

SUBSTRATE PROCESSING DEVICE

TECHNICAL FIELD

The present invention relates to the field of semiconductor manufacturing technology, and in particular to a substrate processing device.

BACKGROUND

Integrated circuit manufacturing includes processes such as photolithography, etching, deposition, chemical mechanical polishing (CMP), cleaning, and the like. Among the processes, the cleaning process is used to remove various contamination impurities generated during substrate processing, and is the most frequently used process in integrated circuit manufacturing, running through almost the entire integrated circuit manufacturing process. Contamination impurities refer to any substance introduced during integrated circuit manufacturing that adversely affects the yield and electrical performance of chips, specifically including particles, organics, metals, natural oxide layers, etc.

Semiconductor cleaning technology is mainly divided into wet cleaning process and dry cleaning process. In a wet cleaning process, a substrate is generally fixed on a rotatable substrate fixture, and during the process, chemical liquid and deionized water are used to process the surface of the rotating substrate. After the wet etching or cleaning process is completed, the substrate is then dried.

Conventional drying processes mostly adopt nitrogen purge or isopropyl alcohol (IPA) combined with high-speed rotation of the substrate. However, as advanced integrated circuit process technology develops, feature sizes continue to shrink. During the drying process, the dimensions, aspect ratios, and densities of feature pattern structures at various locations on the substrate differ, distances from the rotation axis vary, and the liquid flow and evaporation rates in the pattern structures attached to the substrate also differ. Under the action of liquid surface tension, uneven forces on adjacent pattern structures may occur, ultimately leading to problems such as collapse, adhesion, deformation, and other damages to the feature pattern structures on the substrate, which can cause device failure, affect chip yield, and result in product scrap.

To avoid damage to the feature pattern structures on the substrate during the drying process, precise control of the surface tension and evaporation rate of IPA or other drying formulation liquids on the substrate surface during the drying process is particularly important.

SUMMARY

To avoid damage to feature pattern structures on a substrate during the drying process and improve precise control of the surface tension and evaporation rate of IPA or other drying formulation liquids on the substrate surface during the drying process, the present invention proposes a substrate processing device.

The present invention provides a substrate processing device, comprising:

a control mechanism;

a clamping mechanism, configured to clamp a substrate during a process;

a nozzle mechanism, including a liquid nozzle and a swing arm, the liquid nozzle being configured to dispense liquid onto the surface of the substrate placed on the clamping mechanism; the swing arm being configured to supply liquid to the liquid nozzle and being capable of driving the liquid nozzle to reciprocate in the radial direction of the substrate between the substrate center and the substrate edge;

a rotation drive mechanism, configured to drive the clamping mechanism to rotate;

a heating mechanism, configured to heat the substrate clamped by the clamping mechanism;

a temperature monitoring mechanism, wherein the temperature monitoring mechanism includes a first temperature monitoring unit, the first temperature monitoring unit is configured to: during a process in which the liquid nozzle moves radially from the substrate center toward the substrate edge and continuously dispenses liquid onto the substrate surface, when the liquid nozzle moves to a specific region above the substrate, monitor the temperature of the liquid film formed in the substrate surface region corresponding to the specific region, and send the temperature to the

control mechanism; the control mechanism is configured to receive the temperature and, based on the temperature, regulate the heating temperature of the heating mechanism for the substrate surface region corresponding to the specific region.

According to a specific embodiment of the present application, the temperature monitoring mechanism further includes a second temperature monitoring unit;

during the process in which the liquid nozzle moves radially from the substrate center toward the substrate edge and continuously dispenses liquid onto the substrate surface, when the liquid nozzle leaves a region N above the substrate and moves toward a next region N+1 in a direction away from the substrate center, the second temperature monitoring unit is configured to monitor the temperature of the substrate surface region corresponding to the region N, and store the monitored temperature.

According to a specific embodiment of the present application, the second temperature monitoring unit is disposed on the swing arm.

According to a specific embodiment of the present application, the temperature monitoring mechanism further includes a third temperature monitoring unit configured to monitor real-time temperatures of various locations on the back side of the heating mechanism and transmit the real-time temperatures to the control mechanism.

According to a specific embodiment of the present application, the control mechanism is configured to:

receive the real-time temperatures monitored by the third temperature monitoring unit in real time, and when a value of the real-time temperatures is greater than a preset value, the control mechanism issues an alarm message.

According to a specific embodiment of the present application, the heating mechanism includes a mounting plate and a plurality of heating elements, and the plurality of heating elements are disposed on the mounting plate.

According to a specific embodiment of the present application, the heating elements include LED lamp beads;

the LED lamp beads are disposed on circumferences of a plurality of concentric circles centered at the center of the mounting plate.

According to a specific embodiment of the present application, the plurality of heating elements are divided into a plurality of heating element groups; and the heating power of each of the heating element groups can be independently controlled.

According to a specific embodiment of the present application, the heating elements include edge heating elements located in the edge region of the mounting plate, the edge heating elements are obliquely disposed, and the obliquely disposed heating elements are used to allow the edge region of the mounting plate to be covered in the heating region of the obliquely disposed heating elements.

According to a specific embodiment of the present application, the edge region of the mounting plate is a region between a circumference at a specified distance from the edge of the mounting plate toward the center of the mounting plate and the edge of the mounting plate.

According to a specific embodiment of the present application, the tilt angle of the edge heating elements is 0.1° – 60° .

According to a specific embodiment of the present application, the wavelength range of light emitted by the LED lamp beads is: [200, 380) nm or (650, 2500] nm.

According to a specific embodiment of the present application, the control mechanism is configured to:

during the process in which the liquid nozzle moves radially from the substrate center toward the substrate edge and continuously dispenses liquid onto the substrate surface, when the liquid nozzle moves to a specific region above the substrate, control the heating elements located on the radius of the mounting plate corresponding to the specific region to a second power, and the heating elements reaching the second power heat the substrate surface region corresponding to the specific region to a second temperature.

According to a specific embodiment of the present application, the control mechanism is further configured to:

when the first temperature monitoring unit detects that the temperature of the liquid film formed in the substrate surface region is lower than the second temperature, control the heating mechanism to increase heating power, so as to increase the heating temperature of the substrate surface region.

According to a specific embodiment of the present application, before the liquid nozzle dispenses liquid onto the substrate surface, the control mechanism is configured to:

control the heating power of the heating elements to be a first heating power, and the heating elements reaching the first heating power heat the substrate to a first temperature.

According to a specific embodiment of the present application, the first temperature monitoring unit is disposed on the swing arm.

According to a specific embodiment of the present application, the heating mechanism includes a heating plate and a fluid delivery unit;

the heating plate is provided with at least two cavities in the radial direction, the cavities are respectively distributed on different radii, the bottom of each cavity is provided with a fluid inlet hole, the top of each cavity is provided with a fluid outlet hole, and the fluid inlet holes are connected to a fluid delivery tube;

the fluid delivery unit is connected to the fluid delivery tube, the fluid delivery unit is configured to deliver fluid to the heating plate, a heater is provided on the fluid delivery unit, and the heater is used to heat fluid in the fluid delivery unit.

According to a specific embodiment of the present application, the substrate processing device comprises a cooling mechanism, the cooling mechanism includes a cooling portion, the cooling portion is disposed on the mounting plate and located below the heating elements, and the cooling portion is configured to reduce the temperature of the heating elements.

According to a specific embodiment of the present application, the substrate processing device further comprises a plate, wherein light emitted by the heating elements is transmittable through the plate, the plate is disposed between the heating mechanism and the substrate, the plate is fixedly connected to the clamping mechanism, and when the rotation drive mechanism drives the clamping mechanism to rotate, the plate rotates together with the clamping mechanism.

By providing the first temperature monitoring unit, the present invention can, as the liquid nozzle moves, monitor the temperature of the liquid film formed by the liquid dispensed by the liquid nozzle onto the substrate surface in real time and provide feedback, enabling more precise monitoring of the temperature of the liquid discharged by the liquid nozzle; at the same time, based on the monitoring result of the first temperature monitoring unit, the control mechanism performs real-time control to adjust the heating power of the heating element group corresponding to a region where the liquid film temperature on the substrate surface is lower than the second temperature, so as to quickly and precisely regulate the heating temperature of the region monitored in real time by the first temperature monitoring unit, making the drying process and drying result more controllable.

Using the second temperature monitoring unit to monitor the instantaneous temperature of the substrate after the completion of drying in real time and perform statistics can assist in monitoring the process safety of the substrate processing device. When the substrate completes a corresponding process on the substrate processing device, the substrate is taken out from the substrate processing device for inspection of the process result. Once pattern structure collapse is detected in a specific region of the substrate, a review can be performed based on the data recorded by the second temperature monitoring unit. The target during maintenance becomes clearer, thereby improving the work efficiency of machine maintenance and ensuring substrate processing yield.

By providing the third temperature monitoring unit to monitor real-time temperatures of various locations on the back side of the heating element groups of the heating mechanism, and transmitting the real-time temperatures to the control mechanism, the working status of the heating element groups can be determined in real

time. Once a status abnormality occurs, an alarm message will be sent to notify the staff to perform timely maintenance.

Other features and advantages of the present invention will be set forth in the following specification, and, in part, will become apparent from the specification, or may be learned by practicing the present invention. The objective and other advantages of the present invention can be achieved and obtained through the structures pointed out in the specification and accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The features and performance of the present application are further described through the following embodiments and the accompanying drawings of the embodiments. To further clarify the technical solutions in the embodiments of the present invention or in the prior art, the accompanying drawings needed for describing the embodiments or the prior art will be briefly introduced below. Obviously, the accompanying drawings in the following description are some embodiments of the present invention. For those of ordinary skill in the art, other accompanying drawings can also be obtained based on these accompanying drawings without creative effort.

FIG. 1 shows a perspective structural schematic diagram of the substrate processing device according to Embodiment 1 of the present invention;

FIG. 2a shows a top structural schematic diagram of a heating mechanism according to an embodiment of the present invention;

FIG. 2b shows a bottom structural schematic diagram of a heating mechanism according to an embodiment of the present invention;

FIG. 3 shows a structural schematic diagram of the heating mechanism according to Embodiment 2 of the present invention;

FIG. 4 shows a perspective structural schematic diagram of the substrate processing device according to Embodiment 3 of the present invention;

FIG. 5 shows a simplified schematic diagram of the substrate processing device according to Embodiment 3 of the present invention;

FIG. 6 shows a simplified schematic diagram of the substrate processing device according to Embodiment 4 of the present invention;

FIG. 7 shows a structural schematic diagram of the cooling portion according to Embodiment 5 of the present invention;

FIG. 8 shows a structural schematic diagram of a sealing ring disposed between the cooling portion and the mounting plate according to Embodiment 5 of the present invention;

FIG. 9 shows a structural schematic diagram of a cooling portion according to another embodiment of the present invention; and

FIG. 10 shows a structural schematic diagram of the heating mechanism according to Embodiment 6 of the present invention.

PREFERRED EMBODIMENTS OF THE APPLICATION

To further clarify the objective, technical solutions, and advantages of the embodiments of the present invention, the technical solutions in the embodiments of the present invention will be clearly and completely described below with reference to the accompanying drawings in the embodiments of the present invention. Obviously, the described embodiments are a part of the embodiments of the present invention, not all of the embodiments. Based on the embodiments of the present invention, all other embodiments obtained by those of ordinary skill in the art without making creative effort shall fall within the protection scope of the present invention.

Embodiment 1

As shown in FIG. 1, the present invention proposes a substrate processing device. The substrate processing device comprises: a clamping mechanism 200, a rotation drive mechanism 300, a heating mechanism 400, a nozzle mechanism 500, a temperature monitoring mechanism, and a control mechanism 800.

The clamping mechanism 200 is used to clamp a substrate 100 during a process and maintain the substrate 100 in a horizontal state. The clamping mechanism 200 further includes a support portion 202 and a plurality of positioning pins 201, and the plurality of positioning pins 201 are disposed on the edge of the support portion 202. During the process, when the clamping mechanism 200 clamps the substrate 100, the substrate 100 is clamped and fixed through the plurality of positioning pins 201, thereby maintaining the substrate 100 in the horizontal state.

The rotation drive mechanism 300 is used to drive the support portion 202 to rotate. The rotation drive mechanism 300 includes a transmission mechanism 301 and a driving mechanism 302. Exemplarily, in this embodiment, the transmission mechanism 301 is a transmission shaft, and the driving mechanism 302 can be selected according to actual operational requirements during actual use. Exemplarily, this embodiment selects a stepper motor as the driving mechanism 302. During the process, the rotation drive mechanism 300 drives the support portion 202 to rotate the substrate 100 with a plumb line passing through the center of the substrate 100 as the axis.

The heating mechanism 400 is disposed between the support portion 202 and the substrate 100. Please refer to FIG. 1, FIG. 2a, and FIG. 2b. FIG. 2a shows a top structural schematic diagram of a heating mechanism according to an embodiment of the present invention; FIG. 2b shows a bottom structural schematic diagram of a heating mechanism according to an embodiment of the present invention. The heating mechanism 400 includes a mounting plate 401 and a plurality of heating elements 402. The plurality of heating elements 402 can be divided into a plurality of heating element groups 4021. The mounting plate 401 is configured to carry the plurality of heating elements 402. The heating elements 402 are configured to heat the substrate 100 during the process. It should be noted that, to improve efficiency and facilitate installation, during actual installation, the plurality of heating elements 402 are first integrated onto a circuit board 4023, and then installed on the mounting plate 401. The bottom of the mounting plate 401 is fixedly connected to one end of a support shaft 405, and the other end of the support shaft 405 passes through the transmission mechanism 301 and is fixed outside the transmission mechanism 301. During the process, the clamping mechanism 200 drives the substrate 100 to rotate, while the heating mechanism 400 does not rotate. Further, a plate 700 through which light emitted by the heating elements is transmittable is disposed between the substrate 100 and the heating

mechanism 400. Exemplarily, the plate 700 is made of sapphire or quartz. When the plate 700 is positioned on the clamping mechanism 200, during the process, the plate 700 is configured to rotate together with the clamping mechanism 200.

Exemplarily, in the embodiment of the present invention, the heating elements 402 are LED lamp beads. A plurality of LED lamp beads are disposed on circumferences of a plurality of concentric circles centered at the center of the mounting plate 401. The plurality of heating elements 402 are grouped into a plurality of heating element groups 4021. Further, the center of the circle formed by each heating element group 4021 is aligned with the center of the clamping mechanism 200, and also aligned with the center of the substrate 100 clamped by the clamping mechanism 200. To achieve independent temperature regulation of a local region of the substrate 100, the heating temperature of each heating element group 4021 can be independently controlled in the present invention. By independently controlling the heating power of each group of LED lamp beads, the purpose of changing the heating temperature to regulate the temperature of a local region of the substrate 100 is achieved. In the embodiment of the present invention, the wavelength range of light emitted by the LED lamp beads is [200, 380) nm or (650, 2500] nm.

With continued reference to FIG. 1, the nozzle mechanism 500 includes a liquid nozzle 501 and a swing arm 502. The liquid nozzle 501 is disposed on the swing arm 502. During the process, the liquid nozzle 501 is configured to dispense liquid onto the surface of the substrate 100 placed on the clamping mechanism 200; the swing arm 502 is provided with a liquid delivery pipeline that supplies liquid to the liquid nozzle 501, and the swing arm 502 can drive the liquid nozzle 501 to reciprocate in the radial direction of the substrate 100 between the center of the substrate 100 and the edge of the substrate 100.

The temperature monitoring mechanism includes a first temperature monitoring unit 601. The first temperature monitoring unit 601 is configured to: during a process in which the liquid nozzle 501 moves radially from the center of the substrate 100 toward the edge of the substrate 100 and continuously dispenses liquid onto the surface of the substrate 100, when the liquid nozzle 501 moves to a specific region above the substrate 100, monitor the temperature of the liquid film formed in the surface region of the substrate 100 corresponding to the specific region, and send the temperature to

the control mechanism 800. Exemplarily, the first temperature monitoring unit 601 is a temperature sensor. The first temperature monitoring unit 601 can be disposed at any position where the first temperature monitoring unit 601 can monitor the temperature of the liquid film formed on the surface of the substrate 100. In this embodiment, the first temperature monitoring unit 601 is selected to be disposed on the swing arm 502.

The control mechanism 800 is configured to receive the temperature and, based on the temperature, regulate the heating temperature of the heating mechanism 400 for the corresponding region of the substrate 100.

Specifically, during the process in which the liquid nozzle 501 moves radially from the center of the substrate 100 toward the edge of the substrate 100 and continuously dispenses liquid onto the surface of the substrate 100, when the liquid nozzle 501 moves to a specific region above the substrate 100, the heating element group 4021 located on the radius of the mounting plate 401 corresponding to the specific region is controlled to a second power, and the heating element group 4021 reaching the second power heats the corresponding region of the substrate 100 to a second temperature. The second temperature is a preset value. The second temperature is approximately the temperature at which the liquid dispensed by the liquid nozzle 501 onto the substrate 100 reaches the boiling point. In this embodiment, the second temperature is greater than or equal to the boiling point of the liquid. Taking IPA as an example, a preferable second temperature process range is 78–85 °C.

As the liquid nozzle 501 moves in the radial direction of the substrate 100 and continuously dispenses liquid onto the surface of the substrate 100, when the liquid nozzle 501 dispenses liquid into a region on the surface of the substrate 100 and forms a liquid film, the first temperature monitoring unit 601 monitors the temperature of the liquid film in real time and feeds the temperature back to the control mechanism 800. The control mechanism 800 evaluates the received temperature. When the evaluation result is that the temperature of the liquid film formed on the surface of the substrate 100 is lower than the preset second temperature, the control mechanism 800 controls the heating power of the heating element group 4021 corresponding to the region where the liquid film temperature on the surface of the substrate 100 is lower than the second temperature to increase to the second power, so as to quickly increase the heating temperature of the region, making the heating temperature quickly reach the second

temperature. As the working power of the LED lamp beads can be changed instantaneously, the local temperature can be adjusted very quickly. Once it is detected that the liquid film temperature in a specific region is lower than the second temperature, the control mechanism 800 controls the working power of the LED lamp beads included in the heating element group 4021 corresponding to the region to increase, almost instantaneously changing the heating temperature of the region, thereby ensuring the drying effect.

It should be noted that in the present invention, the heating element groups 4021 may be heating elements on a certain radius, or may be all heating elements centered on a certain radius within a certain distance range extending away from the center of the mounting plate 401, or may be all heating elements centered on a certain radius within a certain distance range extending both away from the center of the mounting plate 401 and toward the center of the mounting plate 401. Specifically, the coverage range of each heating element group 4021 can be adaptively adjusted and selected according to actual conditions. It should be understood that the "a certain radius" herein refers to the radius of the mounting plate 401 corresponding to a region to which the liquid nozzle 501 moves above the substrate 100 during the process in which the liquid nozzle 501 moves radially from the center of the substrate 100 toward the edge of the substrate 100.

Further, the nozzle mechanism 500 further includes a nitrogen nozzle for nitrogen purge.

Further, before the liquid nozzle 501 dispenses liquid onto the surface of the substrate 100, the control mechanism 800 controls the overall heating power of the heating elements 402 to be a first power, and the heating elements 402 reaching the first power heat the substrate 100 to a first temperature. The first temperature is a preheating temperature, with the function of uniformly heating the entire substrate 100. Taking IPA as an example, a preferable first temperature process range is 60–70 °C. The first power refers to the working power of the LED lamp beads required to heat the substrate 100 to the first temperature. By pre-adjusting the overall heating power of the heating elements 402 to the first power, the substrate 100 can be preheated, so that the substrate 100 has the first temperature before being dispensed with liquid. When the heating elements 402 need to adjust the heating temperature of a local region,

the second temperature can be reached more quickly, improving the drying efficiency. The first temperature is lower than the second temperature.

By providing the first temperature monitoring unit 601, the embodiment of the present invention can monitor the temperature of the liquid film dispensed by the liquid nozzle 501 onto the surface of the substrate 100 as the liquid nozzle 501 moves in real time, and provide feedback, enabling more precise monitoring of the temperature of the liquid dispensed by the liquid nozzle 501; at the same time, based on the monitoring result of the first temperature monitoring unit 601, the control mechanism 800 performs real-time control to adjust the heating power of the heating element group 4021 corresponding to the region where the liquid film temperature on the surface of the substrate 100 is lower than the second temperature, so as to quickly and precisely regulate the heating temperature of the region monitored in real time by the first temperature monitoring unit 601, making the drying process and drying result more controllable.

It should be noted that the device of the present invention is not only applicable to drying the substrate 100 after the completion of a cleaning process, but can also be used in an etching process. When the device is used in a wet etching process, an etching chemical liquid or formulation liquid is delivered to the surface of a rotating substrate through the nozzle mechanism to partially etch or completely remove the thin film on the substrate surface.

In a wet etching process, generally, an etching chemical liquid or formulation liquid is delivered to the surface of a rotating substrate through a nozzle mechanism to partially etch or completely remove the thin film on the substrate surface. Since temperature is one of the important parameters affecting the etching rate and uniformity, the device of the present application and the processing method described above can achieve partitioned dynamic precise control of the temperature of the substrate and the liquid on the substrate surface, thereby obtaining good control of etching rate and uniformity, and improving the processing precision and stability of integrated circuit wet etching processes.

The embodiment of the present invention further provides a substrate processing method, comprising: clamping a substrate on a clamping mechanism; driving the

clamping mechanism to rotate the substrate; heating the substrate using a heating mechanism; dispensing liquid onto the substrate surface through a liquid nozzle of a nozzle mechanism; during a process in which the liquid nozzle moves radially from the substrate center toward the substrate edge and continuously dispenses liquid onto the substrate surface, when the liquid nozzle moves to a specific region above the substrate, a temperature monitoring mechanism monitoring the temperature of the liquid film formed in the substrate surface region corresponding to the specific region, and based on the temperature, a control mechanism regulating the heating temperature of the heating mechanism for the substrate surface region corresponding to the specific region.

Exemplarily, during the process, the clamping mechanism 200 clamps the substrate 100 and maintains the substrate 100 horizontally disposed, and the nozzle mechanism 500 is located above the substrate 100. In this embodiment, the liquid dispensed by the liquid nozzle 501 of the nozzle mechanism 500 onto the substrate 100 is a dry liquid IPA. Before the liquid nozzle 501 moves directly above the center of the substrate 100 and dispenses liquid onto the surface of the substrate 100, the control mechanism 800 controls the overall working power of the heating elements 402 of the heating mechanism 400 to be the first power, and the heating elements 402 at the first power heat the entire substrate 100 to the first temperature, for example, 70 °C.

After the substrate 100 is uniformly heated to the first temperature, the liquid nozzle 501 starts to move radially from the center of the substrate 100 toward the edge of the substrate 100, and dispenses the dry liquid IPA onto the substrate 100. During this process, when the liquid nozzle 501 moves to a specific region above the substrate 100, the control mechanism 800 controls the working power of the heating element group 4021 located on the radius of the mounting plate 401 corresponding to the specific region to increase from the first power to the second power, and the heating element group 4021 reaching the second power quickly heats the region of the substrate 100 corresponding to the specific region to the second temperature, for example, 80 °C.

It should be understood that the device is also suitable for a substrate backside cleaning process. When the device is used in a backside cleaning process, a backside cleaning nozzle is required to pass through the center of the heating mechanism 400 and the plate 700 to reach below the substrate 100, so that cleaning liquid can be

sprayed onto the lower surface of the substrate 100 to perform the backside cleaning process.

Embodiment 2

This embodiment provides a substrate processing device. The structure of this device is substantially the same as the structure of the substrate processing device in Embodiment 1, with the difference being that, as shown in FIG. 3, edge heating elements 4022 located in the edge region of the mounting plate 401 are obliquely disposed, and the obliquely disposed heating elements are used to allow the edge region of the mounting plate to be covered in the heating region of the obliquely disposed heating elements.

In actual process, the inventors found that pattern structure collapse often occurs in the edge region of the substrate 100. Analysis revealed that the reason is that light emitted by the edge heating elements 4022 located in the edge region of the mounting plate 401 cannot cover the edge region of the substrate 100, making the temperature at the edge of the substrate 100 fail to reach the target temperature during the heating and drying process, which can affect the process effect, cause pattern structure collapse in the edge region of the substrate 100, and result in scrap wafers. To this end, the edge heating elements 4022 located in the edge region of the mounting plate 401 are obliquely disposed. In one embodiment, the tilt angle of the edge heating elements 4022 is 0.1° – 60° . Further, the tilt angle of the edge heating elements 4022 is set to 5° to 40° . The edge heating elements 4022 obliquely disposed at a certain angle can ensure that the target region of the edge heating elements 4022 is aligned with the edge region of the substrate 100, ensuring normal heating of the edge of the substrate 100 during the heating and drying process, thereby preventing pattern structure collapse in the edge region of the substrate 100 and ensuring drying effect.

It should be understood that the edge region of the mounting plate 401 is a region between a circumference at a specified distance from the edge of the mounting plate 401 toward the center of the mounting plate 401 and the edge of the mounting plate 401. Exemplarily, the specified distance is 0–1.5 mm. Within the specified distance, one group of edge heating elements 4022 can be provided, or more than one group of

edge heating elements 4022 can be provided. The specific arrangement can be set according to actual process requirements.

The remaining structure of the substrate processing device in this embodiment is the same as the structure of the substrate processing device in Embodiment 1.

Embodiment 3

This embodiment provides a substrate processing device. The structure of this device is substantially the same as the structure of the substrate processing device in Embodiment 1, with the difference being that, as shown in FIG. 4, the temperature monitoring mechanism of this device further includes a second temperature monitoring unit 602. During actual installation, the second temperature monitoring unit 602 can be disposed at any position where the second temperature monitoring unit 602 can monitor the temperature of various regions on the surface of the substrate 100. It should be understood that the second temperature monitoring unit 602 and the first temperature monitoring unit 601 can be combined and disposed in a single component, or can be disposed separately. In this embodiment, as shown in FIG. 5, the second temperature monitoring unit 602 is selected to be disposed on the swing arm 502, and is disposed separately from the first temperature monitoring unit 601.

As shown in FIG. 5, during the process in which the liquid nozzle 501 moves radially from the center of the substrate 100 toward the edge of the substrate 100 and continuously dispenses liquid onto the surface of the substrate 100, when the liquid nozzle 501 leaves a region N above the substrate and moves toward a next region N+1 in a direction away from the substrate center, the second temperature monitoring unit 602 is configured to monitor the temperature of the substrate surface region corresponding to the region N, and store the monitored temperature result. Using the second temperature monitoring unit 602 to monitor the instantaneous temperature of the substrate after the completion of drying in real time and perform statistics can assist in monitoring the process safety of the substrate processing device. When the substrate completes a corresponding process on the substrate processing device and is taken out from the substrate processing device for inspection of the process result, once pattern structure collapse is detected in a specific region of the substrate, a review can be performed based on the data recorded by the second temperature monitoring unit 602.

Ideally, when heating elements on adjacent radii heat the substrate, the target heating temperature is the same, and the substrate surface temperature when the liquid film on the substrate surface is completely dried should also be substantially consistent. From the monitoring result of the second temperature monitoring unit 602, the data should be substantially equal. If a large deviation is found in temperature data of adjacent regions on the substrate surface in the data recorded by the second temperature monitoring unit 602, it indicates that the heating elements in the regions encounter a problem. The target during maintenance becomes clearer, thereby improving the working efficiency of machine maintenance and ensuring substrate processing yield.

The remaining structure of the substrate processing device in this embodiment is the same as the structure of the substrate processing device in Embodiment 1.

Embodiment 4

This embodiment provides a substrate processing device. The structure of this device is substantially the same as the structure of the substrate processing device in Embodiment 1, with the difference being that the temperature monitoring mechanism of this device further includes a third temperature monitoring unit. The third temperature monitoring unit is configured to monitor real-time temperatures of various locations on the back side of the heating mechanism, and transmit the real-time temperatures to the control mechanism 800.

Specifically, as shown in FIG. 6, the third temperature monitoring unit 603 includes a plurality of groups of temperature sensors 6031. The plurality of groups of temperature sensors 6031 are respectively disposed below the heating elements 402, and each group of temperature sensors 6031 is disposed corresponding to each heating element group 4021. At this time, the third temperature monitoring unit 603 is configured to monitor real-time temperatures of different heating element groups 4021 and transmit the real-time temperatures to the control mechanism 800. At the same time, the control mechanism 800 receives the real-time temperatures of the third temperature monitoring unit 603 in real time. When a value of the real-time temperatures is greater than a preset value, the control mechanism 800 issues an alarm message. Wherein, the preset value is the normal process temperature of the heating elements. Exemplarily, the preset value is 80 °C. When the third temperature

monitoring unit 603 detects that the working temperature of a certain heating element group is greater than 80 °C, the control mechanism 800 receives the temperature monitored by the third temperature monitoring unit 603, then determines that the heating element group is in an abnormal working state and requires timely maintenance, and will send an alarm message to notify the staff to perform timely maintenance.

The remaining structure of the substrate processing device in this embodiment is the same as the structure of the substrate processing device in Embodiment 1.

Embodiment 5

This embodiment provides a substrate processing device. The structure of this device is substantially the same as the structure of the substrate processing device in Embodiment 1, with the difference being that, as shown in FIG. 7, the substrate processing device further comprises a cooling mechanism. The cooling mechanism includes a cooling portion disposed on the mounting plate 401. The cooling portion is located below the heating elements 402. During the process, the cooling portion is configured to reduce the temperature of the heating elements 402. The actual selection of the cooling portion includes, but is not limited to: a cooling tank. The specific type can be selected according to actual process requirements. The cooling portion is configured to reduce the temperature of the heating elements 402, thereby avoiding damage to the heating elements 402 caused by an excessively high temperature of the heating elements 402 during the process.

Specifically, as shown in FIG. 7, when the cooling portion is a cooling tank 404, the cooling tank 404 is provided on the upper end surface of the mounting plate 401. When the heating elements 402 are mounted on the mounting plate 401, the circuit board 4023 carrying the plurality of heating elements 402 is snap-fitted and fixed to the mounting plate 401, forming a sealed space. A liquid inlet 9 and a liquid outlet 4042 are provided at the bottom of the mounting plate 401. When the heating elements 402 are cooled, external cooling liquid enters the cooling tank through the liquid inlet 4041, fills the entire cooling tank 404 to make the liquid level of the cooling liquid directly contact the heating elements 402 to cool the heating elements 402, and at the same time, the cooling liquid is continuously discharged from the liquid outlet 4042, forming a dynamic equilibrium process. During the dynamic equilibrium process, the

cooling tank 404 is always kept in a state filled with cooling liquid to continuously cool the heating elements 402.

As shown in FIG. 8, to further ensure the sealing effect, a sealing ring 403 is provided at the fixed position between the mounting plate 401 and the circuit board 4023 for sealing, achieving better sealing performance.

In another embodiment, to further ensure cooling uniformity, a plurality of cooling tanks 404 are provided in the cooling portion. As shown in FIG. 9, each cooling tank 404 is substantially annular, and each cooling tank 404 is provided with a liquid inlet 4041 and a liquid outlet 4042. Further, one cooling tank 404 is disposed correspondingly below each heating element group 4021 to achieve precise and uniform cooling.

Embodiment 6

This embodiment provides a substrate processing device. The structure of this device is substantially the same as the structure of the substrate processing device in Embodiment 1, with the difference being that, as shown in FIG. 10, the heating mechanism 400 in this embodiment includes a heating plate and a fluid delivery unit. The heating plate is disposed below the substrate 100 clamped by the clamping mechanism 200. The heating plate is provided with at least two cavities 4011 in the radial direction, with the cavities 4011 respectively distributed on different radii. A fluid inlet hole 4012 is provided at the bottom of each cavity 4011, and a fluid outlet hole 4013 is provided at the top of each cavity 4011. The fluid inlet holes 4012 are connected to a fluid delivery tube 4014. The fluid delivery unit 4022 is connected to the fluid delivery tube 4014. The fluid delivery unit 4022 delivers heating fluid to the heating plate. A heater 4023 is provided on the fluid delivery unit 4022, and the heater is used to heat the fluid in the fluid delivery unit. During the process in which the liquid nozzle 501 moves radially from the center of the substrate 100 toward the edge of the substrate 100, when the liquid nozzle 501 moves to a specific region above the substrate 100, the control mechanism 800 controls the thermal energy of the fluid in the cavity on the corresponding radius of the region, thereby increasing the local temperature of the substrate 100 below the liquid nozzle 501. The specific control process and specific implementation are described in patent PCT/CN2021/120372,

filed by ACM Research (Shanghai), Inc. on September 24, 2021, and the related content is incorporated herein by reference.

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

What is claimed is:

1. A substrate processing device, comprising:

a control mechanism;

a clamping mechanism, configured to clamp a substrate during a process;

a nozzle mechanism, including a liquid nozzle and a swing arm, the liquid nozzle being configured to dispense liquid onto the surface of the substrate placed on the clamping mechanism; the swing arm being configured to supply liquid to the liquid nozzle and being capable of driving the liquid nozzle to reciprocate in the radial direction of the substrate between the substrate center and the substrate edge;

a rotation drive mechanism, configured to drive the clamping mechanism to rotate;

a heating mechanism, configured to heat the substrate clamped by the clamping mechanism;

a temperature monitoring mechanism, wherein the temperature monitoring mechanism includes a first temperature monitoring unit, the first temperature monitoring unit is configured to: during a process in which the liquid nozzle moves radially from the substrate center toward the substrate edge and continuously dispenses liquid onto the substrate surface, when the liquid nozzle moves to a specific region above the substrate, monitor the temperature of the liquid film formed in the substrate surface region corresponding to the specific region, and send the temperature to the control mechanism; the control mechanism is configured to receive the temperature and, based on the temperature, regulate the heating temperature of the heating mechanism for the substrate surface region corresponding to the specific region.

2. The substrate processing device according to claim 1, wherein the temperature monitoring mechanism further includes a second temperature monitoring unit; during the process in which the liquid nozzle moves radially from the substrate center toward the substrate edge and continuously dispenses liquid onto the substrate surface, when the liquid nozzle leaves a region N above the substrate and moves toward a next region N+1 in a direction away from the substrate center, the second temperature monitoring

unit is configured to monitor the temperature of the substrate surface region corresponding to the region N, and store the monitored temperature.

3. The substrate processing device according to claim 2, wherein the second temperature monitoring unit is disposed on the swing arm.

4. The substrate processing device according to claim 1, wherein the temperature monitoring mechanism further includes a third temperature monitoring unit configured to monitor real-time temperatures of various locations on the back side of the heating mechanism and transmit the real-time temperatures to the control mechanism.

5. The substrate processing device according to claim 4, wherein the control mechanism is configured to: receive the real-time temperatures monitored by the third temperature monitoring unit in real time, and when a value of the real-time temperatures is greater than a preset value, the control mechanism issues an alarm message.

6. The substrate processing device according to claim 1, wherein the heating mechanism includes a mounting plate and a plurality of heating elements, and the plurality of heating elements are disposed on the mounting plate.

7. The substrate processing device according to claim 6, wherein the heating elements include LED lamp beads; the LED lamp beads are disposed on circumferences of a plurality of concentric circles centered at the center of the mounting plate.

8. The substrate processing device according to claim 7, wherein the plurality of heating elements are divided into a plurality of heating element groups; and the heating power of each of the heating element groups can be independently controlled.

9. The substrate processing device according to claim 8, wherein the heating elements include edge heating elements located in the edge region of the mounting plate, the edge heating elements are obliquely disposed, and the obliquely disposed heating elements are used to allow the edge region of the mounting plate to be covered in the heating region of the obliquely disposed heating elements.

10. The substrate processing device according to claim 9, wherein the edge region of the mounting plate is a region between a circumference at a specified distance from the edge of the mounting plate toward the center of the mounting plate and the edge of the mounting plate.

11. The substrate processing device according to claim 9, wherein the tilt angle of the edge heating elements is 0.1° – 60° .

12. The substrate processing device according to claim 7, wherein the wavelength range of light emitted by the LED lamp beads is: [200, 380) nm or (650, 2500] nm.

13. The substrate processing device according to claim 6, wherein the control mechanism is configured to: during the process in which the liquid nozzle moves radially from the substrate center toward the substrate edge and continuously dispenses liquid onto the substrate surface, when the liquid nozzle moves to a specific region above the substrate, control the heating elements located on the radius of the mounting plate corresponding to the specific region to a second power, and the heating elements reaching the second power heat the substrate surface region corresponding to the specific region to a second temperature.

14. The substrate processing device according to claim 13, wherein the control mechanism is further configured to: when the first temperature monitoring unit detects that the temperature of the liquid film formed in the substrate surface region is lower than the second temperature, control the heating mechanism to increase heating power, so as to increase the heating temperature of the substrate surface region.

15. The substrate processing device according to claim 14, wherein before the liquid nozzle dispenses liquid onto the substrate surface, the control mechanism is configured to: control the heating power of the heating elements to be a first heating power, and the heating elements reaching the first heating power heat the substrate to a first temperature.

16. The substrate processing device according to claim 1, wherein the first temperature monitoring unit is disposed on the swing arm.

17. The substrate processing device according to claim 1, wherein the heating mechanism includes a heating plate and a fluid delivery unit; the heating plate is provided with at least two cavities in the radial direction, the cavities are respectively distributed on different radii, the bottom of each cavity is provided with a fluid inlet hole, the top of each cavity is provided with a fluid outlet hole, and the fluid inlet holes are connected to a fluid delivery tube; the fluid delivery unit is connected to the fluid delivery tube, the fluid delivery unit is configured to deliver fluid to the heating plate, a heater is provided on the fluid delivery unit, and the heater is used to heat fluid in the fluid delivery unit.

18. The substrate processing device according to claim 6, wherein the substrate processing device further comprises a cooling mechanism, the cooling mechanism includes a cooling portion, the cooling portion is disposed on the mounting plate and located below the heating elements, and the cooling portion is configured to reduce the temperature of the heating elements.

19. The substrate processing device according to claim 6, wherein the substrate processing device further comprises a plate, wherein light emitted by the heating elements is transmittable through the plate, the plate is disposed between the heating mechanism and the substrate, the plate is fixedly connected to the clamping mechanism, and when the rotation drive mechanism drives the clamping mechanism to rotate, the plate rotates together with the clamping mechanism.