ELECTROPLATING SOLUTION REFLUX CONTROL SYSTEM AND CONTROL METHOD

FIELD OF THE INVENTION

The present application relates to the field of semiconductor manufacturing, and in particular, to an electroplating solution reflux control system and a 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 a plating layer. The control of 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, since the bubbles contain oxygen, additives in the electroplating solution may be oxidized and decomposed, resulting in instability of the electroplating solution and affecting the electroplating rate; in another aspect, the bubbles enter an electroplating process chamber along with a circulation system, and when a wafer is electroplated, positions in contact with the bubbles will have voids that hinder metal deposition, that is, effective electroplating is difficult to perform at positions of the wafer with the bubbles.

In an electroplating process, air is very easily entrained to generate bubbles when the electroplating solution flows back from the electroplating process chamber to a solution storage tank. Therefore, it is necessary to design an electroplating solution reflux control system and a control method to effectively reduce or even eliminate the bubbles generated during the reflux of the electroplating solution from the electroplating process chamber to the solution 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 above-mentioned shortcomings of the prior art, the object of the present invention is to provide an electroplating solution reflux control system and a control method, which are used to solve the problems in the prior art that bubbles are

very easily introduced during the reflux of an electroplating solution from an electroplating process chamber to a solution storage tank in an electroplating process, resulting in low efficiency and process stability of the electroplating process, and the like.

To achieve the above object and other related objects, the present invention provides an electroplating solution reflux control system, comprising: a process chamber, a solution storage tank, a reflux line, a reflux control valve, an image acquisition device, and a control device; wherein the process chamber includes a reaction tank and an overflow tank, the overflow tank is arranged at the periphery of the reaction tank and is used for receiving the electroplating solution overflowing from the reaction tank; a reflux port is arranged at the bottom of the overflow tank, the reflux line is in communication with the reflux port and the solution storage tank, so as to reflux the electroplating solution in the overflow tank to the solution storage tank; the reflux control valve is arranged on the reflux line; the image acquisition device is arranged above the reflux port and is used for acquiring image information of the reflux port region and sending the image information to the control device; and the control device is used for comparing the image information with pre-stored reference image information and adjusting the opening degree of the reflux control valve according to the comparison result, so as to adjust the flow rate of the reflux line.

The present invention provides another electroplating solution reflux control system, comprising a process chamber, a solution storage tank, a reflux line, a reflux control valve, an image acquisition device, and a control device; wherein the process chamber includes a reaction tank and an overflow tank, the overflow tank is arranged at the periphery of the reaction tank and is used for receiving the electroplating solution overflowing from the reaction tank; a reflux port is arranged at the bottom of the overflow tank, the reflux line is in communication with the reflux port and the solution storage tank, so as to reflux the electroplating solution in the overflow tank to the solution storage tank; the reflux control valve is arranged on the reflux line; the image acquisition device is arranged above the overflow tank and is used for acquiring image information inside the overflow tank and sending the image information to the control device; and the control device is used for comparing the image information with pre-stored reference image information and adjusting the opening degree of the reflux

control valve according to the comparison result.

The present invention further provides an electroplating solution reflux control method, comprising:

S1, starting a process in a process chamber, allowing an electroplating solution to overflow from a reaction tank to an overflow tank, and then to flow into a solution storage tank through a reflux line;

S2, an image acquisition device acquiring image information of a reflux port region and sending the image information to a control device;

S3, the control device comparing the image information with pre-stored reference image information;

S4, the control device adjusting the opening degree of a reflux control valve according to the comparison result.

The present invention further provides an electroplating solution reflux control method, comprising:

S10, starting a process in a process chamber, allowing an electroplating solution to overflow from a reaction tank to an overflow tank, and then to flow into a solution storage tank through a reflux line;

S20, an image acquisition device acquiring image information inside the overflow tank and sending the image information to a control device;

S30, the control device comparing the image information with pre-stored reference image information;

S40, the control device adjusting the opening degree of a reflux control valve according to the comparison result.

As described above, according to the electroplating solution reflux control system and the control method provided by the present invention, the image acquisition device is arranged above the reflux port and is used for acquiring image information of the

reflux port region and sending the image information to the control device; the control device is used for comparing the image information with pre-stored reference image information and adjusting the opening degree of the reflux control valve of the reflux line according to the comparison result, so that the bubbles generated during the reflux of the electroplating solution from the electroplating process chamber to the solution storage tank are effectively reduced or even eliminated, the stability of the electroplating solution is improved, and the efficiency and process stability of the electroplating process are further improved.

BRIEF DESCRIPTION OF THE DRAWINGS

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

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

FIG. 2 is a schematic diagram of the electroplating solution reflux control system in Embodiment 1 of the present invention;

FIG. 3 is a schematic structural diagram of the process chamber in Embodiment 1 and Embodiment 2 of the present invention;

FIG. 4 is a schematic diagram of the electroplating solution reflux control system in Embodiment 2 of the present invention;

FIG. 5 is a schematic diagram of the correspondence between different electroplating solution volumes in the overflow tank and the form of the electroplating solution in the reflux port region in Embodiment 1 and Embodiment 2 of the present invention.

PREFERRED EMBODIMENTS OF THE INVENTION

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 the present specification. The present invention may also be implemented or applied through other specific

embodiments, and various details in the present specification may 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 of the present disclosure merely illustrate the basic idea of the present invention in a schematic manner, the accompanying drawings only show components related to the present invention rather than being drawn according to the number, shape, and size of the components during actual implementation, the form, number, and proportion of each component may be changed arbitrarily during actual implementation, and the component layout form may also be more complex.

When the following description refers to the accompanying drawings, the same numerals in different accompanying drawings represent the same or similar elements unless otherwise indicated. The implementation manners described in the following exemplary embodiments do not represent all implementation manners consistent with the present invention. Instead, the implementation manners 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 for the purpose of describing particular embodiments only and are not intended to limit the present disclosure. As used in the present disclosure and the appended claims, the singular forms "a/an," "the," and "this" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It should also be understood that the term “and/or” as used herein refers to and encompasses any and all possible combinations of one or more of the associated listed items.

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

It should be understood that although terms "first," "second," "third," and the like may be used in the present disclosure to describe various kinds of 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 terms such as "upper," "lower," "front," "rear," "left," "right," "vertical," "horizontal," "top," "bottom," "inner," "outer," and the like indicate orientations or positional relationships based on the orientations or positional relationships shown in the accompanying drawings, are merely for convenience of describing the present invention and simplifying the description, and do not indicate or imply that the referred device or element must have a specific orientation, be constructed and operated in a specific orientation, and thus should not be construed as limiting the present invention.

As shown in FIG. 1, a schematic diagram of an electroplating solution reflux system is provided. The system comprises a process chamber 10, a reflux line 20, and a solution storage tank 30. The reflux line 20 is in communication with the process chamber 10 and the solution storage tank 30. Specifically, in an embodiment, the process chamber 10 is located above the solution storage tank 30, the upper end of the reflux line 20 is connected to the process chamber 10, and the lower end of the reflux line 20 is connected to the solution storage tank 30. It should be understood that in a wafer manufacturing process, a multi-chamber electroplating apparatus is usually adopted to improve 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 solution storage tank 30 to the reaction tank 110, and then overflows from the reaction tank 110 to the overflow tank 120. A reflux port is arranged at the bottom of the overflow tank 120, so that the electroplating solution 130 flows back from the reflux port to the solution storage tank 30 through the reflux line 20.

In order to buffer the electroplating solution 130 in the reflux line 20 to a certain extent, a liquid collection funnel 200 is usually arranged on the reflux line 20, that is, the reflux line 20 includes the liquid collection funnel 200 and a pipeline main body 201. The liquid collection funnel 200 includes a liquid collection pipe 2001 at the top

of the liquid collection funnel 200 and a liquid discharge port at a side wall or the bottom of the liquid collection funnel 200. The liquid collection pipe 2001 is in communication with the reflux port of the overflow tank 120, and the liquid discharge port is in communication with the upper end of the pipeline main body 201. The electroplating solution 130 in the overflow tank 120 first flows into the liquid collection funnel 200 from the reflux port, and then flows from the liquid collection funnel 200 to the solution 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 insufficient, air 40 is mixed into the overflow tank 120 to form a large number of bubbles. The bubbles enter the solution storage tank 30 along the reflux line 20 and enter the process chamber 10 along with the circulation of the electroplating solution, which affects the stability of the electroplating solution 130 and further affects the process efficiency and process stability.

Through repeated researches and experiments, the inventor finds that in an electroplating process, the control of the bubbles in the reflux line 20 is related to image information in the overflow tank 120 acquired from above the overflow tank 120. Therefore, an electroplating solution reflux control system and a control method are provided. By acquiring and analyzing image information in the overflow tank 120, the opening degree of a reflux control valve 23 on the reflux line 20 is adjusted to reduce or even eliminate the bubbles generated during the reflux of the electroplating solution, so that the efficiency and process stability of the electroplating process are improved.

Embodiment 1

One aspect of the present invention provides an electroplating solution reflux control system. Referring to FIG. 2, which shows a schematic diagram of the electroplating solution reflux control system in Embodiment 1 of the present invention, the electroplating solution reflux control system comprises a process chamber 1, a solution storage tank 3, a reflux line 2, a reflux control valve 23, an image acquisition device 5, and a control device 6. 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 and is used for receiving an electroplating solution 13 overflowing from the reaction tank 11. A reflux port 122 is arranged at the bottom of the overflow

tank 12. The reflux line 2 is in communication with the reflux port 122 and the solution storage tank 3, so as to reflux the electroplating solution 13 in the overflow tank 12 to the solution storage tank 3. The reflux control valve 23 is arranged on the reflux line 2. The image acquisition device 5 is arranged above the reflux port 122 and is used for acquiring real-time image information of the reflux port 122 region, that is, acquiring real-time image information of the reflux port 122 region and sending the real-time image information to the control device 6. The control device 6 is used for comparing the real-time image information with pre-stored reference image information and adjusting the opening degree of the reflux control valve 23 according to the comparison result, so as to adjust the flow rate of the electroplating solution 13 in the reflux line 2.

It should be understood that in the present embodiment, the image acquisition device 5 acquires real-time image information of the reflux port 122 region. In other embodiments of the present invention, the image acquisition device 5 may also acquire image information of the reflux port 122 region periodically, for example, acquire image information of the reflux port 122 region at intervals of 1 second or 2 seconds.

Referring to FIG. 3, which shows a schematic diagram of the process chamber in Embodiment 1 of the present invention, a mounting hole 15 is arranged in a region corresponding to the reflux port 122 of the process chamber 1. The image acquisition device 5 is mounted in the mounting hole 15 to acquire real-time image information of the reflux port 122 region. Exemplarily, the image acquisition device 5 may be a device capable of acquiring images, such as a video camera or a camera.

Since in an electroplating process, the process chamber 1 usually needs to be further used as a cleaning chamber after electroplating, as shown in FIG. 3, a water receiving edge 14 is arranged above the reaction tank 11. The water receiving edge 14 surrounds the inner wall of the process chamber 1 and extends from the inner wall of the process chamber 1 in an obliquely upward direction. When the process chamber 1 is used as the cleaning chamber after electroplating, a cleaning solution may be discharged out of the process chamber 1 along the water receiving edge 14.

Since the water receiving edge 14 is located between the image acquisition device 5 and the reflux port 122, the water receiving edge 14 is configured to be transparent to avoid affecting the acquisition, by the image acquisition device 5, of real-time image

information of the reflux port 122 region.

In the present embodiment, the control device 6 pre-stores reference image information. The reference image information includes a first form, a second form, and a third form of the electroplating solution 13 in the reflux port 122 region.

In an electroplating process, the image acquisition device 5 acquires real-time image information of the electroplating solution 13 in the reflux port 122 region and sends the real-time image information to the control device 6. The control device 6 compares the real-time image information with the first form, the second form, and the third form of the electroplating solution 13, respectively, and adjusts the opening degree of the reflux control valve 23 according to the correspondence shown in Table 1 on the basis of the comparison result. Exemplarily, the reflux control valve 23 may be an automatic ball valve.

Table 1

Comparison Result	Conform to First Form	Conform to Second Form	Conform to Third Form
Action of Reflux Control Valve	Maintain Current Opening Degree	Increase Opening Degree	Decrease Opening Degree

If the comparison result shows that the real-time image information of the electroplating solution 13 in the reflux port 122 region conforms to the first form, the current opening degree of the reflux control valve 23 is maintained; if the comparison result shows that the real-time image information of the electroplating solution 13 in the reflux port 122 region conforms to the second form, the opening degree of the reflux control valve 23 is increased; if the comparison result shows that the real-time image information of the electroplating solution 13 in the reflux port 122 region conforms to the third form, the opening degree of the reflux control valve 23 is decreased.

Through researches and experiments, the inventor finds that, compared with the

electroplating solution reflux system shown in FIG. 1, in an electroplating process, if the opening degree of the reflux control valve 23 is adjusted to keep a vortex appearing in the electroplating solution 13 in the reflux port 122 region, that is, the upper portion of the reflux port 122 is covered by the electroplating solution 13 and the electroplating solution 13 presents a vortex form, a large number of bubbles will not appear in the reflux line 2 or even no bubbles are present.

In addition, the vortex will appear in the electroplating solution 13 in the reflux port 122 region only when the volume of the electroplating solution 13 in the overflow tank 12 is within a certain range, that is, the vortex will not appear in the electroplating solution 13 in the reflux port 122 region when the electroplating solution 13 in the overflow tank 12 is excessive or insufficient. When the electroplating solution 13 in the overflow tank 12 is insufficient to cause no vortex to appear in the electroplating solution 13 in the reflux port 122 region, the electroplating solution 13 flows into the reflux line 2 along the periphery of the reflux port 122, the reflux port 122 is largely exposed to air, and air enters the reflux line 2 from the overflow tank 12 to form a large number of bubbles in the reflux line 2; when the electroplating solution 13 in the overflow tank 12 is excessive to cause no vortex to appear in the electroplating solution 13 in the reflux port 122 region, although air cannot enter the reflux line 2 from the overflow tank 12, the electroplating solution 13 in the overflow tank 12 may not flow into the solution storage tank 3 from the reflux line 2 in time and directly overflows from the top of the overflow tank 12 as shown by a dashed arrow in FIG. 2, resulting in potential safety hazards.

It should be noted that “no vortex appears” refers to a state where the electroplating solution 13 in the reflux port 122 region does not present a vortex form or the vortex form is not obvious, resulting from stable reflux of the electroplating solution 13.

Therefore, in the present embodiment, the first form includes a form in which a vortex appears in the electroplating solution 13 in the reflux port 122 region; the second form includes a form in which no vortex appears in the reflux port 122 region resulting from excessive electroplating solution 13 in the overflow tank 12; the third form includes a form in which no vortex appears in the reflux port 122 region resulting from insufficient electroplating solution 13 in the overflow tank 12.

Specifically, before an electroplating process is performed, an operator may perform a simulated electroplating process according to the steps of the electroplating process, so that the control device 6 pre-stores the reference image information.

Exemplary steps of pre-storing the reference image information by the control device 6 are given below.

First, the opening degree of the reflux control valve 23 is adjusted to 100%, so that the electroplating solution 13 circulates in the electroplating solution reflux control system.

Then, the opening degree of the reflux control valve 23 is decreased, so that the electroplating solution 13 in the overflow tank 12 is gradually accumulated. When a vortex appears in the reflux port 122 region, the image acquisition device 5 acquires first image information and sends the first image information to the control device 6, and the control device 6 stores the first image information as the first form.

The electroplating solution 13 in the overflow tank 12 is continuously accumulated until no vortex appears in the reflux port 122 region, the image acquisition device 5 acquires second image information and sends the second image information to the control device 6, and the control device 6 stores the second image information as the second form.

The opening degree of the reflux control valve 23 is increased, so that the electroplating solution 13 in the overflow tank 12 is gradually reduced until no vortex appears in the reflux port 122 region again. The image acquisition device 5 acquires third image information and sends the third image information to the control device 6, and the control device 6 stores the third image information as the third form.

In an electroplating process, the image acquisition device 5 acquires real-time image information of the reflux port 122 region and sends the real-time image information to the control device 6. The control device 6 compares the real-time image information with the pre-stored first, second, and third forms, respectively, and then controls the reflux control valve 23 to execute corresponding actions according to the correspondence shown in Table 1, so that a vortex always appears in the electroplating

solution 13 in the reflux port 122 region, thereby reducing or even eliminating the bubbles generated during the reflux of the electroplating solution in the electroplating process, and further improving the efficiency and process stability of the electroplating process.

It should be understood that in the present embodiment, the control device 6 may be a computer, and the first, second, and third image information sent by the image acquisition device 5 may be analyzed through a computer algorithm, for example, analyzed through an image binarization algorithm to obtain feature values of the first, second, and third image information, and the first, second, and third forms are correspondingly stored, respectively.

Similarly, the control device 6 may analyze the real-time image information sent by the image acquisition device 5 by using the same method to obtain a feature value of the real-time image information, compare the feature value of the real-time image information with the feature values of the first, second, and third image information, respectively, and set a similarity threshold. Exemplarily, the similarity threshold is set to 90%. If the similarity between the feature value of the real-time image information and one of the feature values of the first, second, and third image information, for example, the first image information, is greater than or equal to 90%, it may be determined that the real-time image information conforms to the first form. It should be understood that those skilled in the art may reasonably set the similarity threshold according to actual situations.

Optionally, since both the second form and the third form are forms in which no vortex appears, in order to avoid misjudgment of the control device 6 during comparison, as shown in FIG. 3, in the present embodiment, the electroplating solution reflux control system further comprises a reference color layer 16, and the reference color layer 16 is arranged on the bottom wall inside the overflow tank 12. Exemplarily, the reference color layer 16 may be a red coating. Under the condition that the volume of the electroplating solution 13 in the overflow tank 12 is different, images acquired from above the reflux port 122 region will present more obvious color depth differences, which can improve the accuracy of comparison.

Optionally, in other implementation manners of the present embodiment, to

improve the accuracy of comparison, each of the first, second, and third forms may also correspond to a plurality of pieces of image information. Taking the first form as an example, under the condition that a vortex appears in the reflux port 122 region, the image acquisition device 5 acquires a plurality of pieces of first image information and sends the plurality of pieces of first image information to the control device 6. The control device 6 analyzes the plurality of pieces of first image information to obtain a plurality of first image information feature values, and correspondingly stores the plurality of first image information feature values as the first form.

It should be understood that the above image information comparison method is merely exemplary, and in other implementation manners of the present embodiment, other known computer algorithms or other methods may also be adopted for image information comparison.

Optionally, in order to avoid possible safety risks, that is, the electroplating solution 13 in the overflow tank 12 is excessive and overflows out of the process chamber 1 from the top of the side wall of the overflow tank 12, and improve the reliability and safety of the electroplating solution reflux control system, as shown in FIG. 2, the electroplating solution reflux control system of the present embodiment further comprises an overflow line 4. An overflow port 124 is arranged in a predetermined height region of the side wall of the overflow tank 12, and the overflow line 4 is in communication with the overflow port 124 and the solution storage tank 3. When the electroplating solution 13 in the overflow tank 12 is excessive, the electroplating solution 13 fails to flow into the solution storage tank 3 from the reflux line 2 in time, and the electroplating solution 13 may flow into the solution storage tank 3 through the overflow port 124.

Optionally, at least for buffering the electroplating solution 13 in the reflux line 2 to a certain extent, as shown in FIG. 2, the reflux line 2 includes a liquid collection funnel 21 and a pipeline main body 22. The liquid collection funnel 21 includes a liquid collection pipe 211 at the top of the liquid collection funnel 21 and a liquid discharge port at a side wall or the bottom of the liquid collection funnel 21. The liquid collection pipe 211 is in communication with the reflux port 122, and the liquid discharge port is in communication with the upper end of the pipeline main body 22. In an electroplating apparatus having a plurality of process chambers 1, each liquid collection funnel 21

may have two liquid collection pipes 211, and at this time, the liquid collection funnel 21 is in communication with two process chambers 1 to serve as a common reflux region in the reflux systems of the two process chambers 1. It should be understood that in an initial state of an electroplating process, the opening degree of the reflux control valve 23 not only needs to be adjusted to make a vortex appear in the electroplating solution 13 in the reflux port 122 region, but also the liquid collection funnel 21 needs to be filled with the electroplating solution 13 to prevent air from entering the liquid collection funnel 21 in the electroplating process.

In the present embodiment, under the condition that the electroplating solution reflux control system works normally, the system automatically adjusts the opening degree of the reflux control valve 23, so that a vortex always appears in the electroplating solution 13 in the reflux port 122 region, thereby reducing or even eliminating the bubbles generated during the reflux of the electroplating solution in the electroplating process, and further improving the efficiency and process stability of the electroplating process.

Embodiment 2

Compared with Embodiment 1, the present embodiment is mainly different in that the reference image information corresponding to the first, second, and third forms in the present embodiment is different from the reference image information in Embodiment 1.

Through further researches and experiments, the inventor finds that in an electroplating solution reflux process, when a vortex appears in the electroplating solution 13 in the reflux port 122 region, different vortex forms also correspond to different bubble control results in the reflux line 2. When no bubbles are present in the reflux line 2, the vortex form of the electroplating solution 13 in the reflux port 122 region presents certain characteristics.

Exemplarily, differences among a first vortex form, a second vortex form, and a third vortex form may be represented by the size of the vortex. Since the vortex is approximately circular, the size of the vortex may be represented by the diameter of the vortex. As the volume of the electroplating solution 13 in the overflow tank 12

decreases, the size of the vortex correspondingly increases from small to large, that is, from the perspective of the vortex size, the third vortex form > the first vortex form > the second vortex form.

Therefore, in order to more effectively reduce or even eliminate the bubbles in the reflux line 2 during the reflux of the electroplating solution in the electroplating process, in the present embodiment, the first form includes a first vortex form of the electroplating solution 13 in the reflux port 122 region when no bubbles are present in the reflux line 2; the second form includes a second vortex form of the electroplating solution 13 in the reflux port 122 region when the electroplating solution 13 in the overflow tank 12 is greater than the electroplating solution 13 corresponding to the first vortex form; the third form includes a third vortex form of the electroplating solution 13 in the reflux port 122 region when the electroplating solution 13 in the overflow tank 12 is less than the electroplating solution 13 corresponding to the first vortex form.

Specifically, before an electroplating process is performed, an operator may perform a simulated electroplating process according to the steps of the electroplating process, so that the control device 6 pre-stores the reference image information.

Exemplary steps of pre-storing the reference image information by the control device 6 are given below.

First, the opening degree of the reflux control valve 23 is adjusted to 100%, so that the electroplating solution 13 circulates in the electroplating solution reflux control system. Then, the flow rate in the reflux line 2 is gradually decreased, so that the electroplating solution 13 in the overflow tank 12 is gradually accumulated until a vortex appears in the reflux port 122 region and no bubbles are present in the reflux line 2. The image acquisition device 5 acquires the first vortex form and sends the first vortex form to the control device 6, and the control device 6 stores the first vortex form as the first form. Wherein, a bubble detection device may be adopted to determine whether bubbles are present in the reflux line 2. Details will be described later.

The electroplating solution 13 in the overflow tank 12 is continuously accumulated until the electroplating solution 13 in the reflux port 122 region presents

a vortex form different from the first vortex form. The image acquisition device 5 acquires the second vortex form and sends the second vortex form to the control device 6, and the control device 6 stores the second vortex form as the second form.

The opening degree of the reflux control valve 23 is increased, so that the electroplating solution 13 in the overflow tank 12 is gradually reduced. After the electroplating solution 13 in the reflux port 122 region presents the first vortex form again, the electroplating solution 13 in the overflow tank 12 is continuously reduced until the electroplating solution 13 in the reflux port 122 region presents a vortex form different from the first vortex form and the second vortex form, the image acquisition device 5 acquires the third vortex form and sends the third vortex form to the control device 6, and the control device 6 stores the third vortex form as the third form.

In an electroplating process, the image acquisition device 5 acquires real-time image information of the reflux port 122 region and sends the real-time image information to the control device 6. The control device 6 compares the real-time image information with the pre-stored first, second, and third forms, respectively, and then controls the reflux control valve 23 to perform corresponding actions according to the correspondence shown in Table 1.

Referring to FIG. 5, which shows a schematic diagram of the correspondence between different electroplating solution 13 volumes in the overflow tank 12 and the form of the electroplating solution 13 in the reflux port 122 region, wherein A represents the first vortex form in Embodiment 2, A2 represents the second vortex form in Embodiment 2, A3 represents the third vortex form in Embodiment 2, B2 represents that no vortex appears in the reflux port 122 region resulting from excessive electroplating solution 13 in the overflow tank 12, corresponding to the second form in Embodiment 1; B3 represents that no vortex appears in the reflux port 122 region resulting from insufficient electroplating solution 13 in the overflow tank 12, corresponding to the third form in Embodiment 1.

As shown in FIG. 5, compared with Embodiment 1, in the present embodiment, the adjustment of the flow rate in the reflux line 2 is more accurate and sensitive.

In Embodiment 1, under the condition that the electroplating solution reflux

control system works normally, the system automatically adjusts the flow rate in the reflux line 2, so that the volume of the electroplating solution 13 in the overflow tank 12 is between B3 and B2, and a vortex always appears in the electroplating solution 13 in the reflux port 122 region. In Embodiment 2, under the condition that the electroplating solution reflux control system works normally, in an initial state of an electroplating process, the flow rate in the reflux line 2 is adjusted, so that a vortex appears in the electroplating solution 13 in the reflux port 122 region until the vortex form in the region conforms to the first vortex form. Then, provided that the vortex form in the region changes and deviates from the first vortex form, the control device 6 adjusts the opening degree of the reflux control valve 23, so that the volume of the electroplating solution 13 in the overflow tank 12 is between A3 and A2 until the first vortex form appears. Thus, not only can a vortex always appear in the electroplating solution 13 in the reflux port 122 region, but also the appearing vortex form fluctuates between the second vortex form and the third vortex form, and is maintained at the first vortex form as much as possible.

Optionally, in another implementation manner of the present embodiment, the image information corresponding to the second and third forms may be further expanded.

Specifically, taking the second form as an example, in addition to corresponding to the second vortex form, second image information that no vortex appears in the reflux port 122 region resulting from excessive electroplating solution 13 in the overflow tank 12 may also be stored as the second form in the present embodiment, that is, the second form further includes a form that no vortex appears in the reflux port 122 region resulting from excessive electroplating solution 13 in the overflow tank 12. Similarly, in addition to corresponding to the third vortex form, third image information that no vortex appears in the reflux port 122 region resulting from insufficient electroplating solution 13 in the overflow tank 12 may also be stored as the third form in the present embodiment, that is, the third form further includes a form that no vortex appears in the reflux port 122 region resulting from insufficient electroplating solution 13 in the overflow tank 12. Thus, under the condition that the electroplating solution reflux control system works normally, in an initial state of an electroplating process, a vortex always appears in the electroplating solution 13 in the

reflux port 122 region, and the opening degree of the reflux control valve 23 can be automatically adjusted until the first vortex form appears.

Optionally, as shown in FIG. 4, the electroplating solution reflux control system of the present embodiment further comprises a bubble detection device 24. The bubble detection device 24 is arranged between the reflux port 122 and the reflux control valve 23, and is used for detecting whether bubbles are present in the electroplating solution 13 flowing through the bubble detection device 24 and feeding the detection result back to the control device 6. The control device 6 is further configured to increase the opening degree of the reflux control valve 23 when no vortex appears in the electroplating solution 13 in the reflux port 122 region and the detection result shows that no bubbles are present; decrease the opening degree of the reflux control valve 23 when no vortex appears in the electroplating solution 13 in the reflux port 122 region and the detection result shows that bubbles are present. Thus, even in an initial state of an electroplating process, the system can automatically adjust the opening degree of the reflux control valve 23, so that a vortex always appears in the electroplating solution 13 in the reflux port 122 region, and the opening degree of the reflux control valve 23 can be automatically adjusted until the first vortex form appears.

It should be understood that the bubble detection device 24 may also be used for bubble detection when reference information is stored, for example, in the step of storing the first vortex form as described above.

Optionally, in other implementation manners of the present embodiment, to improve the accuracy of comparison, each of the first, second, and third forms may also correspond to a plurality of vortex forms. Taking the first form as an example, under the condition that no bubbles are present in the reflux line 2, the image acquisition device 5 acquires a plurality of first vortex forms and sends the plurality of first vortex forms to the control device 6, and the control device 6 stores the plurality of first vortex forms as the first form. For example, the control device 6 analyzes the plurality of first vortex forms to obtain a plurality of first vortex form feature values, and correspondingly stores the plurality of first vortex form feature values as the first form.

In the present embodiment, under the condition that the electroplating solution

reflux control system works normally, the system automatically adjusts the opening degree of the reflux control valve 23, so that a vortex always appears in the electroplating solution 13 in the reflux port 122 region, and the opening degree of the reflux control valve 23 can be automatically adjusted until the first vortex form appears, thereby more effectively reducing or even eliminating the bubbles generated during the reflux of the electroplating solution in the electroplating process, and further improving the efficiency and process stability of the electroplating process.

Embodiment 3

Compared with Embodiment 1 and Embodiment 2, the present embodiment is mainly different in that the image information acquired by the image acquisition device 5 and stored reference image information in the present embodiment are different from the acquired image information and the stored reference image information in Embodiment 1 and Embodiment 2.

Through further researches and experiments, the inventor finds that in an electroplating solution reflux process in an electroplating process, in addition to the different forms of the electroplating solution 13 in the reflux port 122 region correspond to different bubble control results in the reflux line 2, color information in image information inside the overflow tank 12 also has a correspondence with the bubble control result in the reflux line 2.

Therefore, in the present embodiment, color depth information in image information inside the overflow tank 12 is used as reference image information. The image acquisition device 5 is arranged above the overflow tank 12 and is used for acquiring image information inside the overflow tank 12 and sending the acquired image information to the control device 6, without being required to make the image acquisition device 5 correspond to the position of the reflux port 122 as in Embodiment 1 and Embodiment 2.

The electroplating solution 13 contains metal cations and various additives, and is usually a colored transparent liquid. In the overflow tank 12, different volumes of the electroplating solution 13 present different color depths. Moreover, the larger the volume of the electroplating solution in the overflow tank 12, the darker the color

presented. Therefore, the correspondence between the volume of the electroplating solution 13 in the overflow tank 12 and the color depth can be established, and the opening degree of the reflux control valve 23 is adjusted in real time or periodically according to the correspondence, so that the volume of the electroplating solution 13 in the overflow tank 12 is maintained within a relatively stable range, an improved liquid sealing effect on the overflow tank 12 is maintained, the bubbles generated during the reflux of the electroplating solution in the electroplating process are further reduced or even eliminated, and the efficiency and process stability of the electroplating process are further improved.

In the present embodiment, the control device 6 is configured to compare the acquired image information inside the overflow tank 12 with pre-stored color depth information, wherein the color depth information includes a first color depth. The correspondence between the comparison result and an action performed by the reflux control valve 23 is shown in Table 2:

Table 2

Comparison Result	Conform to First Color Depth	Greater than First Color Depth	Less than First Color Depth
Action of Reflux Control Valve	Maintain Current Opening Degree	Increase Opening Degree	Decrease Opening Degree

If the comparison result shows that the image information inside the overflow tank 12 conforms to the first color depth, the current opening degree of the reflux control valve 23 is maintained; if the comparison result shows that the color depth in the image information inside the overflow tank 12 is greater than the first color depth, the opening degree of the reflux control valve 23 is increased; if the comparison result shows that the color depth in the image information inside the overflow tank 12 is less than the first color depth, the opening degree of the reflux control valve 23 is decreased.

Specifically, before an electroplating process is performed, an operator may

perform a simulated electroplating process according to the steps of the electroplating process, so that the control device 6 pre-stores the color depth information.

Exemplary steps of pre-storing the reference image information by the control device 6 in the present embodiment are given below.

First, the opening degree of the reflux control valve 23 is adjusted to 100%, so that the electroplating solution 13 circulates in the electroplating solution reflux control system. Then, the opening degree of the reflux control valve 23 is gradually decreased, so that the electroplating solution 13 in the overflow tank 12 is gradually accumulated until a preset volume of the electroplating solution is reached, for example, 5 L. When the volume of the electroplating solution 13 in the overflow tank 12 reaches the preset volume of the electroplating solution, the electroplating solution 13 can perform an improved liquid sealing function on the overflow tank 12, and air is prevented from being mixed into the reflux line 2 to form bubbles. The image acquisition device 5 acquires image information corresponding to the preset volume of the electroplating solution and sends the image information to the control device 6. The control device 6 analyzes the image information to obtain a color depth feature value of the image information, and stores the color depth feature value as the first color depth.

For example, the control device 6 (for example, a computer) analyzes the image information through a computer algorithm to obtain a gray value corresponding to the image information. The smaller the gray value, the darker the color of the image at this time. Exemplarily, the computer correspondingly stores the gray value of the image when the volume of the electroplating solution 13 in the overflow tank 12 reaches the preset volume of the electroplating solution as the first color depth. Thus, when the process chamber 1 performs a process, the control device 6 analyzes the image information acquired from the image acquisition device 5 to obtain a corresponding gray value, compares the gray value with the gray value corresponding to the first color depth, and then controls the reflux control valve 23 to perform a corresponding action according to the correspondence shown in Table 2.

It should be understood that in the present embodiment, the preset volume of the electroplating solution should satisfy that the overflow tank 12 can be liquid-sealed and the electroplating solution 13 is guaranteed not to exceed the upper limit height of

the overflow tank 12. The upper limit height is manually preset or automatically set by the system, and refers to a limit height that may cause the electroplating solution 13 to overflow out of the process chamber 1 from the top of the overflow tank 12, or a height of the overflow port 124 in a system having the overflow line 4.

Optionally, in other implementation manners of the present embodiment, to improve the accuracy and fault tolerance of comparison, a volume range of the electroplating solution may be preset, for example, 5 L to 7 L. When the electroplating solution 13 is within the preset volume range of the electroplating solution, an improved liquid sealing function can be performed on the overflow tank 12, and air is prevented from being mixed into the reflux line 2 to form bubbles. The image acquisition device 5 acquires a plurality of pieces of image information corresponding to the preset volume range of the electroplating solution, for example, acquires one piece of image information corresponding to every 100 milliliters (mL), and sends the plurality of pieces of image information to the control device 6. The control device 6 analyzes the plurality of pieces of image information to obtain a plurality of color depth feature values of the plurality of pieces of image information, and stores the plurality of color depth feature values as the first color depth.

In an electroplating process, the image acquisition device 5 acquires real-time image information inside the overflow tank 12 and sends the real-time image information to the control device 6. The control device 6 compares the color depth feature value of the real-time image information with the pre-stored first color depth, and then controls the reflux control valve 23 to perform corresponding actions according to the correspondence shown in Table 2, so as to automatically adjust the opening degree of the reflux control valve 23, thereby automatically adjusting the volume of the electroplating solution 13 in the overflow tank 12 to be maintained at the preset volume (or volume range) of the electroplating solution or fluctuate around the preset volume (or volume range) of the electroplating solution, maintaining an improved liquid sealing effect on the overflow tank 12, further reducing or even eliminating the bubbles generated during the reflux of the electroplating solution in the electroplating process, and further improving the efficiency and process stability of the electroplating process.

Optionally, in the present embodiment, a reference color device is further

comprised, and the reference color device is used for providing a reference color for the image information inside the overflow tank acquired by the image acquisition device. Exemplarily, as shown in FIG. 3, the reference color device includes a reference color layer 16, and the reference color layer 16 is arranged on the bottom wall inside the overflow tank 12. Thus, color depth differences presented by the electroplating solution 13 at different volumes of the electroplating solution can be increased, and relatively accurate color depth feature values can be extracted even if the color of the electroplating solution 13 is light.

Embodiment 4

The present embodiment provides an electroplating solution reflux control method applied to the electroplating solution reflux control system in Embodiment 1, comprising the following steps:

S1, starting the process in the process chamber 1, allowing the electroplating solution 13 to overflow from the reaction tank 11 to the overflow tank 12, and then to flow into the solution storage tank 3 through the reflux line 2;

S2, the image acquisition device 5 acquiring image information of the reflux port 122 region, and sending the image information to the control device 6;

S3, the control device 6 comparing the image information with pre-stored reference image information;

S4, the control device 6 adjusting the opening degree of the reflux control valve 23 according to the comparison result.

Further, in the present embodiment, the reference image information includes a first form, a second form, and a third form of the electroplating solution in the reflux port 122 region.

Step S3 includes: the control device 6 comparing the image information with the first form, the second form, and the third form, respectively.

Step S4 includes:

S41, if the control device 6 determines that the image information conforms to the first form according to the comparison result, maintaining the current opening degree of the reflux control valve 23;

S42, if the control device 6 determines that the image information conforms to the second form according to the comparison result, increasing the opening degree of the reflux control valve 23;

S43, if the control device 6 determines that the image information conforms to the third form according to the comparison result, decreasing the opening degree of the reflux control valve 23.

Optionally, before step S1, the method further comprises the control device 6 pre-storing the reference image information. Exemplary steps of pre-storing the reference image information by the control device 6 comprise:

S140, adjusting the opening degree of the reflux control valve 23 to 100%, so that the electroplating solution 13 circulates in the electroplating solution reflux control system;

S141, decreasing the opening degree of the reflux control valve 23, so that the electroplating solution 13 in the overflow tank 12 is gradually accumulated, when a vortex appears in the reflux port 122 region, the image acquisition device 5 acquiring first image information and sending the first image information to the control device 6, and the control device 6 storing the first image information as the first form;

S142, continuously accumulating the electroplating solution 13 in the overflow tank 12 until no vortex appears in the reflux port 122 region, the image acquisition device 5 acquiring second image information and sending the second image information to the control device 6, and the control device 6 storing the second image information as the second form;

S143, increasing the opening degree of the reflux control valve 23, so that the electroplating solution 13 in the overflow tank 12 is gradually reduced until no vortex appears in the reflux port 122 region again, the image acquisition device 5 acquiring third image information and sending the third image information to the control device

6, and the control device 6 storing the third image information as the third form.

Optionally, in other implementation manners of the present embodiment, to improve the accuracy of comparison, each of the first, second, and third forms may also correspond to a plurality of pieces of image information. Taking the first form as an example, under the condition that a vortex appears in the reflux port 122 region, the image acquisition device 5 is controlled to acquire a plurality of pieces of first image information, the plurality of pieces of first image information are analyzed to obtain a plurality of first image information feature values, and the plurality of first image information feature values are correspondingly stored as the first form.

Embodiment 5

The present embodiment provides an electroplating solution reflux control method applied to the electroplating solution reflux control system in Embodiment 2. Compared with Embodiment 4, the present embodiment is mainly different in that the reference image information corresponding to the first, second, and third forms in the present embodiment is different from the reference image information in Embodiment 4. The same parts of the present embodiment as the same parts of Embodiment 4 are not described herein again, and only the differences between the present embodiment and Embodiment 4 are described below.

Optionally, in the present embodiment, before step S1, the method further comprises the control device 6 pre-storing the reference image information. Exemplary steps of pre-storing the reference image information by the control device 6 comprise:

S150, adjusting the opening degree of the reflux control valve 23 to 100%, so that the electroplating solution 13 circulates in the electroplating solution reflux control system;

S151, decreasing the opening degree of the reflux control valve 23, so that the electroplating solution 13 in the overflow tank 12 is gradually accumulated until a vortex appears in the reflux port 122 region and no bubbles are present in the reflux line 2, the image acquisition device 5 acquiring a first vortex form and sending the first vortex form to the control device 6, and the control device 6 storing the first vortex

form as the first form;

S152, continuously accumulating the electroplating solution 13 in the overflow tank 12 until the electroplating solution 13 in the reflux port 122 region presents a vortex form different from the first vortex form, the image acquisition device 5 acquiring a second vortex form and sending the second vortex form to the control device 6, and the control device 6 storing the second vortex form as the second form;

S153, increasing the opening degree of the reflux control valve 23, so that the electroplating solution 13 in the overflow tank 12 is gradually reduced, after the electroplating solution 13 in the reflux port 122 region presents the first vortex form again, continuously reducing the electroplating solution 13 in the overflow tank 12 until the electroplating solution 13 in the reflux port 122 region presents a vortex form different from the first vortex form and the second vortex form, the image acquisition device 5 acquiring a third vortex form and sending the third vortex form to the control device 6, and the control device 6 storing the third vortex form as the third form.

Optionally, in another implementation manner of the present embodiment, the image information corresponding to the second and third forms may be further expanded. The second form further includes a form that no vortex appears in the reflux port 122 region resulting from excessive electroplating solution 13 in the overflow tank 12, that is, the second form may further include second image information; and the third form further includes a form that no vortex appears in the reflux port 122 region resulting from insufficient electroplating solution 13 in the overflow tank 12, that is, the third form may further include third image information.

Thus, under the condition that the electroplating solution reflux control system works normally, in an initial state of an electroplating process, the system can automatically adjust the opening degree of the reflux control valve 23, so that a vortex always appears in the electroplating solution 13 in the reflux port 122 region, and the opening degree of the reflux control valve 23 can be automatically adjusted until the first vortex form appears.

Optionally, in the method of the present embodiment, after step S2, the method further comprises:

S21, performing step S3 if the control device 6 determines that a vortex appears in the image information of the reflux port region; performing step S22 if the control device 6 determines that no vortex appears in the image information of the reflux port region;

S22, detecting whether bubbles are present in the electroplating solution 13 in the reflux line 2 between the reflux port and the reflux control valve 23, and the control device 6 acquiring detection information; if the detection information shows that no bubbles are present, increasing the opening degree of the reflux control valve 23 and returning to step S21; if the detection result shows that bubbles are present, decreasing the opening degree of the reflux control valve 23 and returning to step S21.

Thus, even in an initial state of an electroplating process, the system can automatically adjust the flow rate in the reflux line 2, so that a vortex always appears in the electroplating solution 13 in the reflux port 122 region, and the opening degree of the reflux control valve 23 can be automatically adjusted until the first vortex form appears.

Optionally, in other implementation manners of the present embodiment, to improve the accuracy of comparison, each of the first, second, and third forms may also correspond to a plurality of pieces of image information. Taking the first form as an example, the flow rate in the reflux line 2 is gradually decreased, so that the electroplating solution 13 in the overflow tank 12 is gradually accumulated until a vortex appears in the reflux port 122 region and no bubbles are present in the reflux line 2. The image acquisition device 5 is controlled to acquire a plurality of first vortex forms, and the control device 6 stores the plurality of first vortex forms as the first form. For example, the control device 6 analyzes the plurality of first vortex forms to obtain a plurality of first vortex form feature values, and correspondingly stores the plurality of first vortex form feature values as the first form.

Embodiment 6

The present embodiment provides an electroplating solution reflux control method applied to the electroplating solution reflux control system in Embodiment 3. Compared with Embodiment 4 and Embodiment 5, the present embodiment is mainly

different in that the image information acquired by the image acquisition device 5 and stored reference image information in the present embodiment are different from the acquired image information and the stored reference image information in Embodiment 4 and Embodiment 5.

The electroplating solution reflux control method of the present embodiment comprises:

S10, starting a process in a process chamber 1, allowing an electroplating solution 13 to overflow from a reaction tank 11 to an overflow tank 12, and then to flow into a solution storage tank 3 through a reflux line 2;

S20, an image acquisition device 5 acquiring image information inside the overflow tank 12 and sending the image information to a control device 6;

S30, the control device 6 comparing the image information with pre-stored reference image information;

S40, the control device 6 adjusting the opening degree of a reflux control valve 23 according to the comparison result.

Further, in the present embodiment, the reference image information includes a first color depth of the image information inside the overflow tank 12;

Step S30 includes: the control device 6 comparing the color depth of the image information with the first color depth.

Step S40 includes:

S401, if the comparison result shows that the color depth of the image information conforms to the first color depth, maintaining the current opening degree of the reflux control valve 23;

S402, if the comparison result shows that the color depth of the image information is greater than the first color depth, increasing the opening degree of the reflux control valve 23;

S403, if the comparison result shows that the color depth of the image information is less than the first color depth, decreasing the opening degree of the reflux control valve 23.

Optionally, before step 10, the method further comprises the control device 6 pre-storing the reference image information. Exemplary steps of pre-storing the reference image information by the control device 6 comprise:

S1060, adjusting the opening degree of the reflux control valve 23 to 100%, so that the electroplating solution 13 circulates in the electroplating solution reflux control system;

S1061, decreasing the opening degree of the reflux control valve 23, so that the electroplating solution 13 in the overflow tank 12 is gradually accumulated;

S1062, when the volume of the electroplating solution 13 in the overflow tank 12 reaches a preset volume of the electroplating solution, the image acquisition device 5 acquiring image information corresponding to the preset volume of the electroplating solution and sending the image information to the control device 6, the control device 6 analyzing the image information to obtain a color depth feature value of the image information, and storing the color depth feature value as the first color depth.

Optionally, in other implementation manners of the present embodiment, to improve the accuracy and fault tolerance of comparison, step S1062 may also be: when the electroplating solution 13 in the overflow tank 12 reaches a preset volume range of the electroplating solution, the image acquisition device 5 acquiring a plurality of pieces of image information corresponding to the preset volume range of the electroplating solution, for example, acquiring one piece of image information corresponding to every 100 milliliters (mL), and sending the plurality of pieces of image information to the control device 6, the control device 6 analyzing the plurality of pieces of image information to obtain a plurality of color depth feature values of the plurality of pieces of image information, and storing the plurality of color depth feature values as the first color depth.

The above embodiments merely illustrate the principles and effects of the present

invention by way of example, and are not intended to limit the present invention. Anyone skilled in the art can modify or change the above embodiments without departing from the spirit and scope of the present invention. Therefore, all equivalent modifications or changes made by those having ordinary skill in the art without departing from the spirit and technical ideas disclosed by the present invention shall be covered by the claims of the present invention.