CONTROL SYSTEM FOR BUBBLES IN LIQUID FILM, WAFER CLEANING APPARATUS, AND WAFER CLEANING METHOD

FIELD OF THE INVENTION

The present application relates to the field of integrated circuit manufacturing, and in particular, to a control system for bubbles in a liquid film, a wafer cleaning apparatus, and a wafer cleaning method.

BACKGROUND

With the rapid development of the integrated circuit industry, higher requirements are put forward for the operating speed and performance of integrated circuits. At present, the feature size of integrated circuit chips is designed to be smaller and smaller, and the aspect ratio is getting larger and larger. Meanwhile, the challenges faced in various processes are becoming increasingly severe. According to statistics, more than half of the yield loss in semiconductor manufacturing is caused by micro-contamination. Therefore, wafer cleaning is a key step in integrated circuit manufacturing. With the continuous reduction of the feature size on a wafer, not only is the number of cleaning steps increasing, but also more stringent requirements are imposed on the tolerable size and quantity of particles on the wafer surface.

To solve such problems, ultrasonic or megasonic cleaning technologies have emerged as the times require. Ultrasonic or megasonic equipment generates bubble cavitation oscillation during the wafer cleaning process, which can effectively remove fine impurity particles. At present, the use of megasonic energy to remove particles and other contaminants during the wafer cleaning process has been widely adopted. Megasonic waves generate bubbles during the wafer cleaning process, and the expansion-contraction oscillation of the bubbles helps to remove particles on the wafer surface to a certain extent. However, the expansion-contraction oscillation of the bubbles may also cause the "cavitation effect" of the bubbles, thereby leading to the collapse and damage of the patterned structure on the wafer during processing. Moreover, with the reduction of the feature size on the wafer, the influence of the "cavitation effect" will become greater.

SUMMARY

Embodiments of the present application provide a control system for bubbles in a liquid film, a wafer cleaning apparatus, and a wafer cleaning method, so as to at least solve the problem in the prior art where the "cavitation effect" of bubbles caused by the expansion-contraction oscillation of the bubbles leads to the collapse and damage of the patterned structure on the wafer during processing.

In a first aspect, an embodiment of the present application provides a control system for regulating bubbles in a liquid film on a wafer when a megasonic generator cleans the wafer, comprising:

a megasonic generator, configured to transmit acoustic energy to the liquid film on the wafer to clean the wafer;

a sampler, configured to obtain liquid in the liquid film on the wafer during the period when the megasonic generator cleans the wafer;

a bubble detection module, connected to the sampler and configured to perform bubble detection on the liquid obtained by the sampler to determine the bubble parameter in the liquid;

a controller, connected to the bubble detection module and configured to adjust the operating parameter of the megasonic generator according to the bubble parameter, so that the bubble parameter falls within a preset range.

In some embodiments, the control system further includes a mounting assembly, the mounting assembly includes a mounting plate and at least one fixing member, the mounting plate is connected to the megasonic generator, the fixing member is fixed to the mounting plate, and the fixing member is configured to fix the sampler.

In some embodiments, a plurality of first fixing holes are arranged on the mounting plate, and protrusions configured to mate with the first fixing holes are arranged on the fixing member, the protrusions mate with the first fixing holes to fix the fixing member.

In some embodiments, at least one second fixing hole is arranged on the fixing member, and the sampler is installed in the second fixing hole and configured to obtain the liquid from the liquid film during wafer cleaning.

In some embodiments, the control system further includes a liquid pump, the liquid pump is arranged between the bubble detection module and the sampler, and the liquid pump is configured to provide power for the sampler to obtain the liquid from the liquid film during wafer cleaning.

In some embodiments, the bubble parameter includes bubble size and/or bubble concentration.

In some embodiments, the operating parameter of the megasonic generator includes power, power-on duty cycle, and pulse period.

In a second aspect, an embodiment of the present application further provides a wafer cleaning apparatus, comprising the control system as described in the first aspect.

In a third aspect, an embodiment of the present application further provides a wafer cleaning method, comprising:

applying a cleaning liquid onto a wafer and forming a liquid film on the wafer;

using a megasonic generator to transmit acoustic energy to the liquid film on the wafer to clean the wafer;

obtaining the liquid from the liquid film on the wafer during the period when the megasonic generator cleans the wafer;

performing bubble detection on the obtained liquid to determine the bubble parameter in the liquid;

adjusting the operating parameter of the megasonic generator according to the bubble parameter, so that the bubble parameter falls within a preset range.

In summary, the control system for bubbles in the liquid film, the wafer cleaning

apparatus, and the wafer cleaning method provided by the embodiments of the present application realize the control and adjustment of the bubble parameter by means of applying a cleaning liquid onto a wafer and forming a liquid film on the wafer; using a megasonic generator to transmit acoustic energy to the liquid film on the wafer to clean the wafer; obtaining the liquid from the liquid film on the wafer during the period when the megasonic generator cleans the wafer; performing bubble detection on the obtained liquid to determine the bubble parameter in the liquid; and adjusting the operating parameter of the megasonic generator according to the bubble parameter, so that the bubble parameter falls within a preset range. The present application solves the problem in the prior art where the "cavitation effect" of bubbles caused by the expansion-contraction oscillation of the bubbles leads to the collapse and damage of the patterned structure on the wafer during processing, thereby improving the wafer production yield.

The details of one or more embodiments of the present application are set forth in the accompanying drawings and the description below to make other features, objects, and advantages of the present application more concise and understandable.

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.

The accompanying drawings described herein are used to provide a further understanding of the present application and form a part of the present application. The illustrative embodiments of the present application and the descriptions of the embodiments are used to explain the present application and do not constitute an improper limitation of the present application. In the accompanying drawings:

FIG. 1 is a schematic structure diagram of a control system for bubbles in a liquid film according to an embodiment of the present application;

FIG. 2 is a schematic structure diagram of a control system for bubbles in a liquid film according to another embodiment of the present application;

FIG. 3 is a partial schematic structure diagram of a control system for bubbles in a liquid film according to an embodiment of the present application;

FIG. 4 is a schematic structure diagram of a wafer cleaning apparatus according to an embodiment of the present application;

FIG. 5 is a flow chart of a wafer cleaning method according to an embodiment of the present application.

EMBODIMENTS OF THE INVENTION

To further clarify the objects, technical solutions, and advantages of the present application, the present application is described and illustrated below in conjunction with the accompanying drawings and embodiments. It should be understood that the specific embodiments described herein are only used to explain the present application and are not intended to limit the present application. Based on the embodiments provided in the present application, all other embodiments obtained by those of ordinary skill in the art without making creative efforts shall fall within the protection scope of the present application. In addition, it can be understood that although the efforts made in such a development process may be complex and time-consuming, for those of ordinary skill in the art related to the content disclosed in the present application, some variations in design, manufacturing, or production made on the basis of the technical content disclosed in the present application are merely conventional technical means, and shall not be construed as insufficient disclosure of the present application.

Unless otherwise defined, the technical or scientific terms involved in the present application shall have the ordinary meanings understood by those with general skills in the technical field to which the present application belongs. The similar words such as "a," "an," "one kind of," and "the" involved in the present application do not indicate a quantity limitation, and may indicate a singular form or a plural form. The terms "include," "comprise," "have" and any variations thereof involved in the present application are intended to cover non-exclusive inclusion; for example, a process, method, system, product, or apparatus including a series of steps or modules (units) is not limited to the listed steps or units, but may also include unlisted steps or units, or

may also include other steps or units inherent to these processes, methods, products, or apparatuses. The similar words such as "connect," "interconnect," and "couple" involved in the present application are not limited to physical or mechanical connections, but may include electrical connections, whether direct or indirect. The term "a plurality of" involved in the present application refers to two or more. The term "and/or" describes the association relationship of associated objects, indicating that three relationships may exist, for example, "A and/or B" may indicate: A exists alone, both A and B exist, and B exists alone. The terms "first," "second," "third," and the like involved in the present application are only used to distinguish similar objects and do not represent a specific ordering of the objects.

As shown in FIG. 1, an embodiment of the present application proposes a control system for bubbles in a liquid film, which can be applied to a wafer cleaning apparatus, and the structure of the control system for bubbles in the liquid film will be described later. FIG. 4 shows a wafer cleaning apparatus comprising the control system for bubbles in the liquid film. As shown in FIG. 4, the wafer cleaning apparatus comprises a control system 4 for bubbles in a liquid film, a mechanical arm 2, a wafer carrying and rotating assembly 1, a spray head 7, and a chamber 10. The control system 4 for bubbles in the liquid film includes a megasonic generator 43, and the megasonic generator 43 is arranged on the mechanical arm 2. The control system 4 for bubbles in the liquid film is configured to detect the bubble parameter in a liquid film 5 on the surface of a wafer 6 during the period when the megasonic generator 43 cleans the wafer, and adjust the operating parameter of the megasonic generator 43 according to the bubble parameter, so that the bubble parameter in the liquid film 5 falls within a preset range. The wafer carrying and rotating assembly 1 is arranged inside the chamber 10 and configured to carry the wafer 6 and drive the wafer 6 to rotate.

It should be noted that the liquid film 5 is formed by spraying a cleaning liquid onto the wafer 6 through the spray head 7 during the cleaning of the wafer 6.

When the wafer 6 is cleaned by using the wafer cleaning apparatus of the present application, the wafer carrying and rotating assembly 1 holds the wafer 6 and drives the wafer 6 to rotate at a set rotational speed, the spray head 7 sprays the cleaning liquid onto the wafer 6 to form the liquid film 5 on the wafer 6, the mechanical arm 2 is driven by a driving device (not shown) to drive the megasonic generator 43 to rotate above

the wafer 6 and transmit acoustic energy to the wafer 6 through the liquid film 5 to clean the wafer 6, and the control system 4 for bubbles in the liquid film detects the bubble parameter in the liquid film 5 on the surface of the wafer 6 in real time during the period when the megasonic generator 43 cleans the wafer 6, and adjusts the operating parameter of the megasonic generator 43 according to the bubble parameter, so that the bubble parameter in the liquid film 5 falls within a preset range.

The present application realizes the adjustment of the bubble parameter in the liquid film 5 by arranging the control system 4 for bubbles in the liquid film to detect the bubble parameter in the liquid film 5 on the wafer 6 in real time during the cleaning of the wafer 6 and adjusting the operating parameter of the megasonic generator 43 according to the bubble parameter, so that the bubble parameter in the liquid film 5 falls within a preset range, prevents the "cavitation effect" caused by excessively large bubbles, solves the problem in the prior art where the "cavitation effect" of bubbles caused by the expansion-contraction oscillation of the bubbles leads to the collapse and damage of the patterned structure on the wafer, thereby improving the wafer production yield.

It should be noted that the bubble "cavitation effect" refers to a dynamic process in which micro-gas-nucleus cavitation bubbles existing in a liquid oscillate under the action of acoustic waves, and grow and collapse when the acoustic pressure reaches a certain value.

The bubble parameter in the embodiments of the present application may be bubble size and/or bubble concentration. In this embodiment, when the bubble size is constant, the higher the bubble concentration, the greater the probability of the cavitation effect occurring in the bubbles; when the bubble concentration is constant, the larger the bubble size, the greater the probability of the cavitation effect occurring in the bubbles. Therefore, in the present application, by detecting the bubble size and/or bubble concentration and adjusting the operating parameter of the megasonic generator 43 according to the detected bubble size and/or bubble concentration, the bubble size and/or bubble concentration are all within the preset range, so as to avoid the "cavitation effect" of the bubbles, solve the problem in the prior art where the "cavitation effect" of bubbles caused by the expansion-contraction oscillation of the bubbles leads to the damage of the patterned structure on the wafer, thereby improving

the wafer production yield.

It should be noted that corresponding preset ranges are set for both the bubble size and the bubble concentration in the embodiments of the present application.

The operating parameter of the megasonic generator 43 in the embodiments of the present application may include, but are not limited to, the power, power-on duty cycle, and pulse period of the megasonic generator 43. For example, when it is detected that the bubble size or bubble concentration exceeds the preset range, the bubble size or bubble concentration can be made within the preset range by one or more of the ways of reducing the power of the megasonic generator 43, increasing the duty cycle, and reducing the pulse period.

In some embodiments, the megasonic generator 43 may be installed on the mechanical arm 2 through a mounting frame (not shown), and other components of the control system 4 for bubbles in the liquid film may also be installed on the mounting frame, so that the mechanical arm 2 can control the bottom of the sampler 42 and the bottom of the megasonic generator 43 in the control system 4 for bubbles in the liquid film to be at the same horizontal height at the same time, which facilitates the sampler 42 to obtain the liquid from the liquid film 5. In these embodiments, since the other components of the control system 4 for bubbles in the liquid film and the megasonic generator 43 are all installed on the mechanical arm 2, the other components of the control system 4 for bubbles in the liquid film and the megasonic generator 43 may not have a direct connection relationship, and may be either in contact with each other or separated.

It should be noted that the mounting frame in this embodiment is not equivalent to a mounting assembly 41, the mounting frame is used to fix the megasonic generator 43 to the mechanical arm 2, and the mounting assembly 41 is used to install the sampler 42 in the control system 4 for bubbles in the liquid film, for example, the sampler 42 may be installed on the mounting frame through the mounting assembly 41.

With continued reference to FIG. 1, an embodiment of the present application provides a control system 4 for bubbles in a liquid film on a wafer when a megasonic generator cleans the wafer. The control system 4 for bubbles in the liquid film includes

a megasonic generator 43, a sampler 42, a bubble detection module 44, and a controller 45. The sampler 42 is configured to obtain the liquid from the liquid film 5 on the wafer 6 during the period when the megasonic generator 43 cleans the wafer 6. The bubble detection module 44 is connected to the sampler 42 and configured to perform bubble detection on the liquid obtained by the sampler 42 to determine the bubble parameter in the liquid. The controller 45 is electrically connected to the bubble detection module 44 and communicatively connected to the megasonic generator 43, and configured to adjust the operating parameter of the megasonic generator 43 according to the bubble parameter, so that the bubble parameter falls within a preset range.

According to this embodiment, the sampler 42 can be used to obtain the liquid from the liquid film 5 on the wafer 6 in real time during the cleaning of the wafer 6 and deliver the liquid to the bubble detection module 44, the bubble detection module 44 detects the bubble parameter of the liquid obtained by the sampler 42 and sends the bubble parameter detection result to the controller 45, and finally the controller 45 adjusts the operating parameter of the megasonic generator 43 according to the obtained bubble parameter, so that the bubble parameter falls within a preset range, thereby realizing the adjustment of the bubble parameter, avoiding the excessively large bubble size or excessively high bubble concentration in the liquid film 5, further preventing the "cavitation effect" of bubbles generated by the expansion-contraction oscillation of the bubbles from damaging the patterned structure on the wafer, and ultimately improving the wafer production yield.

The bubble detection module 44 in the embodiments of the present application may be, but is not limited to, a Nano-Transferrin Albumin (NTA) nanoparticle tracking instrument, and this type of instrument can be used to monitor the bubble parameter and analyze the bubble parameter in a sample in real time. The controller 45 may include, but is not limited to, a receiver or a computer, and can be used to receive the bubble parameter sent by the bubble detection module 44 in real time and perform real-time analysis at the same time. When it is monitored that the bubble parameter reaches a set early warning value for the occurrence of the "cavitation effect", the operating parameter of the megasonic generator 43 is automatically adjusted, so that the bubble size and/or bubble concentration are adjusted to be within the preset range, avoiding the occurrence of the bubble "cavitation effect".

It should be noted that the early warning value can be determined according to the bubble parameter when the bubbles in the liquid film experience the "cavitation effect" in the current process flow. In addition, the preset range in the above embodiments can be adjusted according to different wafer cleaning processes, and is not specifically limited herein.

According to FIG. 2, in some embodiments, the control system 4 for bubbles in the liquid film further includes a liquid pump 46, the liquid pump 46 is arranged between the bubble detection module 44 and the sampler 42, and configured to provide power for the sampler 42 to obtain the liquid from the liquid film 5 during the cleaning of the wafer 6. The liquid pump 46 obtains the liquid from the liquid film 5 during the cleaning of the wafer 6 through the sampler 42 and delivers the liquid to the bubble detection module 44. The arrangement of the liquid pump 46 facilitates the obtainment of the liquid from the liquid film 5 on the wafer 6.

According to FIG. 3, which is a front view of the sampler 42 and the mounting assembly 41, in some embodiments, the control system 4 for bubbles in the liquid film further includes a mounting assembly 41, and the mounting assembly 41 includes a mounting plate 411 and at least one fixing member 412. The mounting plate 411 is connected to the megasonic generator 43 and fixed to the mechanical arm 2. The fixing member 412 is fixed to the mounting plate 411, and the fixing member 412 is configured to fix the sampler 42.

In this embodiment, the mounting plate 411 and the megasonic generator 43 may be detachably connected, so as to facilitate the replacement of the mounting plate 411 and avoid the complex replacement problem caused by damage of the mounting plate 411 after long-term use. In addition, a plurality of fixing members 412 may be arranged on the mounting plate 411, so as to realize the installation and fixation of a plurality of samplers 42. Installing the plurality of samplers 42 can realize the sampling of the liquid at different positions in the liquid film on the wafer 6, so as to ensure the accuracy of the sampling result. In this embodiment, both the sampler 42 and the megasonic generator 43 are connected to the mounting plate 411, so as to facilitate controlling the bottom of the sampler 42 and the bottom of the megasonic generator 43 to be at the same horizontal height, which facilitates the sampler 42 to obtain the liquid from the liquid film 5 during the operation of the megasonic generator 43.

With continued reference to FIG. 3, in some embodiments, a plurality of first fixing holes 413 are arranged on the mounting plate 411, and protrusions (not shown) configured to mate with the first fixing holes 413 are arranged on the fixing member 412, the protrusions mate with the first fixing holes 413 to fix the fixing member 412. For example, the protrusions may be cylinders adapted to the first fixing holes 413, and according to FIG. 3, the protrusions are inserted into the first fixing holes 413 in a direction inward toward the paper surface.

It should be noted that the fixing manner of the fixing member on the mounting plate may also be other existing technologies capable of realizing fixation, such as welding, bonding, and the like.

In some embodiments, at least one second fixing hole (not shown) is arranged on the fixing member 412, the second fixing hole penetrates through the upper surface and the lower surface of the fixing member 412, and the sampler 42 is installed in the second fixing hole and extends through the lower surface of the second fixing hole to obtain the liquid from the liquid film during wafer cleaning. As shown in FIG. 3, the second fixing hole may penetrate through the fixing member 412 along the direction D shown in FIG. 3. The control system 4 for bubbles in the liquid film may further include a position fixing member, and after the sampler 42 is height-adjusted, so that the lower surface of the sampler 42 is located in the liquid film 5, the height of the sampler 42 is fixed by the position fixing member. According to different thicknesses of the liquid film 5, the height of the sampler 42 can be adjusted to be applicable to liquid films 5 with different thicknesses. It should be noted that the end of the sampler 42 extending into the liquid film 5 should not contact the wafer surface.

An embodiment of the present application also provides a wafer cleaning method, which can be applied to the wafer cleaning apparatus as shown in FIG. 4. As shown in FIG. 5, the wafer cleaning method comprises the following steps:

Step S501: applying a cleaning liquid onto a wafer and forming a liquid film on the wafer;

Step S502: using a megasonic generator to transmit acoustic energy to the liquid film on the wafer to clean the wafer;

Step S503: obtaining the liquid from the liquid film on the wafer during the period when the megasonic generator cleans the wafer;

Step S504: performing bubble detection on the obtained liquid to determine the bubble parameter in the liquid;

Step S505: adjusting the operating parameter of the megasonic generator according to the bubble parameter, so that the bubble parameter falls within a preset range.

In the embodiment of the present application, the bubble parameter in the liquid is determined by performing bubble detection on the obtained liquid, and the operating parameter of the megasonic generator is adjusted according to the bubble parameter, so that the bubble parameter falls within a preset range, thereby realizing the adjustment of the bubble parameter, preventing the "cavitation effect" of bubbles caused by excessively large bubble size or excessively high bubble concentration, solving the problem in the prior art where the "cavitation effect" of bubbles caused by the expansion-contraction oscillation of the bubbles leads to the collapse and damage of the patterned structure on the wafer, thereby improving the wafer production yield.

Those skilled in the art should understand that the various technical features of the above embodiments can be combined arbitrarily. For the sake of a concise description, all possible combinations of the various technical features in the above embodiments are not described. However, provided that the combinations of these technical features entail no contradiction, the combinations shall be deemed to fall within the scope recorded in the present specification.

The above embodiments only express several implementation modes of the present application, and the description of the embodiments is relatively specific and detailed, but the description of the embodiments should not be construed as limiting the scope of the invention patent. It should be pointed out that for those of ordinary skill in the art, without departing from the concept of the present application, various modifications and improvements can be made, and these modifications and improvements all fall within the protection scope of the present application. Therefore, the protection scope of the patent of the present application shall be subject to the

appended claims.

What is claimed is:

1. A control system for regulating bubbles in a liquid film on a wafer when a megasonic generator cleans the wafer, comprising:

a megasonic generator, configured to transmit acoustic energy to the liquid film on the wafer to clean the wafer;

a sampler, configured to obtain liquid from the liquid film on the wafer during the period when the megasonic generator cleans the wafer;

a bubble detection module, connected to the sampler and configured to perform bubble detection on the liquid obtained by the sampler to determine the bubble parameter in the liquid;

a controller, connected to the bubble detection module and configured to adjust the operating parameter of the megasonic generator according to the bubble parameter, so that the bubble parameter falls within a preset range.

2. The control system according to claim 1, wherein the control system further comprises a mounting assembly, the mounting assembly includes a mounting plate and at least one fixing member, the mounting plate is connected to the megasonic generator, the fixing member is fixed to the mounting plate, and the fixing member is configured to fix the sampler.

3. The control system according to claim 2, wherein a plurality of first fixing holes are arranged on the mounting plate, protrusions configured to mate with the first fixing holes are arranged on the fixing member, and the protrusions mate with the first fixing holes to fix the fixing member.

4. The control system according to claim 3, wherein at least one second fixing hole is arranged on the fixing member, and the sampler is installed in the second fixing hole.

5. The control system according to claim 1, wherein the control system further comprises a liquid pump, the liquid pump is arranged between the bubble detection

module and the sampler, and the liquid pump is configured to provide power for the sampler to obtain the liquid from the liquid film during wafer cleaning.

6. The control system according to claim 1, wherein the bubble parameter includes bubble size and/or bubble concentration.

7. The control system according to claim 1, wherein the operating parameter of the megasonic generator includes power, power-on duty cycle, and pulse period.

8. A wafer cleaning apparatus, wherein the wafer cleaning apparatus comprises the control system according to any one of claims 1 to 7.

9. A wafer cleaning method, comprising:

applying a cleaning liquid onto a wafer and forming a liquid film on the wafer;

using a megasonic generator to transmit acoustic energy to the liquid film on the wafer to clean the wafer;

obtaining the liquid from the liquid film on the wafer during the period when the megasonic generator cleans the wafer;

performing bubble detection on the obtained liquid to determine the bubble parameter in the liquid;

adjusting the operating parameter of the megasonic generator according to the bubble parameter, so that the bubble parameter falls within a preset range.