodic reciprocating motion includes three or more continuous sub-periodic reciprocating motions, that is, the main stroke  $L$  is divided into  $N$  times,  $N - 1$  sub-strokes will be generated in the process of completing the main stroke  $L$ , and the  $N - 1$  sub-strokes may be equal or unequal.

For example, according to FIG. 5, when  $N$  is equal to 3, that is, when  $L$  includes two sub-strokes in the present embodiment, the distances traveled after the completion of each sub-period are set to be unequal, that is, the sub-stroke  $M1$  is not equal to the sub-stroke  $M2$ . As shown in FIG. 5, one main-periodic reciprocating motion includes one main stroke  $L$  and two sub-strokes  $M1$ ,  $M2$ , and the number  $N$  of sub-periodic reciprocating motions in one main-periodic reciprocating motion is equal to 3. The preset frequency  $f1$  in each sub-periodic reciprocating motion is 5 Hz, the preset amplitude  $A1$  is 20 mm, and the duration  $t$  of each sub-period is 1 s. The main stroke  $L$  is equal to 12 mm, the sub-stroke  $M1$  is equal to 4 mm, and the sub-stroke  $M2$  is equal to 8 mm.

According to FIG. 6, in another embodiment, when  $N$  is equal to 3, that is, when  $L$  includes two sub-strokes in the present embodiment, the distances traveled after the completion of each sub-period are set to be equal, that is, the sub-stroke  $M1$  is equal to the sub-stroke  $M2$ . It can be seen from FIG. 6 that one main-periodic reciprocating motion of the stirring mechanism 300 includes three sub-periodic reciprocating motions; one main-periodic reciprocating motion includes one main stroke and two equal sub-strokes, i.e.,  $N$  is equal to 3,  $M1$  and  $M2$  are both equal to 6 mm, and the main stroke  $L$  is equal to 12 mm. Within each sub-periodic reciprocating motion, the vibration frequency of the stirring mechanism 300 is equal to the preset frequency  $f1$  of 5 Hz, the preset amplitude  $A1$  is equal to 20 mm; the duration  $t$  of each sub-period reciprocating motion is equal to 1 s. When adjacent sub-periodic reciprocating motions

are switched, the stirring mechanism 300 does not need to return to the origin position of the current sub-period, but directly takes the ending position of the current sub-period as the origin position of the subsequent sub-period to perform subsequent sub-period motion. Thus, by setting the starting position and the ending position of each sub-period, that is, setting the sub-stroke, the stirring mechanism 300 can gradually move outward in the motion range of each sub-period in one main period, the peak and valley values of the position of the stirring mechanism gradually increase, and in the final sub-period, the farthest motion position that the stirring mechanism 300 reaches is the reversal position. Similarly, when the stirring mechanism 300 moves in the electroplating chamber 100 and completes one main period, the driving mechanism 400 drives the stirring mechanism 300 to the origin position of the last sub-period, then continues to drive the stirring mechanism 300 back to the origin position of the first sub-period, that is, the origin position of the main period, and then continues to perform subsequent main period reciprocating motion to achieve the effect of sufficiently stirring the electroplating solution.

The present invention also provides an electroplating method in which the wafer 500 is held in an electroplating chamber containing an electroplating solution, and the wafer 500 is electroplated. A stirring mechanism 300 is provided inside the electroplating chamber 100 and parallel to the wafer 500. The stirring mechanism 300 is connected to a driving mechanism 400, and the driving mechanism 400 drives the stirring mechanism 300 to perform continuous main-periodic reciprocating motions parallel to the wafer 500, so that the electroplating solution is stirred by the stirring mechanism 300. Wherein, each main-periodic reciprocating motion includes N continuous sub-periodic reciprocating motions, N is an integer greater than or equal to 2, and the amplitudes and frequencies of adjacent sub-periodic reciprocating motions are equal.

Within the same main period, the ending position of the stirring mechanism 300 in the previous sub-period is the starting position of the stirring mechanism in the subsequent adjacent sub-period, and the sub-stroke of the stirring mechanism 300 in the same sub-period is a real number greater than 0, wherein the sub-stroke is the distance between the ending position and the starting position of the stirring mechanism 300 in the same sub-period.

Furthermore, the starting position of the main-periodic reciprocating motion is the origin position; the ending position of the main-periodic reciprocating motion is the reversal position; and the reversal position is the farthest position from the origin position that the stirring mechanism reaches during the main-periodic reciprocating motion. Each main-periodic reciprocating motion includes one main-stroke, and the main-stroke is the distance between the origin position and the reversal position.

Furthermore, in the same process, each sub-periodic reciprocating motion has identical amplitude.

Furthermore, when  $N$  is greater than or equal to 3, the sub-strokes in the same main-periodic reciprocating motion may be either equal or different.

In the process, according to the solution proposed by the present invention, the flow rate of the electroplating solution in each area close to the lower surface of the wafer 500 is simulated and calculated. As a result, according to FIG. 7. FIG. 7 shows a view of the flow rate of an electroplating solution close to the lower surface of a wafer 500 during each sub-periodic reciprocating motion of the main-periodic reciprocating motion, wherein the horizontal axis represents the horizontal position coordinate of the wafer with the wafer center as 0 coordinate, with the unit being millimeters (mm), and the vertical axis represents the flow rate of the electroplating solution on the lower surface of the wafer, with the unit being millimeters/seconds (mm/s). The line 601 represents the flow rate of the electroplating solution on the lower surface of the wafer 500 during the first sub-periodic reciprocating motion; the line 602 represents the flow rate of the electroplating solution on the lower surface of the wafer 500 during the second sub-periodic reciprocating motion; the line 603 represents the flow rate of the electroplating solution on the lower surface of the wafer 500 during the third sub-periodic reciprocating motion; the line 604 represents the average flow rate of the electroplating solution on the lower surface of the wafer in the electroplating method according to the embodiment of the present invention, specifically, the average flow rate of the electroplating solution in each area on the lower surface of the wafer after undergoing one complete main-periodic reciprocating motion. As can be seen from FIG. 7, although the difference of the flow rate (about 100 mm/s) of the electroplating solution in each area on the lower surface of the wafer is large during the first sub-periodic reciprocating motion, the second sub-periodic reciprocating

motion, and the third sub-periodic reciprocating motion, after the process of one main-periodic reciprocating motion is completed, that is, after experiencing the first sub-periodic reciprocating motion, the second sub-periodic reciprocating motion, and the third sub-periodic reciprocating motion, it can be seen from the line 604 that the flow rate of the electroplating solution in each area on the lower surface of the wafer is basically maintained within a relatively stable range, the difference is small (about 20 mm/s), and the flow rate of the electroplating solution can also be maintained at a high flow rate (about 110 mm/s). This demonstrates that, with the design of the electroplating apparatus and the electroplating method of the present invention, the flow rate of the electroplating solution on the lower surface of the wafer 500 can reach a relatively uniform and high level, thereby ensuring sufficient stirring intensity of the electroplating solution and resulting in a stable and uniform electroplating effect.

Although the present invention has been described in detail with reference to the aforementioned embodiments, those of ordinary skill in the art should understand that the technical solutions described in the aforementioned embodiments can be modified or some technical features can be equivalently replaced. However, these modifications or substitutions do not make the essence of the corresponding technical solutions deviate from the spirit and scope of the technical solutions of each embodiment of the present invention.

What is claimed is:

1. An electroplating apparatus, comprising:

an electroplating chamber, used for accommodating an electroplating solution;

a wafer holding device, configured to hold a wafer;

a stirring mechanism, provided inside the electroplating chamber, when the wafer holding device holds the wafer, the stirring mechanism being provided parallel to the wafer;

a driving mechanism, configured to drive the stirring mechanism to perform continuous main-periodic reciprocating motions parallel to the wafer to make the stirring mechanism stir the electroplating solution;

wherein, each main-periodic reciprocating motion includes N continuous sub-periodic reciprocating motions, N is an integer greater than or equal to 2, and the amplitudes and frequencies of adjacent sub-periodic reciprocating motions are equal;

within the same main period, the ending position of the stirring mechanism in the previous sub-period is the starting position of the stirring mechanism in the subsequent adjacent sub-period, the sub-stroke of the stirring mechanism in the same sub-period is a real number greater than 0, and the sub-stroke is the distance between the ending position and the starting position of the stirring mechanism in the same sub-period.

2. The electroplating apparatus according to claim 1, wherein the starting position of the main-periodic reciprocating motion is the origin position, the ending position of the main-periodic reciprocating motion is the reversal position, and the reversal position is the farthest position from the origin position that the stirring mechanism reaches during the main-periodic reciprocating motion; each main-periodic reciprocating motion includes one main stroke, and the main stroke is the distance between the origin position and the reversal position.

3. The electroplating apparatus according to claim 2, wherein the main stroke is set within the range of 10 to 30 mm.

4. The electroplating apparatus according to claim 1, wherein in the same process, each sub-periodic reciprocating motion has identical amplitude.

5. The electroplating apparatus according to claim 1, wherein, when N is greater than or equal to 3, each sub-stroke in the same main-periodic reciprocating motion may be either equal or different.

6. The electroplating apparatus according to claim 1 or 5, wherein the sub-stroke is set within the range of 1 to 10 mm.

7. The electroplating apparatus according to claim 1, wherein the stirring mechanism performs the sub-periodic reciprocating motion at a preset frequency, and the preset frequency is set within the range of 3 to 12 Hz.

8. The electroplating apparatus according to claim 1 or 7, wherein the stirring mechanism performs the sub-periodic reciprocating motion with a preset amplitude, and the preset amplitude is set within the range of 12 to 20 mm.

9. The electroplating apparatus according to claim 1, wherein the duration of each sub-period is set within the range of 1 to 600 seconds.

10. An electroplating method, comprising:

holding a wafer in an electroplating chamber containing an electroplating solution;

a driving mechanism driving a stirring mechanism to perform continuous main-periodic reciprocating motions parallel to the wafer to make the stirring mechanism stir the electroplating solution;

wherein, each main-periodic reciprocating motion includes N continuous sub-periodic reciprocating motions, N is an integer greater than or equal to 2, and the amplitudes and frequencies of adjacent sub-periodic reciprocating motions are equal;

within the same main period, the ending position of the stirring mechanism in the previous sub-period is the starting position of the stirring mechanism in the subsequent adjacent sub-period, the sub-stroke of the stirring mechanism in the same sub-period

is a real number greater than 0, and the sub-stroke is the distance between the ending position and the starting position of the stirring mechanism in the same sub-period.

11. The electroplating method according to claim 10, wherein the starting position of the main-periodic reciprocating motion is the origin position, the ending position of the main-periodic reciprocating motion is the reversal position, the reversal position is the farthest position from the origin position that the stirring mechanism reaches during the main-periodic reciprocating motion; each main-periodic reciprocating motion includes one main stroke, and the main stroke is the distance between the origin position and the reversal position.

12. The electroplating method according to claim 11, wherein in the same process, each sub-periodic reciprocating motion has identical amplitude.

13. The electroplating method according to claim 11, wherein, when  $N$  is greater than or equal to 3, each sub-stroke in the same main-periodic reciprocating motion may be either equal or different.