

# **DRYING-MEDIUM RECOVERY SYSTEM AND SEMICONDUCTOR DRYING APPARATUS**

## **FIELD OF THE INVENTION**

The present application relates to the field of semiconductor manufacturing, and in particular to a drying-medium recovery system and a semiconductor drying apparatus.

## **BACKGROUND**

In the manufacturing process of integrated circuits, the feature size of semiconductor devices continues to shrink, and the aspect ratio of patterned structures continues to increase, thereby posing higher requirements on wafer cleaning technologies.

In the conventional wafer cleaning process, large volumes of ultrapure water are required to flush a wafer, and then the wafer is dried with isopropyl alcohol (IPA). However, as the aspect ratio of the patterned structures formed on the wafer becomes increasingly larger, it is difficult for the conventional wafer cleaning process to meet the production needs. This is mainly because when IPA is used to dry the wafer, the surface tension at the gas-liquid interface is prone to cause adhesion and collapse on high-aspect-ratio patterned structures. To solve this problem, supercritical carbon dioxide drying technology has been gradually applied to the wafer cleaning process. This drying technology uses supercritical carbon dioxide with near-zero surface tension to dry the surface of a cleaned wafer. Taking advantage of the characteristics of supercritical carbon dioxide such as high solubility, high diffusivity, and low viscosity, the carbon dioxide in the supercritical state and IPA are fully dissolved. Finally, IPA on the wafer surface is removed from the wafer surface by releasing the carbon dioxide, so as to complete non-damaging drying of the patterned structures on the wafer. However, studies have found that the amount of the carbon dioxide used in the process of drying a wafer with supercritical carbon dioxide is very large. If the carbon dioxide used is not treated and directly released into the atmosphere, it will cause environmental pollution, and can easily result in the waste of carbon dioxide.

## SUMMARY

An embodiment of the present application provides a supercritical drying-medium recovery system and a semiconductor drying apparatus, so as to at least solve the problem in the related art of how to recover the drying medium (such as carbon dioxide) during wafer drying.

In a first aspect, an embodiment of the present application provides a drying-medium recovery system applied to a semiconductor drying apparatus. The semiconductor drying apparatus comprises a drying device, and the drying device is configured to dissolve an organic solvent on a wafer through a supercritical drying medium; the drying-medium recovery system is configured to recover the drying medium from the drying medium containing the organic solvent discharged from the drying device. The drying-medium recovery system comprises a separation device. The separation device comprises a condensate line and a first chamber. A liquid discharge port is provided on the lower side wall of the condensate line, and the liquid discharge port is in communication with the first chamber. An inlet of the condensate line is configured to receive the drying medium containing the organic solvent, and an outlet of the condensate line is configured to discharge the separated drying medium for recovery. Wherein,

the condensate line is configured to condense the organic solvent in the drying medium containing the organic solvent, so that the organic solvent is condensed into a liquid state and flows into the first chamber from the liquid discharge port.

In some embodiments, the condensate line is spiral-shaped.

In some embodiments, the inlet of the condensate line and the outlet of the condensate line are disposed at different vertical levels.

In some embodiments, the condensate line is arranged inside the first chamber or outside the first chamber.

In some embodiments, a first liquid outlet is provided at the bottom of the first chamber, and the first liquid outlet is configured to discharge the organic solvent in the first chamber.

In some embodiments, a first gas outlet is provided on the side wall of the first chamber for discharging the drying medium in the first chamber for recovery.

In some embodiments, the drying-medium recovery system further comprises a first cooling device, and the first cooling device is connected to the condensate line and is configured to keep the temperature of the condensate line within a preset temperature range.

In some embodiments, the first cooling device is spirally wound around the condensate line.

In some embodiments, the drying-medium recovery system further comprises a purification device. The purification device comprises a second chamber provided with a second gas outlet, a gas inlet line, and a drying-medium filter membrane. Wherein, the drying-medium filter membrane is arranged in the second chamber and divides the second chamber into an upper space and a lower space; the lower space of the second chamber is configured to contain a purification solvent; a gas inlet end of the gas inlet line is in communication with the outlet of the condensate line, and a gas outlet end of the gas inlet line is inserted into the second chamber; the second gas outlet is arranged in the upper space and is configured to discharge the purified drying medium for recovery.

In some embodiments, the drying-medium recovery system further comprises a first line, a second line, a detection device, a switching device, and a controller. Wherein, the line through which the drying device discharges the drying medium containing the organic solvent is respectively connected to the first line and the second line through the switching device; the first line is connected to the separation device; the second line is connected to the purification device. Wherein,

the detection device is configured to detect the concentration of the organic solvent in the drying medium containing the organic solvent discharged from the drying device; the controller is configured to control the switching device to switch between the first line and the second line according to the concentration of the organic solvent detected by the detection device;

when the concentration of the organic solvent detected by the detection device is greater than a preset concentration, the controller controls the switching device to connect the first line; when the concentration of the organic solvent detected by the detection device is smaller than the preset concentration, the controller controls the switching device to connect the second line.

In some embodiments, the drying-medium recovery system further comprises a dehumidification device, and the dehumidification device is connected to the outlet of the condensate line or the second gas outlet.

In some embodiments, the drying-medium recovery system further comprises a filter device, and the filter device is connected to the dehumidification device.

In a second aspect, an embodiment of the present application further provides a semiconductor drying apparatus comprising: the drying-medium recovery system as described in the first aspect, a storage device, a supercritical drying-medium preparation device, and a drying device. The drying-medium recovery system, the storage device, the supercritical drying-medium preparation device, and the drying device are sequentially connected and form a circulation loop. Wherein,

the storage device is configured to store the drying medium recovered by the drying-medium recovery system;

the supercritical drying-medium preparation device is configured to process the drying medium discharged from the storage device into supercritical drying medium;

the drying device is configured to dissolve the organic solvent on the wafer surface through the supercritical drying medium for wafer drying, and discharge the drying medium containing the organic solvent to the drying-medium recovery system to recover the drying medium.

In some embodiments, the supercritical drying-medium preparation device comprises:

a second cooling device, for cooling the drying medium discharged from the storage device to the liquid state;

a pressure-boosting device, for boosting the pressure of the drying medium in liquid form to exceed the critical pressure of the drying medium;

a heating device, for heating the drying medium exceeding the critical pressure to exceed the critical temperature of the drying medium to obtain a supercritical drying medium.

Compared with the related art, the embodiment of the present application provides a drying-medium recovery system and a semiconductor drying apparatus. The semiconductor drying apparatus comprises a drying device, and the drying device is configured to dissolve an organic solvent on a wafer through a supercritical drying medium; the drying-medium recovery system is configured to recover the drying medium from the drying medium containing the organic solvent discharged from the drying device. A separation device is arranged in the drying-medium recovery system. The separation device comprises a condensate line and a first chamber. A liquid discharge port is provided on the lower side wall of the condensate line, and the liquid discharge port is in communication with the first chamber. The inlet of the condensate line is configured to receive the drying medium containing the organic solvent, and the outlet of the condensate line is configured to discharge the separated drying medium for recovery. Wherein, the condensate line is configured to condense the organic solvent in the drying medium containing the organic solvent, so that the organic solvent is condensed into a liquid state and flows into the first chamber from the liquid discharge port. By means of this arrangement, the problem in the related art of how to recover the carbon dioxide during wafer drying is solved, and the carbon dioxide during wafer drying can be recovered.

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

## BRIEF DESCRIPTION OF THE DRAWINGS

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

FIG. 1 is a schematic structure diagram of embodiment 1 of a drying-medium recovery system provided by the present application;

FIG. 2 is a schematic structure diagram of embodiment 2 of a drying-medium recovery system provided by the present application;

FIG. 3 is a schematic structure diagram of embodiment 3 of a drying-medium recovery system provided by the present application;

FIG. 4 is a schematic structure diagram of embodiment 4 of a drying-medium recovery system provided by the present application;

FIG. 5 is a schematic structure diagram of embodiment 5 of a drying-medium recovery system provided by the present application;

FIG. 6 is a schematic structure diagram of embodiment 6 of a drying-medium recovery system provided by the present application;

FIG. 7 is a schematic structure diagram of embodiment 7 of a drying-medium recovery system provided by the present application;

FIG. 8 is a schematic structure diagram of embodiment 8 of a drying-medium recovery system provided by the present application;

FIG. 9 is a schematic structure diagram of a semiconductor drying apparatus according to an embodiment of the present application;

FIG. 10 is a structural block diagram of a semiconductor drying apparatus according to an embodiment of the present application.

Reference numerals: 10. separation device; 11. first chamber; 111. first liquid outlet; 112. first gas outlet; 12. condensate line; 121. liquid discharge port; 122. inlet of condensate line; 123. outlet of condensate line; 124. first cooling device; 30. purification device; 31. second chamber; 311. second gas outlet; 312. second liquid outlet; 313. third gas outlet; 314. upper space; 315. lower space; 32. gas inlet line; 33. drying-medium filter membrane; 20. controller; 40. first line; 50. second line; 60.

switching device; 70. detection device; 80. dehumidification device; 90. filter device; 100. drying-medium recovery system; 200. supercritical drying-medium preparation device; 201. second cooling device; 202. pressure-boosting device; 203. heating device; 300. drying device; 400. third line; 500. fourth line; 600. fifth line; 700. storage device; 800. sixth line.

## PREFERRED EMBODIMENTS OF THE INVENTION

In order to make the object, technical solutions, and advantages of the present application clearer, the present application will be described and illustrated below with reference to the accompanying drawings and embodiments. It should be understood that the specific embodiments described here are only used to illustrate the present application, and are not used to limit the present application. Based on the embodiments provided by 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 also be understood that although the efforts made in this development process may be complex and protracted, for those of ordinary skill in the art related to the content disclosed in the present application, some design, manufacturing, or production changes made on the basis of the technical content disclosed in the present application are only conventional technical means, and should not be taken as an indication that the disclosure of the present application is insufficient.

Unless otherwise defined, the technical terms or scientific terms involved in the present application shall have the usual meanings understood by those of ordinary skill in the technical field to which the present application belongs. The words such as "one," "a/an," and "the" involved in the present application do not indicate numerical limitation and may refer to either the singular or the plural. The terms "include," "comprise," "have," and any variations of the terms involved in the present application are intended to cover non-exclusive inclusion; for example, a process, method, system, product, or device 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 the process, method, product, or device. The words such as "connect," "interconnect," and "couple" involved in the present application are not limited to physical or mechanical connections, and 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 associative relationship of associated objects, indicating that there can be three relationships. For example, "A and/or B" can indicate: A alone, A and B together, and B 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 order for the objects.

#### Embodiment 1

As shown in FIG. 1, the present embodiment proposes a drying-medium recovery system 100, and the drying-medium recovery system is applied to a semiconductor drying apparatus.

For ease of understanding, the semiconductor drying apparatus comprising the drying-medium recovery system 100 will be briefly described first with reference to FIG. 9. As shown in FIG. 9, the semiconductor drying apparatus comprises a drying-medium recovery system 100, a storage device 700, a supercritical drying-medium preparation device 200, and a drying device 300 that are sequentially connected and form a circulation loop. Wherein, the drying-medium recovery system 100 stores the recovered drying medium into the storage device 700 through a sixth line 800; the storage device 700 introduces the stored drying medium into the supercritical drying-medium preparation device 200 through a fourth line 500 to process the drying medium into supercritical drying medium; the supercritical drying-medium preparation device 200 introduces the supercritical drying medium into the drying device 300 through a fifth line 600 to dissolve an organic solvent remaining on a wafer to dry the wafer; the drying device 300 discharges the drying medium containing the organic solvent into the drying-medium recovery system 100 through a third line 400, so as to achieve the recycling of the drying medium.

In the present embodiment, the drying medium in the drying medium containing the organic solvent discharged from the drying device 300 is substantially in gaseous form, because a pressure-reducing valve is generally arranged on the third line 400, and the pressure is reduced through the pressure-reducing valve so that most of the drying medium turns into gas.

Next, the drying-medium recovery system 100 provided by the present embodiment will be described in detail with reference to FIG. 1 and FIG. 10.

FIG. 1 is a schematic structure diagram of the drying-medium recovery system 100 according to the embodiment of the present application. As shown in FIG. 1, the drying-medium recovery system 100 comprises a separation device 10. The separation device 10 comprises a condensate line 12 and a first chamber 11. The condensate line 12 is used to receive the drying medium containing the organic solvent and cool and liquefy the organic solvent. A liquid discharge port 121 is provided on the lower side wall of the condensate line 12, and the liquid discharge port 121 is in communication with the first chamber 11, so that the liquefied organic solvent can be discharged into the first chamber 11.

Specifically, an inlet of condensate line 122 is used to receive the drying medium containing the organic solvent. According to FIG. 1 and FIG. 9, the inlet of condensate line 122 can be connected to the drying device 300 through the third line 400, so as to receive the drying medium containing the organic solvent discharged from the drying device 300. An outlet of condensate line 123 is used to discharge the separated drying medium for recovery. As shown in FIG. 1 and FIG. 9, the outlet of condensate line 123 can be connected to the storage device 700 through the sixth line 800, so as to recover and store the separated drying medium and achieve the reuse of the drying medium.

A mixture of the organic solvent and drying medium is discharged through the third line 400 into the drying-medium recovery system 100, such as a mixture of IPA and carbon dioxide. Therefore, in the present embodiment, by cooling the drying medium containing the organic solvent through the condensate line 12 in the separation device 10, the organic solvent can be liquefied and separated from the drying medium, and flow into the first chamber 11 from the liquid discharge port 121, and the drying medium is discharged through the outlet of condensate line 123 for recovery and/or storage. This achieves the separation of the organic solvent and the drying medium, solves the problem in the related art of how to recover the drying medium (such as carbon dioxide) during wafer drying, enables the recovery of the carbon dioxide during wafer drying, and reduces the environmental pollution caused by the carbon dioxide and the waste of carbon dioxide resources.

With continued reference to FIG. 1, in the present embodiment, the condensate line 12 is arranged inside the first chamber 11, thereby reducing the volume of the separation device 10.

With continued reference to FIG. 1, in this example, the inlet of condensate line 122 is arranged below, and the outlet of condensate line 123 is arranged above.

In other examples, the inlet of condensate line 122 is arranged above, and the outlet of condensate line 123 is arranged below.

In the above embodiment, by arranging the inlet of condensate line 122 and the outlet of condensate line 123 at different heights, the fluidity of the carbon dioxide containing IPA in the condensate line 12 can be improved, thereby improving the condensation efficiency of IPA.

With continued reference to FIG. 1, a first liquid outlet 111 is provided at the bottom of the first chamber 11, and the first liquid outlet 111 is used to discharge the organic solvent in the first chamber 11. In the present embodiment, by arranging the first liquid outlet 111 on the first chamber 11, it is possible to prevent excessive IPA from accumulating inside the first chamber 11, an accumulation that would otherwise risk blocking the liquid discharge port 121 and impairing the separation of IPA and carbon dioxide.

With continued reference to FIG. 1, the condensate line 12 may be spiral-shaped. In the present embodiment, by arranging the condensate line 12 in a spiral shape, the contact area of IPA can be increased by virtue of the small volume of the condensate line 12, thereby improving the condensation efficiency of IPA.

In some embodiments, the drying-medium recovery system 100 further comprises a liquid recovery device (not shown), and the liquid recovery device is connected to the first liquid outlet 111 to collect IPA discharged through the condensate line 12 into the first chamber 11.

It should be noted that the organic solvent in the present embodiment may be IPA, acetone, xylene, etc., and the drying medium may be, but is not limited to, carbon dioxide, ethylene, ethane, propane, or chloroform. No particular limitation is placed on

the specific types in the embodiment of the present application.

For the convenience of description, in the following embodiments of the present application, IPA is used as the organic solvent and carbon dioxide is employed as the drying medium for exemplary description, that is, the drying medium containing the organic solvent received by the drying-medium recovery system 100 in the following specific examples is carbon dioxide containing IPA.

#### Embodiment 2

As shown in FIG. 2, compared with embodiment 1, the present embodiment is different in that the condensate line 12 is arranged outside the first chamber 11. By means of this arrangement, the volume of the first chamber 11 can be reduced.

For the convenience of description, in the following embodiments of the present application, the condensate line 12 in embodiment 2 is arranged inside the first chamber 11 for exemplary description.

#### Embodiment 3

As shown in FIG. 3, on the basis of embodiment 1, in the present embodiment, the drying-medium recovery system 100 may further comprise a first cooling device 124, and the first cooling device 124 is sleeved around the condensate line 12 and is used to cool the temperature of the condensate line 12 within a preset temperature range.

In the present embodiment, the first cooling device 124 is sleeved around the condensate line 12, and the temperature of the condensate line 12 is cooled within the preset temperature range through heat transfer. This can enhance the condensation capacity of the condensate line 12, improve the liquefaction efficiency of IPA, and thus improve the separation effect of carbon dioxide and IPA.

In a specific example, the first cooling device 124 can be spirally wound around the condensate line 12.

#### Embodiment 4

As shown in FIG. 4, on the basis of embodiment 1, in the present embodiment, a first gas outlet 112 is further provided on the side wall of the first chamber 11 for discharging the drying medium in the first chamber 11 for recovery. As shown in FIG. 4, the drying medium discharged from the first gas outlet 112 and the outlet of condensate line 123 can merge into the sixth line 800 through lines, so that the drying medium can be discharged and recovered.

In the present embodiment, by arranging the first gas outlet 112 on the side wall of the first chamber 11, it is possible to prevent the following problem: when IPA and carbon dioxide are separated in the condensate line 12, part of the carbon dioxide escapes through the liquid discharge port 121 into the first chamber 11. This would cause an excessive accumulation of carbon dioxide in the first chamber 11, raising the internal pressure and blocking the flow of IPA—liquefied by the condensate line 12—from the liquid discharge port 121 into the first chamber 11. Thus, the separation effect of IPA and carbon dioxide can be improved.

#### Embodiment 5

In order to prevent the problem that the carbon dioxide may carry IPA during the separation process, the embodiment of the present application can further solve the above problem by the following means.

As shown in FIG. 5, on the basis of embodiment 4, in the present embodiment, the drying-medium recovery system 100 may further comprise a purification device 30. Specifically, the purification device 30 comprises a second chamber 31 provided with a second gas outlet 311, a gas inlet line 32, and a drying-medium filter membrane 33. The drying-medium filter membrane 33 is arranged in the second chamber 31 and divides the second chamber 31 into an upper space 314 and a lower space 315. The lower space 315 of the second chamber 31 is used to contain a purification solvent; the gas inlet end of the gas inlet line 32 is in communication with the outlet of condensate line 123, and the gas outlet end of the gas inlet line 32 is inserted into the second chamber 31 and inserted into the purification solvent during use; the second gas outlet 311 is arranged in the upper space 314 and is used to discharge the purified drying medium for recovery.

As is well known, the organic solvent to be separated is soluble in the purification solvent, and the drying medium to be recovered is insoluble in the purification solvent. In the present embodiment, the purification solvent is water, IPA as the organic solvent is soluble in water, and carbon dioxide as the drying medium is insoluble in water. Therefore, in the present embodiment, by using the purification solvent in the purification device 30 to further dissolve IPA carried in the carbon dioxide, and by using the drying-medium filter membrane 33 to filter out other gases except carbon dioxide, the carbon dioxide can be further purified, the problem that the carbon dioxide carries other gases or IPA can be prevented, and the purity of the carbon dioxide can be improved.

It should be noted that the drying-medium filter membrane 33 in the present embodiment is mainly used to filter out other gases except carbon dioxide; the purification solvent in the present embodiment may be water, or other solvents capable of dissolving IPA, such as ethanol, ether, benzene, etc.

With continued reference to FIG. 5, in some embodiments, the second chamber 31 further comprises a third gas outlet 313 and a second liquid outlet 312. The third gas outlet 313 is used to discharge the gas between the drying-medium filter membrane 33 and the purification solvent, that is, the gas in the lower space 315, and the second liquid outlet 312 is used to discharge the liquid in the second chamber 31.

#### Embodiment 6

As shown in FIG. 6, on the basis of embodiment 5, the drying-medium recovery system 100 in the present embodiment further comprises a first line 40, a second line 50, a switching device 60, a detection device 70, and a controller 20. The line through which the drying device 300 discharges the drying medium containing an organic solvent (i.e., the third line 400) is connected to the first line 40 and the second line 50 through the switching device 60; the first line 40 is connected to the separation device 10; the second line 50 is connected to the purification device 30; the detection device 70 is used to detect the concentration of the organic solvent in the drying medium discharged from the drying device 300, for example, the detection device 70 may be arranged on the third line 400 or on the drying device 300; the controller 20 is used to control the switching device 60 to switch between the first line 40 and the second line

50 according to the concentration of the organic solvent detected by the detection device 70. When the concentration of the organic solvent detected by the detection device 70 is greater than a preset concentration, the controller 20 controls the switching device 60 to connect the first line 40, so that the drying medium containing the organic solvent is recovered through the separation device 10 and the purification device 30 in sequence; when the concentration of the organic solvent detected by the detection device 70 is smaller than the preset concentration, the controller 20 controls the switching device 60 to connect the second line 50, so that the drying medium containing the organic solvent is directly recovered through the purification device 30.

In the present embodiment, by arranging the first line 40 to receive the drying medium containing the organic solvent with a concentration greater than the preset concentration and transfer the drying medium containing the organic solvent to the separation device 10 and the purification device 30 in sequence for carbon dioxide recovery, and arranging the second line 50 to receive the drying medium containing the organic solvent with a concentration smaller than the preset concentration and transfer the drying medium containing the organic solvent to the purification device 30 for carbon dioxide recovery, the carbon dioxide containing different concentrations of IPA can be treated, the time for carbon dioxide recovery is saved, and the efficiency of carbon dioxide recovery is improved.

It should be noted that FIG. 6 is only an example, and is not used to limit the arrangement of the switching device 60 between the third line 400 through which the drying device 300 discharges the drying medium containing the organic solvent and the first line 40 and the second line 50. For example, in some embodiments, two switching devices 60 are provided, the third line 400 is connected to the first line 40 through one of the switching devices 60, and the third line 400 is connected to the second line 50 through the other switching device 60, so as to achieve accurate switching control of each line.

Exemplarily, the switching device 60 may be a valve, and the detection device 70 may be a sensor for detecting the solution concentration.

#### Embodiment 7

As shown in FIG. 7, on the basis of embodiment 6, in the present embodiment, the supercritical drying-medium recovery system 100 further comprises a dehumidification device 80, and the dehumidification device 80 is connected between the storage device 700 and the third gas outlet 313.

In the present embodiment, the carbon dioxide purified by the purification device 30 is dried by the dehumidification device 80, preventing moisture from influencing the purity of the carbon dioxide and improving the purification purity of the carbon dioxide.

#### Embodiment 8

In the related art, particles may be generated during the separation or purification process in the semiconductor preparation process, for example, particles may be generated due to equipment aging and other reasons. These particles may contaminate the drying medium to be recovered, and ultimately affect the purity of the recovered drying medium such as carbon dioxide.

To solve the above problem, as shown in FIG. 8, on the basis of embodiment 7, in the present embodiment, the supercritical drying-medium recovery system 100 further comprises a filter device 90, and the filter device 90 is connected between the storage device 700 and the dehumidification device 80.

In the present embodiment, by configuring the filter device 90 to filter out the particle pollutants mixed in the drying medium to be recovered, the influence of the particles on the purity of the recovered drying medium such as carbon dioxide is reduced.

It should be noted that the filter device 90 may be a filter device 90 that filters out particles larger than 3 nm, or a filter device 90 that filters out smaller particles according to specific processes.

Further, on/off valves can be provided at the gas outlet, liquid outlet, gas inlet, and liquid discharge port in any embodiment of the above drying-medium recovery system 100.

It should be noted that in the drying-medium recovery system 100 as described in embodiments 1 to 4, the above dehumidification device 80 and filter device 90 may also be configured at the outlet of condensate line 123.

It should be noted that for the above embodiments 1 to 8, those skilled in the art should understand that the technical features of the above embodiments can be combined in any configuration. To simplify the description, not all possible combinations of the technical features in the above embodiments have been described. However, provided that there is no contradiction in the combination of these technical features, the combinations should be construed as falling within the scope described in the present specification. For example, the purification device 30 in the above embodiment 5 can also be combined with embodiments 2 to 4. For another example, in addition to embodiment 4 that can be configured with a first cooling device 124, other embodiments can also be configured with the first cooling device 124 as in embodiment 4.

#### Embodiment 9

The embodiment of the present application also provides a semiconductor drying apparatus. FIG. 9 is a schematic structure diagram of the semiconductor drying apparatus according to the embodiment of the present application. As shown in FIG. 9, the semiconductor drying apparatus comprises a drying-medium recovery system 100, a storage device 700, a supercritical drying-medium preparation device 200, and a drying device 300 that are sequentially connected and form a circulation loop. Wherein, the drying-medium recovery system 100 can be the drying-medium recovery system 100 in any one of the above embodiments 1 to 8.

With continued reference to FIG. 9, the drying-medium recovery system 100 stores the recovered drying medium into the storage device 700 through a sixth line 800; the storage device 700 introduces the stored drying medium into the supercritical drying-medium preparation device 200 through a fourth line 500 to process the drying medium into supercritical drying medium; the supercritical drying-medium preparation device 200 introduces the supercritical drying medium into the drying device 300 through a fifth line 600; the drying device 300 dries a wafer through the supercritical drying medium to dissolve an organic solvent remaining on the wafer to

dry the wafer, and discharges the drying medium containing the organic solvent into the drying-medium recovery system 100 through a third line 400; the drying-medium recovery system 100 separates and recovers the drying medium containing the organic solvent, so as to achieve the recycling of the drying medium.

In the present embodiment, the drying medium delivered from the storage device 700 is processed into supercritical drying medium through the supercritical drying-medium preparation device 200, and then the prepared supercritical drying medium is delivered to the drying device 300, so that the supercritical drying medium and the organic solvent on the wafer surface are fully miscible to dry the wafer. By exploiting the near-zero surface tension of the supercritical drying medium, the problem of adhesion and collapse of a high-aspect-ratio structure can be improved. Moreover, in the present embodiment, the drying medium containing the organic solvent discharged from the drying device 300 is sent to the drying-medium recovery system 100 for the recovery of the drying medium, reducing the environmental pollution caused by the drying medium and improving the resource recovery and utilization of the drying medium.

#### Embodiment 10

FIG. 10 is a structural block diagram of the semiconductor drying apparatus according to the embodiment of the present application. As shown in FIG. 10, on the basis of embodiment 9, in the present embodiment, the supercritical drying-medium preparation device 200 comprises: a second cooling device 201, for cooling the drying medium discharged from the storage device 700 into a liquid state; a pressure-boosting device 202, for boosting the pressure of the drying medium in liquid form to exceed the critical pressure of the drying medium; a heating device 203, for heating the drying medium exceeding the critical pressure to exceed the critical temperature of the drying medium to obtain a supercritical drying medium. The supercritical drying medium is introduced into the drying device 300 through the fifth line 600.

In the present embodiment, by using the above devices, the supercritical drying medium is prepared to ensure the recycling of the supercritical drying medium.

The above embodiments are only several implementation modes of the present

application, and the description of the embodiments is relatively specific and detailed, but the embodiments should not be construed as limiting the scope of the invention of the present application. 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 also be made, and the 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 defined by the appended claims.

What is claimed is:

1. A drying-medium recovery system, applied to a semiconductor drying apparatus, the semiconductor drying apparatus comprising a drying device configured to dissolve an organic solvent on a wafer through a supercritical drying medium; the drying-medium recovery system being configured to recover the drying medium from the drying medium containing the organic solvent discharged from the drying device, comprising:

a separation device, comprising a condensate line and a first chamber, a liquid discharge port being provided on the lower side wall of the condensate line, the liquid discharge port being in communication with the first chamber, an inlet of the condensate line being configured to receive the drying medium containing the organic solvent, and an outlet of the condensate line being configured to discharge the separated drying medium for recovery;

wherein, the condensate line is configured to condense the organic solvent in the drying medium containing the organic solvent, so that the organic solvent is condensed into a liquid state and flows into the first chamber from the liquid discharge port.

2. The drying-medium recovery system according to claim 1, wherein the condensate line is spiral-shaped.

3. The drying-medium recovery system according to claim 1, wherein the inlet of the condensate line and the outlet of the condensate line are disposed at different vertical levels.

4. The drying-medium recovery system according to claim 1, wherein the condensate line is arranged inside the first chamber or outside the first chamber.

5. The drying-medium recovery system according to claim 1, wherein a first liquid outlet is provided at the bottom of the first chamber, and the first liquid outlet is configured to discharge the organic solvent in the first chamber.

6. The drying-medium recovery system according to claim 1, wherein a first gas outlet is provided on the side wall of the first chamber for discharging the drying

medium in the first chamber for recovery.

7. The drying-medium recovery system according to claim 1, wherein the separation device further comprises a first cooling device connected to the condensate line, and the first cooling device is configured to keep the temperature of the condensate line within a preset temperature range.

8. The drying-medium recovery system according to claim 7, wherein the first cooling device is spirally wound around the condensate line.

9. The drying-medium recovery system according to claim 1, wherein the drying-medium recovery system further comprises a purification device, the purification device comprises a second chamber provided with a second gas outlet, a gas inlet line, and a drying-medium filter membrane, the drying-medium filter membrane is arranged in the second chamber and divides the second chamber into an upper space and a lower space; the lower space of the second chamber is configured to contain a purification solvent; a gas inlet end of the gas inlet line is in communication with the outlet of the condensate line, and a gas outlet end of the gas inlet line is inserted into the second chamber; the second gas outlet is arranged in the upper space and is configured to discharge the purified drying medium for recovery.

10. The drying-medium recovery system according to claim 9, wherein the drying-medium recovery system further comprises a first line, a second line, a detection device, a switching device, and a controller, the line through which the drying device discharges the drying medium containing the organic solvent is respectively connected to the first line and the second line through the switching device; the first line is connected to the separation device; the second line is connected to the purification device; the detection device is configured to detect the concentration of the organic solvent in the drying medium containing the organic solvent discharged from the drying device; the controller is configured to control the switching device to switch between the first line and the second line according to the concentration of the organic solvent detected by the detection device;

when the concentration of the organic solvent detected by the detection device is greater than a preset concentration, the controller controls the switching device to

switch on the first line; when the concentration of the organic solvent detected by the detection device is smaller than the preset concentration, the controller controls the switching device to switch on the second line.

11. The drying-medium recovery system according to claim 1 or 9, wherein the drying-medium recovery system further comprises a dehumidification device, and the dehumidification device is connected to the outlet of the condensate line or the second gas outlet.

12. The drying-medium recovery system according to claim 11, wherein the drying-medium recovery system further comprises a filter device, and the filter device is connected to the dehumidification device.

13. A semiconductor drying apparatus, comprising:

the drying-medium recovery system as described in any of claims 1 to 12,

a storage device, configured to store the drying medium recovered by the drying-medium recovery system;

a supercritical drying-medium preparation device, configured to process the drying medium discharged from the storage device into supercritical drying medium;  
and

a drying device, configured to dissolve an organic solvent on the wafer surface through the supercritical drying medium for wafer drying, and discharge the drying medium containing the organic solvent to the drying-medium recovery system to recover the drying medium;

wherein, the drying-medium recovery system, the storage device, the supercritical drying-medium preparation device, and the drying device are sequentially connected and form a circulation loop.

14. The semiconductor drying apparatus according to claim 13, wherein the supercritical drying-medium preparation device comprises:

a second cooling device, for cooling the drying medium discharged from the storage device to a liquid state;

a pressure-boosting device, for boosting the pressure of the drying medium in the liquid state form to exceed the critical pressure of the drying medium;

a heating device, for heating the drying medium exceeding the critical pressure to exceed the critical temperature of the drying medium to obtain a supercritical drying medium.