

ELECTROPLATING DEVICE AND SUBSTRATE CLEANING

METHOD

TECHNICAL FIELD

The present application relates to the technical field of semiconductor equipment, and in particular, to an electroplating device and a substrate cleaning method.

BACKGROUND

With the continuous advancement of semiconductor technology, the manufacturing of semiconductor substrates is rapidly developing toward multi-layering, layer stacking, functionalization, and integration. Traditional vertical electroplating process can no longer meet the technical requirements for high-quality and high-reliability interconnect vias. Accordingly, horizontal electroplating technology has emerged as a continuation and advancement of vertical electroplating technology, that is, horizontal electroplating technology is an innovative electroplating technology developed on the basis of vertical electroplating. In the horizontal electroplating process, the stability of an electroplating solution exerts a significant impact on the reliability of electroplated products. The electroplating solution used in each electroplating process differs. To prevent cross-contamination of electroplating solutions in different electroplating processes and ensure the stability of the electroplating solutions, the existing treatment method in the market is as follows: after undergoing one electroplating process, a substrate is subjected to a cleaning process to remove residual electroplating solution from the substrate surface before the substrate is transferred to a chamber for the next electroplating process.

However, when a substrate is cleaned using the existing method, the solution drop volume is relatively large, and a portion of the water falls into the cathode chamber of the electroplating device, diluting the electroplating solution in the cathode chamber and compromising the stability of the electroplating solution. Therefore, this problem urgently needs to be addressed.

SUMMARY

To prevent the relatively large solution drop volume from affecting the stability

of electroplating solutions during substrate cleaning, the present invention provides an electroplating device, comprising:

a chuck, configured to hold a substrate in a horizontal position;

a drive unit, configured to drive the chuck to rotate;

a nozzle, configured to spray a cleaning solution to clean the substrate held by the chuck;

wherein, the coverage area of the cleaning solution sprayed by the nozzle onto the substrate includes a co-rotation zone and a counter-rotation zone, and the co-rotation zone is larger than the counter-rotation zone; the co-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component in the rotation direction of the substrate; the counter-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component against the rotation direction of the substrate.

According to a specific implementation of the embodiment of the present application, the nozzle is a fan-shaped nozzle, a circular nozzle, an annular nozzle, or a cylindrical nozzle.

According to a specific implementation of the embodiment of the present application, the coverage area of the cleaning solution sprayed by the nozzle includes the center of the substrate held by the chuck.

According to a specific implementation of the embodiment of the present application, when the cleaning solution sprayed by the nozzle comes into contact with the substrate, the distance from the boundary of the cleaning solution in the co-rotation zone to the center of the substrate is greater than or equal to $r/2$, where r is the distance from the center of the substrate to the edge of the substrate.

According to a specific implementation of the embodiment of the present application, the distance from the boundary of the cleaning solution sprayed by the nozzle in the counter-rotation zone to the center of the substrate is smaller than or equal to $r/4$.

According to a specific implementation of the embodiment of the present application, the rotation speed of the chuck driven by the drive unit is greater than or equal to 50 r/min.

According to a specific implementation of the embodiment of the present application, the flow rate of the cleaning solution sprayed by the nozzle is between 0.5 LPM and 2.5 LPM.

In a second aspect, the present invention provides a substrate cleaning method, comprising:

holding a substrate in a horizontal position by a chuck;

driving the chuck to rotate by a drive unit;

spraying a cleaning solution onto the substrate by a nozzle to clean the substrate held by the chuck, wherein the coverage area of the cleaning solution sprayed by the nozzle onto the substrate includes a co-rotation zone and a counter-rotation zone, and the co-rotation zone is larger than the counter-rotation zone; the co-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component in the rotation direction of the substrate; the counter-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component against the rotation direction of the substrate.

According to a specific implementation of the embodiment of the present application, the nozzle is a fan-shaped nozzle, a circular nozzle, an annular nozzle, or a cylindrical nozzle.

According to a specific implementation of the embodiment of the present application, the coverage area of the cleaning solution sprayed by the nozzle includes the center of the substrate held by the chuck.

According to a specific implementation of the embodiment of the present application, when the cleaning solution sprayed by the nozzle comes into contact with the substrate, the distance from the boundary of the cleaning solution in the co-rotation zone to the center of the substrate is greater than or equal to $r/2$, where r is the distance

from the center of the substrate to the edge of the substrate.

According to a specific implementation of the embodiment of the present application, the distance from the boundary of the cleaning solution sprayed by the nozzle in the counter-rotation zone to the center of the substrate is smaller than or equal to $r/4$.

In the electroplating device and the substrate cleaning method of the present invention, the coverage area of the cleaning solution sprayed by the nozzle is divided into zones based on the rotation direction of the substrate and the flow direction of the cleaning solution, and the position of the nozzle is set in a strategic manner. In this way, during substrate cleaning, most of the cleaning solution sprayed by the nozzle falls into the co-rotation zone, facilitating the fling of the cleaning solution into a water shield and subsequent drainage of the cleaning solution. This reduces the solution drop volume during substrate cleaning, preventing a large volume of cleaning solution from falling into a cathode chamber, which can otherwise dilute the electroplating solution in the cathode chamber and compromise the stability of the electroplating solution. Other features and advantages of the present invention will be set forth in the following specification, and in part will be apparent from the specification, or may be learned by practice of the present invention. The objectives and other advantages of the present invention can be achieved and learned by the structures pointed out in the specification, claims, and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and performance of the present application are further described by the following embodiments and the accompanying drawings of the embodiments. To further clarify the technical solutions in the embodiment of the present invention or in the prior art, the accompanying drawings used in the description of the embodiment or the prior art will be briefly introduced below. Obviously, the accompanying drawings in the following description are some embodiments of the present invention, and those of ordinary skill in the art can obtain other accompanying drawings based on these accompanying drawings without making creative efforts.

FIG. 1 shows a schematic structural diagram of an electroplating device according

to an embodiment of the present invention;

FIG. 2 shows a schematic diagram of sectional partitioning of the solution drop zone in a cathode chamber during substrate cleaning according to an embodiment of the present invention;

FIG. 3 shows the solution drop volume results of all sections in FIG. 2 when the central axis of a cleaning solution sprayed by a nozzle passes through the center of a substrate according to an embodiment of the present invention;

FIG. 4 shows a schematic structural diagram where the central axis of a cleaning solution sprayed by a nozzle passes through the centers of a chuck and a substrate according to an embodiment of the present invention;

FIG. 5 shows a schematic diagram of the flow velocity of a cleaning solution according to an embodiment of the present invention;

FIG. 6 shows a schematic structural diagram where the central axis of a cleaning solution sprayed by a nozzle does not pass through the centers of a chuck and a substrate according to an embodiment of the present invention;

FIG. 7 shows a schematic flowchart of a substrate cleaning method according to an embodiment of the present invention; and

FIG. 8 shows the solution drop volume results of all sections in FIG. 2 when the central axis of a cleaning solution sprayed by a nozzle does not pass through the center of a substrate according to an embodiment of the present invention.

PREFERRED EMBODIMENTS OF THE PRESENT APPLICATION

To further clarify the objectives, 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 fully described below with reference to the accompanying drawings in the embodiments of the present invention. Obviously, the described embodiments are part of the embodiments of the present invention, not all of the embodiments. All other embodiments obtained by those of ordinary skill in the

art based on the embodiments of the present invention without making creative efforts shall fall within the protection scope of the present invention.

Please refer to FIG. 1, which shows a schematic structural diagram of an electroplating device according to an embodiment of the present invention. As shown in FIG. 1, the electroplating device comprises an electroplating chamber 100, and the electroplating chamber 100 is divided into two independent chambers by a horizontally disposed ion-exchange membrane 200. One side of the ion-exchange membrane 200 is an anode chamber 300, and the other side of the ion-exchange membrane 200 is a cathode chamber 400. An anode 500 is disposed inside the anode chamber 300; a water shield 600, a chuck 700 for holding a substrate in a horizontal position, and a drive unit 800 for driving the chuck 700 to rotate are disposed at the top of the cathode chamber 400. It should be understood that the drive unit 800 may also be configured to drive the chuck 700 to move vertically, so as to drive the chuck into or out of the cathode chamber 400 and hold the chuck 700 at a target height. During actual processes, given that the substrate needs to be cleaned after each electroplating process to remove residual electroplating solution from the substrate, the electroplating device is further provided with a nozzle 900 for cleaning the substrate. The nozzle 900 includes, but is not limited to, a fan-shaped nozzle, a circular nozzle, an annular nozzle, or a cylindrical nozzle. The position of the nozzle 900 can be set according to actual machine conditions. In this embodiment, the nozzle 900 is fixedly disposed on the water shield 600. When the electroplating process is completed, the drive unit 800 drives the chuck 700 to hold a substrate 001 to move up, out of the electroplating solution, until the substrate 001 moves into the water shield 600, and then the drive unit 800 drives the chuck 700 to rotate to clean the substrate 001. During cleaning, part of the cleaning solution will fall into the cathode chamber 400 along path S2, affecting the stability of the electroplating solution. To solve this problem, the present application proposes a solution. With reference to FIG. 5, when the nozzle 900 sprays the cleaning solution onto the substrate 001, the coverage area of the cleaning solution sprayed by the nozzle 900 onto the substrate 001 is required to include a co-rotation zone 901 and a counter-rotation zone 902, wherein the co-rotation zone 901 is larger than the counter-rotation zone 902. Specifically, when the cleaning solution falls onto the substrate 001, the coverage area of the cleaning solution is generally divided into two zones according to the flow direction of the cleaning solution: one zone where the cleaning solution

sprayed by the nozzle 900 has a velocity component in the rotation direction of the substrate is referred to as the co-rotation zone 901; the other zone where the cleaning solution sprayed by the nozzle 900 has a velocity component against the rotation direction of the substrate is referred to as the counter-rotation zone 902. During actual processes, the area near the coverage area of the cleaning solution in the co-rotation zone 901 is also regarded as the co-rotation zone; the area near the coverage area of the cleaning solution in the counter-rotation zone 902 is also regarded as the counter-rotation zone. In the embodiment of the present invention, when the nozzle 900 sprays the cleaning solution onto the substrate 001, the co-rotation zone 901 is required to be larger than the counter-rotation zone 902 to reduce the solution drop volume during the cleaning of the substrate 001. It should be understood that in this embodiment, the cleaning solution may be deionized water.

In the present application, the coverage area of the cleaning solution sprayed by the nozzle is divided into zones based on the rotation direction of the substrate and the flow direction of the cleaning solution, and the position of the nozzle is set in a strategic manner. During substrate cleaning, most of the cleaning solution sprayed by the nozzle falls into the co-rotation zone, facilitating the fling of the cleaning solution into the water shield and subsequent drainage of the cleaning solution. This reduces the solution drop volume during substrate cleaning, preventing a large volume of cleaning solution from falling into the cathode chamber, which can otherwise dilute the electroplating solution in the cathode chamber and compromise the stability of the electroplating solution.

The detailed analysis is as follows: It was found that during actual processes, the stability of the electroplating solution is easily affected during substrate cleaning. To solve this problem, the inventors of the present application have conducted in-depth analysis on this phenomenon. It was found that when the cleaning solution sprayed by the nozzle 900 comes into contact with the substrate 001, the drive unit 800 drives the chuck 700 and the substrate 001 held by the chuck 700 to rotate, flinging most of the cleaning solution into the water shield 600. The cleaning solution is then drained through a drain port (not shown) provided on the water shield 600. However, a small portion of the cleaning solution still falls into the cathode chamber 400 below, diluting the cathode electroplating solution and compromising the stability of the cathode

electroplating solution. Furthermore, it was found that during substrate cleaning, the solution drop volume in each section below the substrate is not uniform. To this end, the inventors of the present application divided the solution drop zone below the substrate during substrate cleaning. For a schematic diagram of specific solution drop zone division, please refer to FIG. 2. The arrow on the left in FIG. 2 indicates the rotation direction of the substrate, and the arrow at the lower right indicates the direction of the cleaning solution sprayed by the nozzle 900. As can be seen from FIG. 2, A, B, C, and D are distributed sequentially from the center of the substrate 001 outward; sections A1, B1, C1, D1, A2, B2, C2, and D2 are the co-rotation zone, and sections A5, B5, C5, D5, A6, B6, C6, and D6 are the counter-rotation zone. The solution drop volume in each section was measured and statistically analyzed under the following test conditions: the central axis of the cleaning solution sprayed by the nozzle passes through the center of the substrate, the flow rate of the cleaning solution is 1.5 L/min, the cleaning operation time is maintained at 60 s, and the chuck rotation speed is 400 rpm. The results are shown in FIG. 3, which presents the solution drop volume results of all sections in FIG. 2 when the central axis of the cleaning solution sprayed by the nozzle passes through the center of the substrate. As can be seen from FIG. 3, under the conditions described above, after completion of one substrate cleaning process during substrate cleaning, the average total solution drop volume is 120.1 ml, wherein the solution drop volume in the co-rotation zone is small, while the solution drop volume in the counter-rotation zone is large. In particular, the solution drop volume results in sections C6 and D6 differ significantly from the solution drop volume results in sections C2 and D2. This may be because C2 and D2 are located within the coverage area of the cleaning solution in the co-rotation zone, while C6 and D6 are located within the coverage area of the cleaning solution in the counter-rotation zone.

Further analysis of the large solution drop volume results in C6/D6 is as follows: As shown in FIG. 4, during the substrate cleaning process, the central axis of the cleaning solution sprayed by the nozzle 900 passes through the center of the chuck 700, and the center of the chuck 700 coincides with the center of the substrate 001, so the central axis of the cleaning solution sprayed by the nozzle 900 passes through the center of the substrate 001 held by the chuck 700, i.e., the cleaning solution is symmetrically distributed on both sides of the center of the substrate 001. The coverage

area of the cleaning solution is divided into the co-rotation zone 901 and the counter-rotation zone 902 according to the relationship between the flow direction of the cleaning solution sprayed by the nozzle 900 and the rotation direction of the substrate. Wherein, the co-rotation zone 901 refers to a zone where the flow direction of the cleaning solution sprayed by the nozzle 900 has a component in the rotation direction of the substrate; the counter-rotation zone 902 refers to a zone where the flow direction of the cleaning solution sprayed by the nozzle 900 has a component against the rotation direction of the substrate. In the example shown in FIG. 4, the coverage area of the co-rotation zone 901 is equal to the coverage area of the counter-rotation zone 902. During the cleaning process, the drive unit 800 drives the chuck 700 and the substrate 001 held by the chuck 700 to rotate at a high speed. The cleaning solution sprayed by the nozzle 900 onto the substrate 001 gradually flows toward the edge of the substrate 001 under centrifugal force, thereby being flung into the water shield 600 (as indicated by the dashed arrow S1 in FIG. 1). A portion of the cleaning solution falls before completely flowing to the edge (as indicated by the dashed arrow S2 in FIG. 1). As shown in FIG. 5, the main reason for the two outcomes is that the cleaning solution sprayed by the nozzle 900 has its own flow velocity, and the substrate has a high rotation speed. The velocity and the speed are superimposed in the co-rotation zone, while in the counter-rotation zone, the flow velocity of the cleaning solution is opposite to the rotation direction of the substrate, causing a counteraction. As a result, the cleaning solution falls into the electroplating chamber before moving to the edge of the substrate 001 and being flung into the water shield 600.

For this, the solution proposed in the present application to improve the problem of relatively large solution drop volume is shown in detail in FIG. 6. As shown in FIG. 6, when the nozzle 900 is disposed, the nozzle 900 is offset relative to the center of the chuck 700, so that the coverage area of the cleaning solution sprayed by the nozzle 900 onto the substrate 001 includes the co-rotation zone 901 and the counter-rotation zone 902, wherein the co-rotation zone 901 is larger than the counter-rotation zone 902. In this way, when the nozzle 900 sprays the cleaning solution onto the substrate 001 to clean the substrate 001, the area where the flow velocity of the cleaning solution counteracts the centrifugal velocity of the substrate is reduced, thereby achieving the purpose of reducing solution drop volume.

Furthermore, the coverage area of the cleaning solution sprayed by the nozzle 900 includes the center of the substrate 001 held by the chuck 700. When the cleaning solution sprayed by the nozzle 900 comes into contact with the substrate, the distance from the boundary 9011 of the cleaning solution in the co-rotation zone 901 to the center of the substrate 001 is greater than or equal to $r/2$, and the distance from the boundary 9021 of the cleaning solution sprayed by the nozzle in the counter-rotation zone 902 to the center of the substrate 001 is smaller than or equal to $r/4$, where r is the distance from the center of the substrate 001 to the edge of the substrate 001.

Furthermore, the rotation speed of the chuck 700 driven by the drive unit 800 is greater than or equal to 50 r/min.

Furthermore, the flow rate of the cleaning solution sprayed by the nozzle is between 0.5 LPM and 2.5 LPM.

In addition, the applicant of the present invention further provides a substrate cleaning method. Please refer to FIG. 7, which comprises the following steps:

Step S100: holding a substrate in a horizontal position by a chuck;

Step S200: driving the chuck to rotate by a drive unit;

Step S300: spraying a cleaning solution onto the substrate by a nozzle to clean the substrate held by the chuck, wherein the coverage area of the cleaning solution sprayed by the nozzle onto the substrate includes a co-rotation zone and a counter-rotation zone, and the co-rotation zone is larger than the counter-rotation zone; the co-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component in the rotation direction of the substrate; the counter-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component against the rotation direction of the substrate.

Furthermore, the nozzle is a fan-shaped nozzle, a circular nozzle, an annular nozzle, or a cylindrical nozzle.

Furthermore, the coverage area of the cleaning solution sprayed by the nozzle includes the center of the substrate held by the chuck. When the cleaning solution

sprayed by the nozzle comes into contact with the substrate, the distance from the boundary of the cleaning solution in the co-rotation zone to the center of the substrate is greater than or equal to $r/2$, and the distance from the boundary of the cleaning solution sprayed by the nozzle in the counter-rotation zone to the center of the substrate is smaller than or equal to $r/4$, where r is the distance from the center of the substrate to the edge of the substrate.

Exemplarily, as shown in FIG. 6, the radius r of the substrate is divided into six equal parts. When the nozzle 900 is disposed, the nozzle 900 is offset relative to the centers of the chuck and the substrate, so that the coverage area of the cleaning solution sprayed by the nozzle 900 includes the co-rotation zone and the counter-rotation zone, wherein the co-rotation zone accounts for $2/3$ of the coverage area of the cleaning solution. In this embodiment, the distance from the boundary of the cleaning solution in the co-rotation zone to the center of the substrate is $2r/3$; the counter-rotation zone accounts for $1/3$ of the coverage area of the cleaning solution. In this embodiment, the distance from the boundary of the cleaning solution in the counter-rotation zone to the center of the substrate is $1r/3$. The solution drop volume in each solution drop section in FIG. 2 was measured and statistically analyzed under the same conditions: cleaning solution flow rate at 1.5 L/min, cleaning operation time of 60 s, and chuck rotation speed of 400 rpm. The results are shown in FIG. 8. As can be seen from FIG. 8, under the conditions described above, after completion of one substrate cleaning process during substrate cleaning, the average total solution drop volume drops to 89.3 ml, a reduction of 25.6% in average solution drop volume. Wherein, the total solution drop volume in sections A6/B6/C6/D6 drops from 11.2 ml to 0.6 ml, and the solution drop volume in the coverage area of the cleaning solution in the counter-rotation zone decreases particularly significantly. Therefore, the solution achieves a remarkable effect in reducing solution drop volume.

Although the present invention has been described in detail with reference to the foregoing embodiments, those of ordinary skill in the art should understand that they can still modify the technical solutions described in the foregoing embodiments, or make equivalent substitutions for some of the technical features thereof; and these modifications or substitutions do not make the essence of the corresponding technical solutions depart from the spirit and scope of the technical solutions of the embodiments

of the present invention.

What is claimed is:

1. An electroplating device, comprising:

a chuck, configured to hold a substrate in a horizontal position;

a drive unit, configured to drive the chuck to rotate;

a nozzle, configured to spray a cleaning solution to clean the substrate held by the chuck;

wherein, the coverage area of the cleaning solution sprayed by the nozzle onto the substrate includes a co-rotation zone and a counter-rotation zone, and the co-rotation zone is larger than the counter-rotation zone; the co-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component in the rotation direction of the substrate; the counter-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component against the rotation direction of the substrate.

2. The electroplating device according to claim 1, wherein the nozzle is a fan-shaped nozzle, a circular nozzle, an annular nozzle, or a cylindrical nozzle.

3. The electroplating device according to claim 1, wherein the coverage area of the cleaning solution sprayed by the nozzle includes the center of the substrate held by the chuck.

4. The electroplating device according to claim 3, wherein when the cleaning solution sprayed by the nozzle comes into contact with the substrate, the distance from the boundary of the cleaning solution in the co-rotation zone to the center of the substrate is greater than or equal to $r/2$, where r is the distance from the center of the substrate to the edge of the substrate.

5. The electroplating device according to claim 4, wherein the distance from the boundary of the cleaning solution sprayed by the nozzle in the counter-rotation zone to the center of the substrate is smaller than or equal to $r/4$.

6. The electroplating device according to claim 1, wherein the rotation speed of the chuck driven by the drive unit is greater than or equal to 50 r/min.

7. The electroplating device according to claim 6, wherein the flow rate of the cleaning solution sprayed by the nozzle is between 0.5 LPM and 2.5 LPM.

8. A substrate cleaning method, comprising:

holding a substrate in a horizontal position by a chuck;

driving the chuck to rotate by a drive unit;

spraying a cleaning solution onto the substrate by a nozzle to clean the substrate held by the chuck, wherein the coverage area of the cleaning solution sprayed by the nozzle onto the substrate includes a co-rotation zone and a counter-rotation zone, and the co-rotation zone is larger than the counter-rotation zone; the co-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component in the rotation direction of the substrate; the counter-rotation zone is a zone where the cleaning solution sprayed by the nozzle has a velocity component against the rotation direction of the substrate.

9. The substrate cleaning method according to claim 8, wherein the nozzle is a fan-shaped nozzle, a circular nozzle, an annular nozzle, or a cylindrical nozzle.

10. The substrate cleaning method according to claim 8, wherein the coverage area of the cleaning solution sprayed by the nozzle includes the center of the substrate held by the chuck.

11. The substrate cleaning method according to claim 10, wherein when the cleaning solution sprayed by the nozzle comes into contact with the substrate, the distance from the boundary of the cleaning solution in the co-rotation zone to the center of the substrate is greater than or equal to $r/2$, where r is the distance from the center of the substrate to the edge of the substrate.

12. The substrate cleaning method according to claim 11, wherein the distance from the boundary of the cleaning solution sprayed by the nozzle in the counter-

rotation zone to the center of the substrate is smaller than or equal to $r/4$.