

ELECTROPLATING SOLUTION BACKFLOW CONTROL SYSTEM **AND CONTROL METHOD**

TECHNICAL FIELD

The present application relates to the field of semiconductor manufacturing equipment, and in particular to an electroplating solution backflow control system and an electroplating solution backflow control method.

BACKGROUND

In an electroplating process, the stability of an electroplating solution is critical to the electroplating effect and directly affects the quality and uniformity of an electroplated layer. Controlling bubbles in the electroplating solution is a key factor affecting the stability of the electroplating solution and the electroplating process. If bubbles are mixed into the electroplating solution, in one aspect, the oxygen contained in the bubbles may cause oxidative decomposition of additives in the electroplating solution, leading to instability of the electroplating solution and affecting the electroplating rate; in another aspect, the bubbles enter an electroplating process chamber along with an electroplating solution circulation system, and when a wafer is electroplated horizontally, voids that hinder metal deposition will appear at the positions in contact with the bubbles, that is, effective electroplating is difficult to perform at the positions of the wafer in contact with the bubbles.

In an electroplating process, air is easily entrained when an electroplating solution flows back from an electroplating process chamber to a liquid storage tank, generating bubbles. Therefore, it is necessary to design an electroplating solution backflow control system and an electroplating solution backflow control method to reduce or even eliminate bubbles generated during the backflow of the electroplating solution from the electroplating process chamber to the liquid storage tank, improve the stability of the electroplating solution, and further improve the efficiency and process stability of the electroplating process.

SUMMARY

In view of the shortcomings of the prior art described above, the objective of the

present invention is to provide an electroplating solution backflow control system and an electroplating solution backflow control method to solve the problems in the prior art that bubbles are easily introduced when an electroplating solution flows back from an electroplating process chamber to a liquid storage tank during an electroplating process, which can otherwise result in low efficiency and process stability of the electroplating process.

To achieve the above objective and other related objectives, one aspect of the present invention provides an electroplating solution backflow control system, comprising: a process chamber, a liquid storage tank, a control device, an overflow pipeline, a backflow pipeline, and a bubble detection device and a backflow control valve arranged on the backflow pipeline; wherein the process chamber includes a reaction tank and an overflow tank, the overflow tank is arranged at the periphery of the reaction tank, for receiving the electroplating solution overflowing from the reaction tank; an overflow port is arranged at a predetermined height on the side wall of the overflow tank, and the overflow pipeline is used for connecting the overflow port to the liquid storage tank; the overflow tank is provided with a backflow port, and the backflow pipeline is used for connecting the backflow port to the liquid storage tank to allow the electroplating solution in the overflow tank to flow back to the liquid storage tank; the bubble detection device is arranged between the backflow port and the backflow control valve, for detecting whether bubbles are present in the electroplating solution flowing through the bubble detection device in the backflow pipeline; the control device is in communication with the backflow control valve and the bubble detection device, and is used for adjusting the opening of the backflow control valve according to the detection result of the bubble detection device and the flow rate of the electroplating solution in the overflow pipeline, so as to adjust the flow rate in the backflow pipeline.

Another aspect of the present invention further provides an electroplating solution backflow control method, comprising the following steps: S1, a process chamber starts to perform a process, and an electroplating solution overflows from a reaction tank to an overflow tank, and then flows into a liquid storage tank through a backflow pipeline, so that the electroplating solution circulates in the system; S2, a bubble detection device detects whether bubbles are present in the electroplating solution flowing

through the bubble detection device, and sends the detection result to a control device; S3, if the detection result is that bubbles are present, the control device reduces the opening of a backflow control valve, after which the process returns to step S2; if the detection result is that no bubbles are present, step S4 is performed after a first preset duration; S4, adjust the opening of the backflow control valve, and calculate the flow rate of the electroplating solution in an overflow pipeline until the flow rate of the electroplating solution in the overflow pipeline is not greater than the upper limit of a preset overflow flow rate range or until the flow rate in the overflow pipeline is within the preset overflow flow rate range.

As described above, the present invention provides an electroplating solution backflow control system and an electroplating solution backflow control method. An overflow port is arranged at a predetermined height on the side wall of the overflow tank, and the overflow pipeline is used for connecting the overflow port to the liquid storage tank; the overflow tank is provided with a backflow port, and the bubble detection device is arranged between the backflow port and the backflow control valve, for detecting whether bubbles are present in the electroplating solution flowing through the bubble detection device in the backflow pipeline; the control device is used for adjusting the opening of the backflow control valve according to the detection result of the bubble detection device and the flow rate of the electroplating solution in the overflow pipeline, so as to adjust the flow rate in the backflow pipeline, which can reduce or even eliminate bubbles generated during the backflow of the electroplating solution from the electroplating process chamber to the liquid storage tank, improve the stability of the electroplating solution, and further improve the efficiency and stability of the electroplating process.

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.

FIG. 1 is a schematic diagram of an electroplating solution backflow control system;

FIG. 2 and FIG. 3 are schematic diagrams of the electroplating solution backflow

control system in embodiment 1 of the present invention; and

FIG. 4 is a schematic flow diagram of the electroplating solution backflow control method of the present invention.

PREFERRED EMBODIMENTS OF THE PRESENT APPLICATION

The embodiments of the present invention are described below through specific examples, and those skilled in the art can easily understand other advantages and effects of the present invention from the content disclosed in this specification. The present invention can also be implemented or applied through other specific embodiments, and various details in the present disclosure can also be modified or changed based on different viewpoints and applications without departing from the spirit of the present invention.

It should be noted that the accompanying drawings in the present disclosure only schematically illustrate the basic concept of the present invention. Although the accompanying drawings only show components related to the present invention instead of being drawn according to the number, shape, and size of the components in actual implementation, the shape, number, and proportion of each component can be changed arbitrarily in actual implementation, and the component layout form may also be more complex.

When the following description involves the accompanying drawings, the same numbers in different accompanying drawings represent the same or similar elements unless otherwise indicated. The implementation methods described in the following exemplary embodiments do not represent all implementation methods consistent with the present invention. On the contrary, the implementation methods are merely examples of devices consistent with some aspects of the present invention as detailed in the appended claims.

The terms used in the present disclosure are only for the purpose of describing specific embodiments and are not intended to limit the present disclosure. The singular forms "a," "an," "the," and "said" used in the present disclosure and the appended claims are also intended to include plural forms unless the context clearly indicates

otherwise. It should also be understood that the term "and/or" used herein refers to and includes any or all possible combinations of one or more related listed items.

In the description of the present disclosure, unless otherwise specified and limited, it should be noted that the terms "install," "interconnect," and "connect" should be understood in a broad sense, for example, the connection can be mechanical connection or electrical connection, or internal communication between two elements, and the connection can be direct connection, or indirect connection via an intermediate medium. For those of ordinary skill in the art, the specific meanings of the terms described above can be understood according to specific situations.

It should be understood that although the terms "first," "second," "third," etc. may be used in the present disclosure to describe various information, the information should not be limited to these terms. These terms are only used to distinguish information of the same type from each other.

In the description of the present disclosure, it should be understood that the terms "upper," "lower," "front," "rear," "left," "right," "vertical," "horizontal," "top," "bottom," "inner," "outer," and the like that may be used indicate the orientation or positional relationship based on the orientation or positional relationship shown in the accompanying drawings, which are only for the convenience of describing the present invention and simplifying the description, rather than indicating or implying that the referred device or element must have a specific orientation, be constructed and operated in a specific orientation, and therefore cannot be understood as a limitation to the present invention.

As shown in FIG. 1, which is a schematic diagram of an electroplating solution backflow control system, the system comprises a process chamber 10, a backflow pipeline 20, and a liquid storage tank 30. The process chamber 10 is located above, the liquid storage tank 30 is located below, the upper end of the backflow pipeline 20 is connected to the process chamber 10, and the lower end of the backflow pipeline 20 is connected to the liquid storage tank 30. It should be understood that in the wafer manufacturing process, a multi-chamber electroplating apparatus is usually used to improve the production capacity, and FIG. 1 only shows one electroplating process chamber 10 in the electroplating apparatus. The process chamber 10 includes a reaction

tank 110 and an overflow tank 120 located at the periphery of the reaction tank 110. An electroplating solution 130 is supplied from the liquid storage tank 30 to the reaction tank 110, and then overflows from the reaction tank 110 into the overflow tank 120. The bottom of the overflow tank 120 is provided with a backflow port to allow the electroplating solution 130 to flow back to the liquid storage tank 30 through the backflow pipeline 20.

In order to buffer the electroplating solution 130 in the backflow pipeline 20 to a certain extent, a liquid collecting funnel 200 is usually arranged on the backflow pipeline 20. The liquid collecting funnel 200 includes a liquid collecting pipe 2001 at the top of the liquid collecting funnel 200 and a liquid discharge port at the side wall or bottom of the liquid collecting funnel 200. The liquid collecting pipe 2001 is connected to the backflow port of the overflow tank 120, the liquid discharge port is connected to the pipeline main body 201 of the backflow pipeline 20, the upper end of the pipeline main body 201 is connected to the liquid discharge port of the liquid collecting funnel 200, and the lower end of the pipeline main body 201 is connected to the liquid storage tank 30. The electroplating solution 130 in the overflow tank 120 first flows into the liquid collecting funnel 200, and then flows from the liquid collecting funnel 200 to the liquid storage tank 30 through the pipeline main body 201. Since the overflow tank 120 is an open tank, as shown in FIG. 1, when the electroplating solution 130 in the overflow tank 120 is too little, air 40 will be mixed into the electroplating solution 130 in the overflow tank 120 to generate a large number of bubbles. The bubbles will enter the liquid storage tank 30 along the backflow pipeline 20 and enter the process chamber 10 along with the circulation of the electroplating solution, affecting the stability of the electroplating solution 130, and further affecting the process efficiency and process stability.

Embodiment 1

To at least solve the problem described above, one aspect of the present invention provides an electroplating solution backflow control system. As shown in FIG. 2, which shows a schematic diagram of the electroplating solution backflow control system in embodiment 1 of the present invention, the electroplating solution backflow control system comprises a process chamber 1, a liquid storage tank 3, a control device 231, an overflow pipeline 4, a backflow pipeline 2, and a bubble detection device 24

and a backflow control valve 23 arranged on the backflow pipeline 2.

Illustratively, in this embodiment, the control device 231 may be a control device such as a computer or a PLC, the backflow control valve 23 may be a ball valve, and the bubble detection device 24 may be a device such as a dielectric constant bubble sensor, an optical bubble sensor, or an ultrasonic bubble sensor.

The process chamber 1 includes a reaction tank 11 and an overflow tank 12. The overflow tank 12 is arranged at the periphery of the reaction tank 11 for receiving the electroplating solution 13 overflowing from the reaction tank 11. The overflow tank 12 is provided with a backflow port 122, and the backflow pipeline 2 is used for connecting the backflow port 122 to the liquid storage tank 3 to allow the electroplating solution 13 in the overflow tank 12 to flow back to the liquid storage tank 3. As shown in FIG. 2, in this embodiment, the backflow port 122 is arranged at the bottom of the overflow tank 12.

The bubble detection device 24 is arranged between the backflow port 122 and the backflow control valve 23 for detecting whether bubbles are present in the electroplating solution 13 flowing through the bubble detection device 24 in the backflow pipeline 2; the control device 231 is in communication with the backflow control valve 23 and the bubble detection device 24, and is used for adjusting the opening of the backflow control valve 23 according to the detection result of the bubble detection device 24 and the flow rate of the electroplating solution 13 in the overflow pipeline 4, so as to adjust the flow rate in the backflow pipeline 2.

Specifically, in this embodiment, the control device 231 is used for: storing a preset overflow flow rate range, reducing the opening of the backflow control valve 23 when the bubble detection device 24 detects that bubbles are present; when the bubble detection device 24 detects that no bubbles are present, after a first preset duration, adjusting the opening of the backflow control valve 23, calculating the flow rate of the electroplating solution 13 in the overflow pipeline 4, and comparing the flow rate of the electroplating solution 13 in the overflow pipeline 4 with the preset overflow flow rate until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is not greater than the upper limit of the preset overflow flow rate range or until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is within the preset

overflow flow rate range.

As shown in FIG. 2, the bubble detection device 24 is arranged below the backflow port 122 and close to the backflow port 122. The bubble detection device 24 detects that bubbles are present, indicating that gas, such as air, is mixed into the electroplating solution 13 in the overflow tank 12, and the air enters the backflow pipeline 2 from the backflow port 122. The bubble detection device 24 sends the detection result to the control device 231, and the control device 231 reduces the opening of the backflow control valve 23, thereby reducing the flow rate in the backflow pipeline 2. The electroplating solution 13 overflowing from the reaction tank 11 can accumulate in the overflow tank 12 to perform a liquid sealing function on the overflow tank 12, preventing air from being mixed into the electroplating solution 13 in the overflow tank 12 and entering the backflow pipeline 2 from the backflow port 122.

Since after the opening of the backflow control valve 23 is reduced, the electroplating solution 13 may continuously accumulate in the overflow tank 12 and finally overflow the process chamber 1 from the top of the overflow tank 12, causing pollution and waste, triggering safety risks, and making the process unable to continue normally. Therefore, while ensuring that the electroplating solution 13 can accumulate in the overflow tank 12 to perform a liquid sealing function on the overflow tank 12, it is also necessary to prevent excessive accumulation of the electroplating solution 13 in the overflow tank 12 from affecting the normal process.

In order to prevent excessive electroplating solution 13 in the overflow tank 12 from overflowing the process chamber 1 from the top of the overflow tank 12 and affecting the normal process, as shown in FIG. 2, an overflow port 124 is arranged at a predetermined height on the side wall of the overflow tank 12, and the overflow pipeline 4 is used for connecting the overflow port 124 to the liquid storage tank 3. When the electroplating solution 13 in the overflow tank 12 is excessive, the electroplating solution 13 can flow into the liquid storage tank 3 through the overflow port 124 to prevent the electroplating solution 13 in the overflow tank 12 from overflowing the process chamber 1.

Through in-depth research and a plurality of experiments, the inventor found that

when the flow rate of the electroplating solution 13 in the overflow pipeline 4 is maintained within a certain range, such as 0–2 L/min, enough electroplating solution 13 is present in the overflow tank 12 to perform a liquid sealing function on the overflow tank 12, and the risk that the electroplating solution 13 in the overflow tank 12 is excessive and overflows the process chamber 1 from the top of the overflow tank 12 can be reduced or even eliminated.

Specifically, a preset overflow flow rate can be set in advance, such as 0–2 L/min, and then the control device 231 adjusts the opening of the backflow control valve 23, and calculates the corresponding flow rate of the electroplating solution 13 in the overflow pipeline 4, until the bubble detection device 24 detects that no bubbles are present and the flow rate of the electroplating solution 13 in the overflow pipeline 4 is not greater than the upper limit of the preset overflow flow rate range or within the preset overflow flow rate range. Exemplary steps of the operation of the electroplating solution backflow control system in this embodiment are given below.

First, the process chamber 1 starts to perform the process, and the electroplating solution 13 overflows from the reaction tank 11 into the overflow tank 12, and then flows into the liquid storage tank 3 through the backflow pipeline 2, so that the electroplating solution 13 circulates in the system;

Then, the bubble detection device 24 detects whether bubbles are present in the electroplating solution 13 flowing through the bubble detection device 24, and sends the detection result to the control device 231; if the detection result is that bubbles are present, the control device 231 reduces the opening of the backflow control valve 23 until the detection result is that no bubbles are present; if the detection result is that no bubbles are present, after a first preset duration, the control device 231 adjusts the opening of the backflow control valve 23, and calculates the flow rate of the electroplating solution 13 in the overflow pipeline 4 until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is within the preset overflow flow rate range. It should be understood that the first preset duration is set to allow the electroplating solution 13 to continue to accumulate in the overflow tank 12 for a period of time, so as to prevent the electroplating solution 13 from decreasing too rapidly, which can otherwise cause air to be mixed into the backflow pipeline 2 during subsequent adjustment. Those skilled in the art can set the first preset duration

according to actual conditions, and the first preset duration can also be 0.

Exemplary steps for calculating the flow rate of the electroplating solution 13 in the overflow pipeline 4 are given below:

First, the control device 231 increases the opening of the backflow control valve 23, and records the opening K1 of the backflow control valve 23 and time T0 at the start of the increase; until the bubble detection device 24 detects that bubbles are present, the control device 231 records the opening K2 of the backflow control valve 23 and time T1 at this time; the control device 231 obtains the pre-stored flow rate F1 in the backflow pipeline 2 at the opening K1, the flow rate F2 in the backflow pipeline 2 at the opening K2, and the volume V of the overflow tank 12 from the overflow port 124 to the critical liquid level when the bubble detection device 24 detects that bubbles are present, and calculates the flow rate F3 of the electroplating solution 13 in the overflow pipeline 4 at the opening K2 according to the equation $F3 = (F2 - F1) - V/(T1 - T0)$.

It should be understood that a known mathematical relationship is present between the opening of the backflow control valve 23 and the liquid flow rate passing through the backflow control valve 23. In the equation $F3 = (F2 - F1) - V/(T1 - T0)$, F1 is the flow rate in the backflow pipeline 2 measured at the opening K1, F2 is the flow rate in the backflow pipeline 2 measured at the opening K2, that is, $F2 = f(K2)$ and $F1 = f(K1)$. T1 and T0 are known quantities, V is the volume of the electroplating solution 13 reduced in the overflow tank 12 during the period from the start of overflow in the overflow pipeline 4 to the detection of bubbles by the bubble detection device 24, that is, V is the volume of the overflow tank 12 from the overflow port 124 to the critical liquid level when the bubble detection device 24 detects that bubbles are present. When the position of the overflow port 124 and the size of the overflow tank 12 are known, V is also a known quantity that can be measured. Therefore, the flow rate F3 of the electroplating solution 13 in the overflow pipeline 4 at this time can be calculated using the equation described above.

If F3 is not greater than the upper limit of the preset overflow flow rate range, the control device 231 maintains the current opening of the backflow control valve 23; if F3 is greater than the upper limit of the preset overflow flow rate range, the control

device 231 increases the opening of the backflow control valve 23, and calculates the flow rate in the overflow pipeline 4 according to the exemplary steps of calculating the flow rate in the overflow pipeline 4 described above until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is not greater than the upper limit of the preset overflow flow rate range.

Through the steps described above, when the bubble detection device 24 detects that bubbles are present, the control device 231 reduces the opening of the backflow control valve 23, so that enough electroplating solution 13 is present in the overflow tank 12 to perform a liquid sealing function on the overflow tank 12, preventing air from being mixed into the backflow pipeline 2 through the overflow tank 12 to generate bubbles; when the bubble detection device 24 detects that no bubbles are present, after a first preset duration, the control device 231 adjusts the opening of the backflow control valve 23, and calculates the flow rate of the electroplating solution 13 in the overflow pipeline 4 until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is not greater than the upper limit of the preset overflow flow rate range, thereby reducing or even eliminating the risk that the electroplating solution 13 in the overflow tank 12 is excessive and overflows the process chamber 1 from the top of the overflow tank 12.

Optionally, in other possible embodiments, after the flow rate F_3 of the electroplating solution 13 in the overflow pipeline 4 at the opening K2 is calculated, if F_3 is within the preset overflow flow rate range, the control device 231 maintains the current opening of the backflow control valve 23; if F_3 is greater than the upper limit of the preset overflow flow rate range, the control device 231 increases the opening of the backflow control valve 23, and calculates the flow rate in the overflow pipeline 4 according to the exemplary steps of calculating the flow rate of the electroplating solution 13 in the overflow pipeline 4 described above until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is within the preset overflow flow rate range; if F_3 is smaller than the lower limit of the preset overflow flow rate range, it indicates that the electroplating solution 13 in the overflow tank 12 is accumulated enough to perform a liquid sealing function on the overflow tank 12, but the volume is smaller than the volume when the electroplating solution 13 reaches the overflow port 124, and may soon reach the critical liquid level when the bubble detection device 24

detects that bubbles are present. Therefore, the opening of the backflow control valve 23 can be reduced first and maintained for a second preset duration, then the opening of the backflow control valve 23 is increased, and the flow rate in the overflow pipeline 4 is calculated according to the exemplary steps of calculating the flow rate of the electroplating solution 13 in the overflow pipeline 4 described above until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is within the preset overflow flow rate range. It should be understood that, in this example, the lower limit of the preset overflow flow rate range is 0, so the calculated F3 may also be a negative value.

Optionally, the system can be updated regularly or irregularly, such as after the electroplating of a batch of wafers is completed, and the opening of the backflow control valve 23 can be re-determined according to the steps described above until the bubble detection device 24 detects that no bubbles are present and the flow rate of the electroplating solution 13 in the overflow pipeline 4 is not greater than the upper limit of the preset overflow flow rate range or within the preset overflow flow rate range, so as to improve the reliability of the electroplating solution backflow control system.

Optionally, before the process chamber 1 performs the process, a suitable initial opening K of the backflow control valve 23 can be obtained by simulating the process with reference to the steps of the process performed by the process chamber 1, so that the flow rate of the electroplating solution 13 in the overflow pipeline 4 is maintained within a certain range, such as 0–2 L/min. In this case, enough electroplating solution 13 is present in the overflow tank 12 to perform a liquid sealing function on the overflow tank 12, and the risk that the electroplating solution 13 in the overflow tank 12 is excessive and overflows the process chamber 1 from the top of the overflow tank 12 can be reduced or even eliminated. In this way, during the process execution, the backflow control valve 23 can be directly adjusted to the initial opening K, and then the system can perform automatic adjustment on the basis of the initial opening K, which can improve the efficiency of automatic adjustment of the system.

Exemplary steps are given below:

Adjust the opening of the backflow control valve 23 to a relatively large initial value, such as 100%, make the electroplating solution 13 start to circulate in the system, and the bubble detection device 24 detects whether bubbles are present in the

electroplating solution 13 flowing through the bubble detection device 24. At this time, the electroplating solution 13 in the overflow tank 12 has not accumulated yet, a large amount of air enters the backflow pipeline 2 along with the electroplating solution 13, and the bubble detection device 24 detects that bubbles are present.

Gradually reduce the opening of the backflow control valve 23, so that the electroplating solution 13 can continuously accumulate in the overflow tank 12 until the electroplating solution 13 overflows into the overflow pipeline 4 through the overflow port 124, record the time T00 and the opening K01 of the backflow control valve 23 at this time. It should be understood that the position of the overflow port 124 can be reasonably designed according to the actual structure of the overflow tank 12, and the purpose is to ensure the safe operation of the system. When the electroplating solution 13 exceeds the overflow port 124, a safety risk is present that the electroplating solution 13 overflows the process chamber 1 from the top of the overflow tank 12.

Gradually increase the opening of the backflow control valve 23, so that the electroplating solution 13 in the overflow tank 12 gradually decreases until the bubble detection device 24 detects that bubbles are present again, record the time as T01 and the opening K02 of the backflow control valve 23 at this time.

It should be understood that K01 and K02 can be empirical values easily known to those skilled in the art, for example, K01 is 55%, and K02 is 60%. A known mathematical relationship is present between the opening of the backflow control valve 23 and the flow rate of the liquid passing through the backflow control valve 23. At the opening K01, the flow rate F01 in the backflow pipeline 2 can be measured, and at the opening K02, the flow rate F02 in the backflow pipeline 2 can be measured, that is, $F01 = f(K01)$, $F02 = f(K02)$.

The flow rate F03 of the electroplating solution 13 in the overflow pipeline 4 at this time can be calculated using the following equation (1):

$$(1) F03 = (F02 - F01) - V/(T01 - T00).$$

Wherein, F01 is the flow rate in the backflow pipeline 2 measured at the opening K01, F02 is the flow rate in the backflow pipeline 2 measured at the opening K02, F01

$= f(K01)$, $F02 = f(K02)$, the opening values of $K01$ and $K02$ are known empirical values, so $F01$ and $F02$ are also known quantities that can be measured; $T01$ and $T00$ are known quantities, V is the volume of the electroplating solution 13 reduced in the overflow tank 12 during the period from time $T00$ when overflow starts to occur in the overflow pipeline 4 to time $T01$ when the bubble detection device 24 detects that bubbles are present, that is, V is the volume of the overflow tank 12 from the overflow port 124 to the critical liquid level when the bubble detection device 24 detects that bubbles are present. When the position of the overflow port 124 and the size of the overflow tank 12 are known, V is also a known quantity that can be measured. Therefore, the flow rate $F03$ of the electroplating solution 13 in the overflow pipeline 4 at this time can be calculated using the equation described above.

If $F03$ is within the preset overflow flow rate range, such as $0 \leq F03 \leq 2 \text{ L/min}$, it indicates that the current opening $K02$ is appropriate;

If $F03$ is greater than the preset overflow flow rate range, such as $F03 > 2 \text{ L/min}$, it indicates that the opening of the backflow control valve 23 needs to be increased at this time, that is, the value of $K02$ needs to be increased;

If $F03$ is smaller than the preset overflow flow rate range, such as $F03 < 0 \text{ L/min}$, it indicates that the opening of the backflow control valve 23 needs to be reduced at this time, that is, the value of $K02$ needs to be reduced.

Repeat the steps described above to obtain an appropriate opening $K02$ such that $0 \leq F03 \leq 2 \text{ L/min}$, and store the current opening $K02$ as the initial opening K . In this way, during the process execution, the backflow control valve 23 can be directly adjusted to the initial opening K , and then the system can perform automatic adjustment on the basis of the initial opening K , which can improve the efficiency of automatic adjustment of the system.

Optionally, at least for the purpose of buffering the electroplating solution 13 in the backflow pipeline 2, the backflow pipeline 2 includes a liquid collecting funnel 21 and a pipeline main body 22. As shown in FIG. 2, illustratively, the liquid collecting funnel 21 includes a liquid collecting pipe 211 at the top of the liquid collecting funnel 21 and a liquid discharge port at the bottom of the liquid collecting funnel 21, the liquid

collecting pipe 211 is connected to the backflow port 122, and the liquid discharge port is connected to the pipeline main body 22. In other possible embodiments, the liquid discharge port can also be arranged on the side wall.

As shown in FIG. 3, in an electroplating apparatus with a plurality of process chambers 1, each liquid collecting funnel 21 can also have 2 liquid collecting pipes 211. At this time, the liquid collecting funnel 21 is connected to two process chambers 1 and becomes a common backflow area in the backflow control system of the two process chambers 1.

Optionally, since the process environment is usually in an acidic or alkaline atmosphere and the process environment is harsh, in order to enhance the reliability of system control, in this embodiment, as shown in FIG. 2, the bubble detection device 24 includes a first bubble detection device 241 and a second bubble detection device 242, and the second bubble detection device 242 is arranged between the first bubble detection device 241 and the backflow control valve 23; the backflow control valve 23 is used for reducing the opening of the backflow pipeline 2 when the first bubble detection device 241 and/or the second bubble detection device 242 detects that bubbles are present. That is, provided that at least one of the first bubble detection device 241 and the second bubble detection device 242 detects that bubbles are present, the backflow control valve 23 reduces the opening of the backflow pipeline 2.

Embodiment 2

As shown in FIG. 4, another aspect of the present invention provides an electroplating solution backflow control method, which is applied to the electroplating solution backflow control system in embodiment 1, comprising:

S1, the process chamber 1 starts to perform the process, and the electroplating solution 13 overflows from the reaction tank 11 into the overflow tank 12, and then flows into the liquid storage tank 3 through the backflow pipeline 2, so that the electroplating solution 13 circulates in the system;

S2, the bubble detection device 24 detects whether bubbles are present in the electroplating solution 13 flowing through the bubble detection device 24, and sends

the detection result to the control device 231;

S3, if the detection result is that bubbles are present, the control device 231 reduces the opening of the backflow control valve 23, after which the process returns to step S2; if the detection result is that no bubbles are present, step S4 is performed after a first preset duration;

S4, adjust the opening of the backflow control valve 23, and calculate the flow rate of the electroplating solution 13 in the overflow pipeline 4 until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is not greater than the upper limit of the preset overflow flow rate range or until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is within the preset overflow flow rate range.

In this embodiment, step S4 further includes:

S41, the control device 231 increases the opening of the backflow control valve 23, and records the opening K1 of the backflow control valve 23 and time T0 at the start of the increase;

S42, until the bubble detection device 24 detects that bubbles are present, record the opening K2 of the backflow control valve 23 and time T1 at this time;

S43, obtain the pre-stored flow rate F1 in the backflow pipeline 2 at the opening K1, the flow rate F2 in the backflow pipeline 2 at the opening K2, and the volume V of the overflow tank 12 from the overflow port 124 to the critical liquid level when the bubble detection device 24 detects that bubbles are present, and calculate the flow rate of the electroplating solution 13 in the overflow pipeline 4 at this time according to the equation $F3 = (F2 - F1) - V/(T1 - T0)$;

S44, if F3 is not greater than the upper limit of the preset overflow flow rate range, the control device 231 maintains the current opening of the backflow control valve 23; if F3 is greater than the upper limit of the preset overflow flow rate range, return to step S41.

Optionally, before the process chamber 1 performs the process, a suitable initial opening K of the backflow control valve 23 can be obtained by simulating the process

with reference to the steps of the process performed by the process chamber 1. Illustratively, before step S1, the method further comprises:

S01, adjust the opening of the backflow control valve 23 to 100%, make the electroplating solution 13 start to circulate in the system, and the bubble detection device 24 detects whether bubbles are present in the electroplating solution 13 flowing through the bubble detection device 24;

S02, gradually reduce the opening of the backflow control valve 23, so that the electroplating solution 13 can continuously accumulate in the overflow tank 12 until the electroplating solution 13 overflows into the overflow pipeline 4 through the overflow port 124, and record the time T00 and the opening K01 of the backflow control valve 23 at this time; during this process, the detection result of the bubble detection device 24 can change from bubbles present to no bubbles;

S03, gradually increase the opening of the backflow control valve 23, so that the electroplating solution 13 in the overflow tank 12 gradually decreases until the bubble detection device 24 detects that bubbles are present again, and record the time as T01 and the opening K01 of the backflow control valve 23 at this time;

S04, calculate the flow rate F03 of the electroplating solution 13 in the overflow pipeline 4 at this time using equation (1):

$$(1) F03 = (F02 - F01) - V/(T01 - T00);$$

wherein, F01 is the flow rate in the backflow pipeline 2 measured at the opening K01, F02 is the flow rate in the backflow pipeline 2 measured at the opening K02, $F01 = f(K01)$, $F02 = f(K02)$, the opening values of K01 and K02 are known empirical values, so F01 and F02 are also known quantities that can be measured; T01 and T00 are known quantities, V is the volume of the overflow tank 12 during the period from time T00 when overflow starts to occur in the overflow pipeline 4 to time T01 when the bubble detection device 24 detects that bubbles are present, that is, V is the volume of the overflow tank 12 from the overflow port 124 to the critical liquid level when the bubble detection device 24 detects that bubbles are present. When the position of the overflow port 124 and the size of the overflow tank 12 are known, V is also a known

quantity that can be measured;

S05, if F03 is not greater than the upper limit of the preset overflow flow rate range, store the current opening K02 as the initial opening K; if F03 is greater than the upper limit of the preset overflow flow rate range, repeat the steps S01 to S04 described above.

In this way, during the process execution, the backflow control valve 23 can be directly adjusted to the initial opening K, and then the system can perform automatic adjustment on the basis of the initial opening K, which can improve the efficiency of automatic adjustment of the system.

Optionally, in other possible embodiments, the steps for obtaining a suitable initial opening K of the backflow control valve 23 can also be different from the steps described above. Another set of exemplary steps is given below.

Specifically, before step S1, the method further comprises:

S010, adjust the opening of the backflow control valve 23 to 100%, make the electroplating solution 13 start to circulate in the system, and the bubble detection device 24 detects whether bubbles are present in the electroplating solution 13 flowing through the bubble detection device 24;

S020, gradually reduce the opening of the backflow control valve 23, so that the electroplating solution 13 can continuously accumulate in the overflow tank 12 until the electroplating solution 13 overflows into the overflow pipeline 4 through the overflow port 124, and record the time T00 and the opening K01 of the backflow control valve 23 at this time; during this process, the detection result of the bubble detection device 24 can change from bubbles present to no bubbles;

S030, gradually increase the opening of the backflow control valve 23, so that the electroplating solution 13 in the overflow tank 12 gradually decreases until the bubble detection device 24 detects that bubbles are present again, and record the time as T01 and the opening K01 of the backflow control valve 23 at this time;

S040, calculate the flow rate F03 of the electroplating solution 13 in the overflow

pipeline 4 at this time using equation (1):

$$(1) F03 = (F02 - F01) - V/(T01 - T00);$$

S050, if F03 is within the preset overflow flow rate range, store the current opening K02 as the initial opening K; if F03 is not within the preset overflow flow rate range, repeat the steps S010 to S040 described above.

Wherein, if F03 is greater than the preset overflow flow rate range, such as $F03 > 2 \text{ L/min}$, it indicates that the opening of the backflow control valve 23 needs to be increased at this time; if F03 is smaller than the preset overflow flow rate range, such as $F03 < 0 \text{ L/min}$, it indicates that the opening of the backflow control valve 23 needs to be reduced at this time.

Embodiment 3

Embodiment 3 provides an electroplating solution backflow control method, which is applied to the electroplating solution backflow control system in embodiment 1. Compared with embodiment 2, this embodiment is mainly different in that:

Step S4 further includes:

S410, the control device 231 increases the opening of the backflow control valve 23, and records the opening K1 of the backflow control valve 23 and time T0 at the start of the increase;

S420, until the bubble detection device 24 detects that bubbles are present, record the opening K2 of the backflow control valve 23 and time T1 at this time;

S430, obtain the pre-stored flow rate F1 in the backflow pipeline 2 at the opening K1, the flow rate F2 in the backflow pipeline 2 at the opening K2, and the volume V of the overflow tank 12 from the overflow port 124 to the critical liquid level when the bubble detection device 24 detects that bubbles are present, and calculate the flow rate of the electroplating solution 13 in the overflow pipeline 4 at this time according to the equation $F3 = (F2 - F1) - V/(T1 - T0)$;

S440, if F3 is within the preset overflow flow rate range, the control device 231 maintains the current opening of the backflow control valve 23; if F3 is greater than the upper limit of the preset overflow flow rate range, return to step S410; if F3 is smaller than the lower limit of the preset overflow flow rate range, reduce the opening of the backflow control valve 23 and maintain the opening for a second preset duration, then return to step S410.

If F3 is smaller than the lower limit of the preset overflow flow rate range, it indicates that the electroplating solution 13 in the overflow tank 12 is accumulated enough to perform a liquid sealing function on the overflow tank 12, but the volume is smaller than the volume when the electroplating solution 13 reaches the overflow port 124, and may soon decrease to the critical liquid level when the bubble detection device 24 detects that bubbles are present. Therefore, the opening of the backflow control valve 23 can be reduced first and maintained for a second preset duration, then the opening of the backflow control valve 23 is increased, and the flow rate of the electroplating solution 13 in the overflow pipeline 4 is calculated according to the exemplary steps of calculating the flow rate of the electroplating solution 13 in the overflow pipeline 4 described above until the flow rate of the electroplating solution 13 in the overflow pipeline 4 is within the preset overflow flow rate range.

The embodiments described above only schematically illustrate the principle and effect of the present invention, and are not intended to limit the present invention. Anyone skilled in the art can modify or change the embodiments described above without departing from the spirit and scope of the present invention. Therefore, all equivalent modifications or changes completed by those with ordinary skill in the art without departing from the spirit and technical idea disclosed in the present invention shall still be covered by the claims of the present invention.

What is claimed is:

1. An electroplating solution backflow control system, comprising:

a process chamber, a liquid storage tank, a control device, an overflow pipeline, a backflow pipeline, and a bubble detection device and a backflow control valve arranged on the backflow pipeline;

wherein, the process chamber includes a reaction tank and an overflow tank, the overflow tank is arranged at the periphery of the reaction tank, for receiving the electroplating solution overflowing from the reaction tank; an overflow port is arranged at a predetermined height on the side wall of the overflow tank, and the overflow pipeline is used for connecting the overflow port to the liquid storage tank; the overflow tank is provided with a backflow port, and the backflow pipeline is used for connecting the backflow port to the liquid storage tank to allow the electroplating solution in the overflow tank to flow back to the liquid storage tank; the bubble detection device is arranged between the backflow port and the backflow control valve, for detecting whether bubbles are present in the electroplating solution flowing through the bubble detection device in the backflow pipeline; the control device is in communication with the backflow control valve and the bubble detection device, and is used for adjusting the opening of the backflow control valve according to the detection result of the bubble detection device and the flow rate of the electroplating solution in the overflow pipeline, so as to adjust the flow rate in the backflow pipeline.

2. The electroplating solution backflow control system according to claim 1, wherein the control device is further used for: storing a preset overflow flow rate range, reducing the opening of the backflow control valve when the bubble detection device detects that bubbles are present; when the bubble detection device detects that no bubbles are present, after a first preset duration, adjusting the opening of the backflow control valve, calculating the flow rate of the electroplating solution in the overflow pipeline, and comparing the flow rate of the electroplating solution in the overflow pipeline with the preset overflow flow rate until the flow rate of the electroplating solution in the overflow pipeline is not greater than the upper limit of the preset overflow flow rate range or until the flow rate in the overflow pipeline is within the preset overflow flow rate range.

3. The electroplating solution backflow control system according to claim 2, wherein the control device is further used for: when the bubble detection device detects that no bubbles are present, after a first preset duration, increasing the opening of the backflow control valve, calculating the flow rate of the electroplating solution in the overflow pipeline, comparing the flow rate of the electroplating solution in the overflow pipeline with the preset overflow flow rate, and maintaining the current opening of the backflow control valve if the flow rate of the electroplating solution in the overflow pipeline is not greater than the upper limit of the preset overflow flow rate range; increasing the opening of the backflow control valve if the flow rate of the electroplating solution in the overflow pipeline is greater than the upper limit of the preset overflow flow rate range until the flow rate of the electroplating solution in the overflow pipeline is not greater than the upper limit of the preset overflow flow rate range.

4. The electroplating solution backflow control system according to claim 2, wherein the control device is further used for: when the bubble detection device detects that no bubbles are present, after a first preset duration, increasing the opening of the backflow control valve, calculating the flow rate of the electroplating solution in the overflow pipeline, comparing the flow rate of the electroplating solution in the overflow pipeline with the preset overflow flow rate, and maintaining the current opening of the backflow control valve if the flow rate of the electroplating solution in the overflow pipeline is within the preset overflow flow rate range; increasing the opening of the backflow control valve if the flow rate of the electroplating solution in the overflow pipeline is greater than the upper limit of the preset overflow flow rate range until the flow rate of the electroplating solution in the overflow pipeline is within the preset overflow flow rate range; reducing the opening of the backflow control valve and maintaining the opening for a second preset duration if the flow rate of the electroplating solution in the overflow pipeline is smaller than the lower limit of the preset overflow flow rate range, then increasing the opening of the backflow control valve until the flow rate of the electroplating solution in the overflow pipeline is within the preset overflow flow rate range.

5. The electroplating solution backflow control system according to claim 1, wherein the backflow pipeline includes a liquid collecting funnel and a pipeline main

body, the liquid collecting funnel includes a liquid collecting pipe and a liquid discharge port, the liquid collecting pipe is connected to the backflow port, and the liquid discharge port is connected to the pipeline main body.

6. The electroplating solution backflow control system according to claim 1, wherein the bubble detection device includes a first bubble detection device and a second bubble detection device, and the second bubble detection device is arranged between the first bubble detection device and the backflow control valve.

7. An electroplating solution backflow control method applied to the electroplating solution backflow control system according to claim 1, comprising:

S1, the process chamber starting to perform the process, and the electroplating solution overflowing from the reaction tank into the overflow tank, and then flowing into the liquid storage tank through the backflow pipeline, so that the electroplating solution circulates in the system;

S2, the bubble detection device detecting whether bubbles are present in the electroplating solution flowing through the bubble detection device, and sending the detection result to the control device;

S3, if the detection result is that bubbles are present, the control device reducing the opening of the backflow control valve, after which the process returns to step S2; if the detection result is that no bubbles are present, step S4 being performed after a first preset duration;

S4, adjusting the opening of the backflow control valve, and calculating the flow rate of the electroplating solution in the overflow pipeline until the flow rate of the electroplating solution in the overflow pipeline is not greater than the upper limit of a preset overflow flow rate range or until the flow rate of the electroplating solution in the overflow pipeline is within the preset overflow flow rate range.

8. The electroplating solution backflow control method according to claim 7, wherein S4 further includes:

S41, the control device increasing the opening of the backflow control valve, and

recording the opening K1 of the backflow control valve and time T0 at the start of the increase;

S42, until the bubble detection device detects that bubbles are present, recording the opening K2 of the backflow control valve and time T1 at this time;

S43, obtaining the pre-stored flow rate F1 in the backflow pipeline at the opening K1, the flow rate F2 in the backflow pipeline at the opening K2, and the volume V of the overflow tank from the overflow port to the critical liquid level when the bubble detection device detects that bubbles are present, and calculating the flow rate of the electroplating solution in the overflow pipeline at this time according to the equation $F3 = (F2 - F1) - V/(T1 - T0)$;

S44, if F3 is not greater than the upper limit of the preset overflow flow rate range, the control device maintaining the current opening of the backflow control valve; if F3 is greater than the upper limit of the preset overflow flow rate range, returning to step S41.

9. The electroplating solution backflow control method according to claim 7, wherein S4 further includes:

S410, the control device increasing the opening of the backflow control valve, and recording the opening K1 of the backflow control valve and time T0 at the start of the increase;

S420, until the bubble detection device detects that bubbles are present, recording the opening K2 of the backflow control valve and time T1 at this time;

S430, obtaining the pre-stored flow rate F1 in the backflow pipeline at the opening K1, the flow rate F2 in the backflow pipeline at the opening K2, and the volume V of the overflow tank from the overflow port to the critical liquid level when the bubble detection device detects that bubbles are present, and calculating the flow rate of the electroplating solution in the overflow pipeline at this time according to the equation $F3 = (F2 - F1) - V/(T1 - T0)$;

S440, if F3 is within the preset overflow flow rate range, the control device

maintaining the current opening of the backflow control valve; if F3 is greater than the upper limit of the preset overflow flow rate range, returning to step S410; if F3 is smaller than the lower limit of the preset overflow flow rate range, reducing the opening of the backflow control valve and maintaining the opening for a second preset duration, then returning to step S410.

10. The electroplating solution backflow control method according to claim 8 or 9, wherein before S1, the method further comprises:

S01, the electroplating solution overflowing from the reaction tank into the overflow tank, then flowing into the liquid storage tank through the backflow pipeline to make the electroplating solution circulate in the system, adjusting the opening of the backflow control valve to 100%, and the bubble detection device detecting whether bubbles are present in the electroplating solution flowing through the bubble detection device;

S02, gradually reducing the opening of the backflow control valve, so that the electroplating solution can continuously accumulate in the overflow tank until the electroplating solution overflows into the overflow pipeline through the overflow port, and recording the time T00 and the opening K01 of the backflow control valve at this time;

S03, gradually increasing the opening of the backflow control valve, so that the electroplating solution in the overflow tank gradually decreases until the bubble detection device detects that bubbles are present again, and recording the time as T01 and the opening K02 of the backflow control valve at this time;

S04, calculating the flow rate F03 of the electroplating solution in the overflow pipeline at this time using equation (1):

$$(1) F03 = (F02 - F01) - V/(T01 - T00);$$

wherein, F01 is the flow rate in the backflow pipeline measured at the opening K01, F02 is the flow rate in the backflow pipeline measured at the opening K02; V is the volume of the overflow tank from the overflow port to the critical liquid level when the bubble detection device detects that bubbles are present;

S05, if F03 is not greater than the upper limit of the preset overflow flow rate range, storing the current opening K02 as the initial opening K; if F03 is greater than the upper limit of the preset overflow flow rate range, repeating the steps S01 to S04.

11. The electroplating solution backflow control method according to claim 8 or 9, wherein before S1, the method further comprises:

S010, the electroplating solution overflowing from the reaction tank into the overflow tank, then flowing into the liquid storage tank through the backflow pipeline to make the electroplating solution circulate in the system, adjusting the opening of the backflow control valve to 100%, and the bubble detection device detecting whether bubbles are present in the electroplating solution flowing through the bubble detection device;

S020, gradually reducing the opening of the backflow control valve, so that the electroplating solution can continuously accumulate in the overflow tank until the electroplating solution overflows into the overflow pipeline through the overflow port, and recording the time T00 and the opening K01 of the backflow control valve at this time;

S030, gradually increasing the opening of the backflow control valve, so that the electroplating solution in the overflow tank gradually decreases until the bubble detection device detects that bubbles are present again, and recording the time as T01 and the opening K02 of the backflow control valve at this time;

S040, calculating the flow rate F03 of the electroplating solution in the overflow pipeline at this time using equation (1):

$$(1) F03 = (F02 - F01) - V / (T01 - T00);$$

wherein, F01 is the flow rate in the backflow pipeline measured at the opening K01, F02 is the flow rate in the backflow pipeline measured at the opening K02; V is the volume of the overflow tank from the overflow port to the critical liquid level when the bubble detection device detects that bubbles are present;

S050, if F03 is within the preset overflow flow rate range, storing the current

opening K02 as the initial opening K; if F03 is not within the preset overflow flow rate range, repeating the steps S010 to S040.