

GAS DISTRIBUTION DEVICE AND SEMICONDUCTOR PROCESSING APPARATUS

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TECHNICAL FIELD

[0001] The present disclosure relates to the field of semiconductor processing technology, and in particular, to a gas distribution device and a semiconductor processing apparatus.

BACKGROUND

10 [0002] An Atomic Layer Deposition (ALD) apparatus is widely applied in the current semiconductor chip manufacturing process. The systems in the ALD apparatus which are related to the gas flow mainly include a gas intake system, a gas mixing system, a gas distribution system, and an exhaust system. The systems mainly adopt a pulsed gas intake mode during a process, so that single-atom films are deposited on a surface of a wafer on a
15 base layer by layer, and the exhaust is discharged through a pumping port.

[0003] As shown in FIG. 1, an ALD apparatus includes a reaction chamber 010, a gas distribution system 101 is disposed at the top of the reaction chamber 010, and a base 018 is further disposed in the reaction chamber 010 for carrying a wafer 017. A pumping port 019 is disposed at the bottom of the reaction chamber 010. Moreover, the ALD apparatus further
20 includes a gas mixing system 102, a first gas mixing pipeline 011, a second gas mixing pipeline 012, a first source gas pipeline 013, a second source gas pipeline 014, a first diluent gas pipeline 015, and a second diluent gas pipeline 016. The first source gas pipeline 013 and the first diluent gas pipeline 015 are both communicated with a first gas inlet of the gas mixing system 102 through the first gas mixing pipeline 011, the second source gas pipeline
25 014 and the second diluent gas pipeline 016 are both communicated with a second gas inlet of the gas mixing system 102 through the second gas mixing pipeline 012, and a gas outlet of the gas mixing system 102 is communicated with a gas inlet of the gas distribution system 101. Further, the first source gas pipeline 013 and the second gas pipeline 014 are provided with a first on-off valve 131 and a second on-off valve 141, respectively.

[0004] Generally, a typical gas intake process of an ALD process in need of two source gases is shown in Table 1 below.

Table 1

step	first gas inlet		second gas inlet		description
	first source gas	first diluent gas	second source gas	second diluent gas	
S1		in		in	purging
S2	in	in		in	introduction of first source gas
S3		in		in	purging
S4		in	in	in	introduction of second source gas
S5		in		in	high-flow purging

[0005] At S1, in a preparation stage, a first diluent gas and a second diluent gas respectively conveyed by the first diluent gas pipeline 015 and the second diluent gas pipeline 016 enter the gas mixing system 102 through the first gas inlet and the second gas respectively and are mixed, and the mixed gases are dispersed through the gas distribution system 101 and uniformly introduced into the reaction chamber; and the first diluent gas and the second diluent gas are gases such as N₂ for purging the chamber and the pipelines.

[0006] At S2, the first on-off valve 131 is opened, the first diluent gas pipeline 015 and the second diluent gas pipeline 016 are kept normally open, a first source gas conveyed by the first source gas pipeline 013 flows into the first gas mixing pipeline 011 and is mixed with the first diluent gas, the mixed gases enter the gas mixing system 102 through the first gas inlet and are mixed with the second diluent gas, and then the mixed gases are dispersed through the gas distribution system 101 and uniformly introduced into the reaction chamber.

[0007] At S3, the first on-off valve 131 is closed to stop the introduction of the first source gas, and the first diluent gas pipeline 015 and the second diluent gas pipeline 016 are kept normally open for purging of the chamber and the pipelines.

[0008] At S4, the second on-off valve 141 is opened, the first diluent gas pipeline 015 and the second diluent gas pipeline 016 are kept normally open, a second source gas conveyed by the second source gas pipeline 014 flows into the second gas mixing pipeline 012 and is mixed with the second diluent gas, the mixed gases enter the gas mixing system 102 through

the second gas inlet and are mixed with the first diluent gas, and then the mixed gases are dispersed through the gas distribution system 101 and uniformly introduced into the reaction chamber.

[0009] At S5, the second on-off valve 141 is closed to stop the introduction of the second source gas, the first diluent gas pipeline 015 and the second diluent gas pipeline 016 are kept normally open, a flow rate of the first diluent gas and that of the second diluent gas are increased for high-flow purging at the end of one cycle.

[0010] At S6, steps S2 to S5 are repeated until a preset number of cycles are completed.

[0011] A gas intake time at each of step S2 and step S4 is very short, usually between several milliseconds and several hundred milliseconds, a purging time at each of step S3 and step S5 is between several hundred milliseconds and several seconds. Generally, several tens to several hundreds of cycles need to be performed for a single process.

[0012] Various source gases and diluent gases (which may include carrier gases and protective gases) are fully mixed through the gas mixing system to realize uniform concentration distribution, the mixed gases are quickly dispersed through the gas distribution system, and then the mixed gases are blown to a surface of a wafer to undergo a chemical reaction to form a film. A concentration of the mixed gases and uniformity of gas distribution and dispersion are directly related to parameters such as film thickness uniformity, and how to quickly mix and distribute the gases is crucial to shortening beat time and improving performance and production capacity.

SUMMARY

[0013] A first objective of the present disclosure is to provide a gas distribution device to solve the technical problem of non-uniform gas flow in the existing atomic layer deposition process.

[0014] The gas distribution device provided herein is applied to a semiconductor processing apparatus, the semiconductor processing apparatus includes a reaction chamber, and a cover plate is disposed at a top of the reaction chamber and provided with a gas inlet communicated with an interior of the reaction chamber; wherein the gas distribution device is configured to be disposed below the cover plate, and includes: a gas distribution plate and at least one diffusion plate;

the gas distribution plate is located below the gas inlet, a gas homogenizing chamber is formed between the gas distribution plate and the cover plate, and the gas distribution plate is provided with a plurality of gas distribution holes penetrating through the gas distribution plate along a plate thickness direction of the gas distribution plate; and

the at least one diffusion plate is disposed in the gas homogenizing chamber, and divides the gas homogenizing chamber into at least two gas homogenizing sub-chambers that are spaced apart along a vertical direction; each diffusion plate of the at least one diffusion plate is provided with a plurality of diffusion holes penetrating through the diffusion plate along a plate thickness direction of the diffusion plate; wherein a gas homogenizing sub-chamber adjacent to the cover plate is communicated with the gas inlet; any two adjacent gas homogenizing sub-chambers are communicated with each other through the diffusion holes; and a gas homogenizing sub-chamber adjacent to the gas distribution plate is communicated with the interior of the reaction chamber through the gas distribution holes.

[0015] The gas distribution device provided herein can produce the following beneficial effects:

by providing the at least one diffusion plate, the gas flow in each gas homogenizing sub-chamber can flow along an upper surface of the diffusion plate after encountering a solid portion of the diffusion plate to pass through the diffusion holes of the diffusion plate. Since a distribution region of the diffusion holes on the diffusion plate is larger than a region of the diffusion plate which corresponds to the gas inlet, after the gas flow passes through the diffusion plate, a dispersion degree of the gas flow flowing into the next gas homogenizing sub-chamber from the diffusion plate is higher than that of the gas flow in the previous gas homogenizing sub-chamber, so that uniformity of the gas flow in different regions is improved, and the accumulation of the gas flow in a central region of the gas distribution plate is weakened, which facilitates improvement in process uniformity.

[0016] In some technical solutions, the diffusion plate has a central region and an edge region around the central region; and the central region and the edge region are both provided with the plurality of diffusion holes; and

the diffusion holes located in the edge region are edge holes, and the edge holes gradually move away from a central axis of the diffusion plate from gas inlet ends of the edge holes to gas outlet ends of the edge holes.

[0017] In some technical solutions, flow guide angles of the edge holes are acute angles, and the flow guide angles are angles between extension directions of the diffusion holes and the central axis of the diffusion plate.

[0018] In some technical solutions, the flow guide angles of the diffusion holes in the central region are 0°.

[0019] In some technical solutions, an upper surface and a lower surface of the diffusion plate are both flat and arranged in parallel.

[0020] In some technical solutions, the plurality of diffusion holes are distributed on a plurality of circumferences of the diffusion plate which have different radii, flow guide angles of the diffusion holes on the plurality of circumferences gradually increase along a direction departing from a center of the diffusion plate, and the flow guide angles are included angles between extension directions of the diffusion holes and a central axis of the diffusion plate.

[0021] In some technical solutions, a hole diameter of each diffusion hole increases gradually along a direction in which gas flow flows in the diffusion hole.

[0022] In some technical solutions, a lower surface of the diffusion plate is a convex downward curved surface, and an upper surface of the gas distribution plate is a flat surface.

[0023] In some technical solutions, an upper surface of the diffusion plate is a flat surface, a convex upward curved surface, or a concave downward curved surface.

[0024] In some technical solutions, the cover plate has a first recess on a side facing the gas distribution device, and the gas homogenizing chamber is formed by an upper surface of the gas distribution plate and the first recess; or

an upper surface of the gas distribution plate is provided with a second recess, and the gas homogenizing chamber is formed by the second recess and a lower surface of the cover plate;

or

the cover plate has a first recess on a side facing the gas distribution device, an upper surface of the gas distribution plate is provided with a second recess, and the gas homogenizing chamber is formed by the first recess and the second recess.

[0025] In some technical solutions, one diffusion plate is provided, and the diffusion plate divides the gas homogenizing chamber into a first gas homogenizing sub-chamber and a second gas homogenizing sub-chamber; and the first gas homogenizing sub-chamber is communicated with the gas inlet; and

the first gas homogenizing sub-chamber has a first funnel-shaped portion and a first cylindrical portion, the gas inlet, the first funnel-shaped portion, and the first cylindrical portion are sequentially arranged from top to bottom, and a cross-sectional area of the first funnel-shaped portion perpendicular to a central axis of the diffusion plate gradually increases from top to bottom.

[0026] In some technical solutions, one diffusion plate is provided, and the diffusion plate divides the gas homogenizing chamber into a first gas homogenizing sub-chamber and a second gas homogenizing sub-chamber; and the first gas homogenizing sub-chamber is communicated with the gas inlet; and

the second gas homogenizing sub-chamber has a second funnel-shaped portion and a second cylindrical portion, the gas inlet, the first gas homogenizing sub-chamber, the second funnel-shaped portion, and the second cylindrical portion are sequentially arranged from top to bottom, and a cross-sectional area of the second funnel-shaped portion perpendicular to a central axis of the diffusion plate gradually increases from top to bottom.

[0027] In some technical solutions, a cross-sectional area of each gas distribution hole perpendicular to an axis of the gas distribution hole is the same at all positions in the vertical direction; and

for the gas distribution holes in a central region of the gas distribution plate, cross sections of the gas distribution holes perpendicular to axes of the gas distribution holes have first dimensions and second dimensions in a circumferential direction, the first dimensions are greater than or equal to the second dimensions, and directions of the first dimension are perpendicular to directions of the second dimensions.

[0028] In some technical solutions, the first dimensions are dimensions of the gas distribution holes along a radial direction of the gas distribution plate.

[0029] In some technical solutions, the gas distribution holes in the central region of the gas distribution plate are elliptical holes, slotted holes, or chamfered diamond-shaped holes.

[0030] In some technical solutions, the second dimensions of the plurality of gas distribution holes increase along a direction from a center of the gas distribution plate to an edge of the gas distribution plate.

[0031] In some technical solutions, a minimum hole diameter of the diffusion holes is 5 to 30 times the mean free path of gas molecules, and/or hole depths of the diffusion holes are 5 to 30 times the mean free path of gas molecules, and/or a minimum hole diameter of the gas distribution holes is 5 to 30 times the mean free path of gas molecules.

[0032] A second objective of the present disclosure is to provide a semiconductor processing apparatus to solve the technical problem of non-uniform gas flow in the atomic layer deposition process.

[0033] The semiconductor processing apparatus provided herein includes a reaction chamber, a base movably disposed in the reaction chamber, and the above gas distribution device disposed in the reaction chamber.

[0034] By disposing the gas distribution device in the semiconductor processing apparatus, the semiconductor processing apparatus is accordingly endowed with all advantages of the gas distribution device, and those advantages will not be described in detail here.

BRIEF DESCRIPTION OF DRAWINGS

[0035] In order to explain the technical solutions in the embodiments or the background part of the present disclosure more clearly, the drawings for the description of the embodiments or the background part will be briefly described below. Apparently, the drawings described below are just for some embodiments of the present disclosure, and other drawings can be derived by those of ordinary skill in the art from the drawings provided herein without any inventive work.

[0036] FIG. 1 is a schematic structural diagram of gas source pipelines in the background part of the present disclosure;

[0037] FIG. 2 is a schematic structural diagram of an ALD apparatus in a first related technique in the present disclosure;

[0038] FIG. 3 is a schematic structural diagram of a semiconductor processing apparatus according to a first embodiment of the present disclosure;

[0039] FIG. 4 is a schematic structural diagram of a partial structure of a gas distribution device according to the first embodiment of the present disclosure;

[0040] FIG. 5 is a half-section view of a diffusion plate in the gas distribution device according to the first embodiment of the present disclosure;

[0041] FIG. 6 is a schematic structural diagram of a gas distribution plate in the gas distribution device according to the first embodiment of the present disclosure;

[0042] FIG. 7 is a schematic diagram illustrating some shapes of gas distribution holes of the gas distribution plate in the gas distribution device according to the first embodiment of the present disclosure;

[0043] FIG. 8 is a schematic diagram illustrating a relationship between a percentage of free radical filtration loss and a hole diameter of gas distribution holes in the gas distribution device according to the first embodiment of the present disclosure;

[0044] FIG. 9 is a schematic diagram illustrating a relationship between a percentage of free radical filtration loss and a hole depth of gas distribution holes in the gas distribution device according to the first embodiment of the present disclosure;

[0045] FIG. 10 is a schematic diagram illustrating the design flow of the gas distribution plate in the gas distribution device according to the first embodiment of the present disclosure;

[0046] FIG. 11 is a schematic structural diagram of a diffusion plate in a gas distribution device according to a second embodiment of the present disclosure;

[0047] FIG. 12 is a half-section view of the diffusion plate in the gas distribution device according to the second embodiment of the present disclosure;

[0048] FIG. 13 is a half-section view of the diffusion plate in the gas distribution device provided in the second embodiment of the present disclosure according to another implementation;

[0049] FIG. 14 is a half-section view of a diffusion plate in a gas distribution device according to a third embodiment of the present disclosure; and

[0050] FIG. 15 is a half-section view of a diffusion plate in a gas distribution device according to a fourth embodiment of the present disclosure.

[0051] Description of reference numerals:

010-reaction chamber; 101-gas distribution system; 102-gas mixing system; 011-first gas mixing pipeline; 012-second gas mixing pipeline; 013-first source gas pipeline; 131-first on-off valve; 014-second source gas pipeline; 141-second on-off valve; 015-first diluent gas pipeline; 016-second diluent gas pipeline; 017-wafer; 018-base; 019-pumping port;

018'-base; 019'-pumping chamber; 020-gas intake block; 030-cover plate; 040-gas distribution plate;

11-first gas mixing pipeline; 12-second gas mixing pipeline; 13-first source gas pipeline; 132-first on-off valve; 14-second source gas pipeline; 142-second on-off valve; 15-first diluent gas pipeline; 16-second diluent gas pipeline; 17-base; 19-pumping port; 20-gas intake block; 201-gas mixing passage; 30-cover plate; 31-gas inlet; 40-gas distribution plate; 41-gas distribution holes; 50-diffusion plate; 51-diffusion holes; 511-edge hole; 60-reaction chamber; 70-side pumping plate.

DETAIL DESCRIPTION OF EMBODIMENTS

First Related Technique:

[0052] FIG. 2 is a schematic structural diagram of an ALD apparatus in a first related technique. As shown in FIG. 2, at present, the ALD apparatus in the first related technique generally adopts a central gas intake mode and a gas distribution structure corresponding to a central gas intake position. The gas distribution structure includes a cover plate 030 and a gas distribution plate 040. After the gas flow enters a passage in the cover plate 030 from a passage in a gas intake block 020, the gas flow flows downwards, is dispersed through a funnel-shaped passage structure, passes through the gas distribution plate 040 provided with many small holes to be distributed, and flows to a surface of a wafer (not shown) on a base 018'. Finally, the gas flow is pumped out through a pumping chamber 019' located on the side of a reaction chamber to be gathered at a pump port, and is discharged to the atmosphere.

[0053] In the above technical solution, the gas flow does not have good diffusion efficiency when flowing from a center to an edge; and for the mixed gas flow containing a plurality of gas components, the gas components are different in density, and are also different in diffusion efficiency. Therefore, the gas component having a higher density tends to accumulate in a central region, resulting in the problem that a concentration of the gas component having the higher density is high in the center and is low at the edge; and for the gas flow carrying remote plasma free radicals, the free radicals are denser in the central region and sparser in an edge region for the same reason.

[0054] In addition, the conventional gas distribution plate 040 only considers uniformity of the gas flow, but for the gas flow carrying the remote plasma free radicals, the conventional gas distribution plate 040 cannot uniformly distribute the free radicals to balance the free radicals in the central region and those in the edge region.

[0055] In order to make the above objectives, technical features, and advantages of the present disclosure more obvious and understandable, specific embodiments of the present disclosure are described in detail below with reference to the drawings. It should be understood that the specific embodiments described herein are just intended to explain the present disclosure, rather than limiting the present disclosure.

First Embodiment:

[0056] FIG. 3 is a schematic structural diagram of a semiconductor processing apparatus according to a first embodiment of the present disclosure; and FIG. 4 is a schematic structural diagram of a partial structure of a gas distribution device according to the first embodiment of the present disclosure. As shown in FIG. 3 and FIG. 4, the gas distribution device provided
5 in the first embodiment of the present disclosure is applied to a semiconductor processing apparatus, such as an ALD apparatus. The semiconductor processing apparatus includes a reaction chamber 60, and a cover plate 30 is disposed at the top of the reaction chamber 60, and is provided with a gas inlet 31 communicated with an interior of the reaction chamber 60; and the gas distribution device is disposed below the cover plate 30.

[0057] The gas distribution device includes a gas distribution plate 40 and at least one
10 diffusion plate 50; the gas distribution plate 40 is located below the gas inlet 31, a gas homogenizing chamber is formed between the gas distribution plate 40 and the cover plate 30, and the gas distribution plate 40 is provided with a plurality of gas distribution holes 41 penetrating through the gas distribution plate 40 along a plate thickness direction of the gas
15 distribution plate 40; the at least one diffusion plate 50 is disposed in the gas homogenizing chamber, and divides the gas homogenizing chamber into at least two gas homogenizing sub-chambers that are spaced apart along a vertical direction; each diffusion plate 50 of the at least one diffusion plate 50 is provided with a plurality of diffusion holes 51 penetrating through the diffusion plate 50 along a plate thickness direction of the diffusion plate 50; the
20 gas homogenizing sub-chamber adjacent to the cover plate 30 is communicated with the gas inlet 31; any two adjacent gas homogenizing sub-chambers are communicated with each other through the diffusion holes 51; and the gas homogenizing sub-chamber adjacent to the gas distribution plate 40 is communicated with the interior of the reaction chamber 60 through the gas distribution holes 41.

[0058] There are various ways of forming the gas homogenizing chamber between the gas
25 distribution plate 40 and the cover plate 30. In some embodiments, the cover plate 30 has a first recess on a side facing the gas distribution device, and the gas homogenizing chamber is formed by an upper surface of the gas distribution plate 40 and the first recess. In other embodiments, an upper surface of the gas distribution plate 40 is provided with a second
30 recess, and the gas homogenizing chamber is formed by the second recess and a lower surface of the cover plate 30; and in still other embodiments, the cover plate 30 has a first recess on a side facing the gas distribution device, an upper surface of the gas distribution plate 40 is

provided with a second recess, and the gas homogenizing chamber is formed by the first recess and the second recess.

[0059] In the present embodiment, a case where the cover plate 30 has the first recess on the side facing the gas distribution device, the gas homogenizing chamber is formed by the upper surface of the gas distribution plate 40 and the first recess, and only one diffusion plate 50 is provided is taken as an example to describe the gas distribution device provided in the first embodiment of the present disclosure. Exemplarily, the gas distribution device includes: the gas distribution plate 40 and the diffusion plate 50.

[0060] The gas distribution plate 40 is located below the first recess, the gas homogenizing chamber is formed by the upper surface of the gas distribution plate 40 and the first recess, and the gas distribution plate 40 is provided with the plurality of gas distribution holes 41 penetrating through the gas distribution plate 40 along the plate thickness direction of the gas distribution plate 40. The diffusion plate 50 is located between the gas distribution plate 40 and the cover plate 30, and the diffusion plate 50 is disposed in the gas homogenizing chamber to divide the gas homogenizing chamber into a first gas homogenizing sub-chamber and a second gas homogenizing sub-chamber; and the diffusion plate 50 is provided with the plurality of diffusion holes 51 penetrating through the diffusion plate 50 along the plate thickness direction of the diffusion plate 50, and the first gas homogenizing sub-chamber and the second gas homogenizing sub-chamber are communicated with each other through the diffusion holes 51. The first gas homogenizing sub-chamber is communicated with the gas inlet 31, and the gas inlet 31 is communicated with the reaction chamber 60 through the first gas homogenizing sub-chamber and the second gas homogenizing sub-chamber in sequence.

[0061] In the present embodiment, the diffusion plate 50 is connected to the cover plate 30 by thread connection using screws, and a radius of the diffusion plate 50 is between 50 mm and 100 mm. A distance between the gas inlet 31 and the diffusion plate 50 is generally within 20 mm, and a cavity of the first recess between a gas outlet end of the gas inlet 31 and an upper surface of the diffusion plate 50 is a tapered cavity with a half cone angle greater than 45°.

[0062] Taking the semiconductor processing apparatus being the ALD apparatus as an example, a process gas enters a passage in a gas intake block 20 through a side gas inlet of the gas intake block 20, and vertically flows downwards into the gas inlet 31 of the cover plate 30. A plurality of side gas inlets are generally provided, so that different reaction gases

can be respectively introduced into the reaction chamber 60 in an independent manner, an alternated manner, or a pulsed manner to realize atomic layer deposition growth, and each group of gases includes a reaction source gas, a carrier gas, and a diluent gas. Meanwhile, the gas in the gas inlet 31, which may be a pure gas such as nitrogen or a mixed gas carrying remote plasma free radicals, enters the cover plate 30 through the gas inlet 31. In a specific embodiment, as shown in FIG. 3, the ALD apparatus further includes the gas intake block 20 disposed at the top of the cover plate 30, a first gas mixing pipeline 11, a second gas mixing pipeline 12, a first source gas pipeline 13, a second source gas pipeline 14, a first diluent gas pipeline 15, and a second diluent gas pipeline 16. The first source gas pipeline 13 and the first diluent gas pipeline 15 are both communicated with a first gas inlet of a gas mixing passage 201 in the gas intake block 20 through the first gas mixing pipeline 11, the second source gas pipeline 14 and the second diluent gas pipeline 16 are both communicated with a second gas inlet of the gas mixing passage 201 in the gas intake block 20 through the second gas mixing pipeline 12, and a gas outlet of the gas mixing passage 201 is communicated with the gas inlet 31. Further, the first source gas pipeline 13 and the second source gas pipeline 14 are provided with a first on-off valve 132 and a second on-off valve 142, respectively.

[0063] In the present embodiment, a gas flow direction at the gas inlet 31 is substantially perpendicular to the diffusion plate 50 and the gas distribution plate 40, in other words, an axial direction of the tapered cavity is also perpendicular to the diffusion plate 50 and the gas distribution plate 40.

[0064] Then, the converging gas flow flows downwards while being mixed in the gas inlet 31 of the cover plate 30, and sequentially enters a two-stage structure formed by the diffusion plate 50 and the gas distribution plate 40 for efficient diffusion and gas distribution. In such two-stage structure, the gas flow first passes through the diffusion plate 50. When the gas flow is in the first gas homogenizing sub-chamber, since the gas flow after contacting the diffusion plate 50 cannot directly pass through the diffusion plate 50 from a region corresponding to the gas inlet 31, the gas flow passes through the diffusion plate 50 from a region other than the region corresponding to the gas inlet 31, so that a dispersion degree of the gas flow is improved. Thus, the gas flow spreads and flows into the whole area of the second gas homogenizing sub-chamber instead of accumulating in a central area of the second gas homogenizing sub-chamber. Then, the gas flow in the second gas homogenizing sub-chamber passes through the gas distribution holes 41 in the gas distribution plate 40 to

enter a reaction region in the reaction chamber 60, reaches a surface of a wafer placed on a base 17, and undergoes a chemical reaction under the action of heat or a plasma environment to grow a film.

[0065] In the present disclosure, by providing the at least one diffusion plate 50, the gas flow in each gas homogenizing sub-chamber can flow along the upper surface of the diffusion plate 50 after encountering a solid portion of the diffusion plate 50 to pass through the diffusion holes 51 of the diffusion plate 50. Since a distribution region of the diffusion holes 51 on the diffusion plate 50 is larger than a region of the diffusion plate 50 which corresponds to the gas inlet 31, after the gas flow passes through the diffusion plate 50, a dispersion degree of the gas flow flowing into the next gas homogenizing sub-chamber from the diffusion plate 50 is higher than that of the gas flow in the previous gas homogenizing sub-chamber, so that uniformity of the gas flow in different regions is improved, and the accumulation of the gas flow in a central region of the gas distribution plate 40 is weakened, which facilitates improvement in process uniformity.

[0066] FIG. 5 is a half-section view of the diffusion plate in the gas distribution device according to the first embodiment of the present disclosure. As shown in FIG. 3 to FIG. 5, exemplarily, the diffusion plate 50 has a central region and an edge region around the central region; and the central region and the edge region are both provided with a plurality of diffusion holes 51.

[0067] It should be noted that, sizes of the central region and the edge region of the diffusion plate 50 are not limited in the present disclosure, and may be designed based on specific products.

[0068] Illustratively, taking the diffusion holes 51 located in the edge region being edge holes 511 as an example, the edge hole 511 gradually departs from a central axis of the diffusion plate 50 from a gas inlet end of the edge hole 511 to a gas outlet end of the edge hole 511, that is, an extension direction of the edge hole 511 is not parallel to the central axis of the diffusion plate 50.

[0069] In an implementation, the diffusion holes 51 in the central region and the edge region may be uniformly distributed along a plurality of rings, and distances between the diffusion holes 51 in a same ring and a center of the diffusion plate 50 may be the same.

[0070] In an embodiment, a region where the diffusion holes 51 in the outermost ring are located is taken as the edge region, that is, the edge holes 511 are the diffusion holes 51 in the outermost ring.

[0071] Exemplarily, in the present embodiment, an included angle between the extension direction of the diffusion hole 51 and the central axis of the diffusion plate 50 is taken as a flow guide angle θ of the diffusion hole 51, and the flow guide angle θ may be an acute angle. A direction of the central axis of the diffusion plate 50 may be the same as a gas intake direction from the gas inlet 31 to the gas homogenizing chamber, that is, the flow guide angle θ may be understood as an angular change amount of a gas flow direction of the gas flow when passing through the diffusion plate 50 relative to a gas flow direction of the gas flow when flowing out from the gas inlet 31.

[0072] By setting the flow guide angle θ of the edge hole 511 at the edge of the diffusion plate 50 to be the acute angle, the gas flow at the edge of the upper surface of the diffusion plate 50 can be dispersed radically outwards; since the gas flow obtains a horizontal velocity component in the edge hole 511 of the diffusion plate 50, the gas flow after leaving the diffusion plate 50 can continue to flow towards an outer edge when the gas flow enters the second gas homogenizing sub-chamber, so when the gas flow reaches the upper surface of the gas distribution plate 40, a capability of the gas flow to flow outwards along the upper surface of the gas distribution plate 40 is improved, which can improve uniformity of the gas flow passing through the edge of the gas distribution plate 40 and the gas flow passing through the center of the gas distribution plate 40.

[0073] In another implementation, the flow guide angles θ of all the diffusion holes 51 may be set to 0° ; and due to a high flow velocity of the diffusion plate 50, a pressure-holding effect may be produced, resulting in a certain flow homogenizing and gas distribution effect. Even if a tendency that gas intake through the holes in the central region of the gas distribution plate 40 is greater than that through the holes in the edge region of the gas distribution plate 40 is not be changed, such difference in the gas intake is much smaller than that in a case without the diffusion plate 50. Therefore, operation conditions with low requirements can be met.

[0074] As shown in FIG. 3 to FIG. 5, exemplarily, the flow guide angles θ of the diffusion holes 51 located in the central region may be 0° .

[0075] Exemplarily, in the present embodiment, the diffusion holes 51 other than those in the outermost ring in the diffusion plate 50 face downward, so that only the gas flow in the central region which flows in from the gas inlet 31 is dispersed into several downward gas flows. The adjustment to a diffusion capability may be achieved through a change of hole diameters R and distribution of hole density.

[0076] Exemplarily, a lower surface of the diffusion plate 50 is tapered at the positions of the edge holes 511, which facilitates reducing a local thickness of the diffusion plate 50 at the positions of the edge holes 511. Together with the adjustment to the flow guide angles θ , such arrangement can enable the edge holes 511 to have a same hole depth h as the other diffusion holes 51, so that uniform flow resistance can be achieved under the condition of a same hole diameter R .

[0077] By arranging the diffusion holes 51 in the above manner, drilling directions of more diffusion holes 51 are unified to be perpendicular to the thickness direction of the diffusion plate 50, which can reduce design difficulty and manufacturing cost, and is applicable to situations with low diffusion requirements.

[0078] As shown in FIG. 3 to FIG. 5, exemplarily, the upper surface and the lower surface of the diffusion plate 50 are both flat and arranged in parallel.

[0079] Since the upper surface and the lower surface of the diffusion plate 50 are both flat, the diffusion holes 51 are uniform in hole depth h , so that the diffusion holes 51 have a same flow resistance under the condition of a same hole diameter R , resulting in almost uniform hole flow rate. Therefore, easy manufacturing is realized, and improvement in flow uniformity of the gas distribution plate 40 is facilitated.

[0080] As shown in FIG. 3 and FIG. 4, exemplarily, the first gas homogenizing sub-chamber has a first funnel-shaped portion and a first cylindrical portion, and the gas inlet 31, the first funnel-shaped portion, and the first cylindrical portion are sequentially arranged from top to bottom.

[0081] A cross-sectional area of the first funnel-shaped portion perpendicular to the central axis of the diffusion plate 50 gradually increases from top to bottom. The first funnel-shaped portion is a conical recess or a quadrangular pyramidal recess disposed on the lower surface of the cover plate 30, and the first cylindrical portion is a cylindrical recess disposed on the upper surface of the diffusion plate 50. The first funnel-shaped portion and the first cylindrical portion form the first gas homogenizing sub-chamber together.

[0082] By disposing the first gas homogenizing sub-chamber in such a way that the gas inlet 31, the first funnel-shaped portion, and the first cylindrical portion are sequentially arranged from top to bottom, a gas after entering the gas inlet 31 can diffuse radially outwards through the first funnel-shaped portion, and then pass through the diffusion plate 50 after entering the area of the first cylindrical portion, so that uniformity of the gas when

flowing in the diffusion holes 51 of the diffusion plate 50 is improved, which further facilitates improvement in uniformity of the gas which enters the reaction chamber 60.

[0083] Exemplarily, the second gas homogenizing sub-chamber has a second funnel-shaped portion and a second cylindrical portion, and the gas inlet 31, the second funnel-shaped portion, and the second cylindrical portion are sequentially arranged from top to bottom.

[0084] A cross-sectional area of the second funnel-shaped portion perpendicular to the central axis of the diffusion plate 50 gradually increases from top to bottom. The second funnel-shaped portion is a conical recess or a quadrangular pyramidal recess disposed on the lower surface of the cover plate 30, the second cylindrical portion is a cylindrical recess disposed on the upper surface of the gas distribution plate 40, and the second funnel-shaped portion and the second cylindrical portion form the second gas homogenizing sub-chamber together. That is, the recess on the lower surface of the cover plate 30 is in a shape of “cone-cylinder-cone”, the first “cone” refers to the first funnel-shaped portion, an inner wall surface of the “cylinder” is matched with an outer circumferential surface of the diffusion plate 50 to accommodate the diffusion plate 50, and the second “cone” refers to the second funnel-shaped portion.

[0085] By disposing the second gas homogenizing sub-chamber in such a way that the gas inlet 31, the second funnel-shaped portion, and the second cylindrical portion are sequentially arranged from top to bottom, the gas after being discharged from the diffusion holes 51 of the diffusion plate 50 can diffuse radially outwards through the second funnel-shaped portion, especially in a case where axes of the edge holes 511 in the edge region extend outwards, the gas can sufficiently diffuse radially outwards. After entering the area of the second cylindrical portion, the gas passes through the gas distribution holes 41 of the gas distribution plate 40, so that uniformity of the gas when flowing in the gas distribution holes 41 of the gas distribution plate 40 is improved, which further facilitates improvement in the uniformity of the gas which enters the reaction chamber 60.

[0086] FIG. 6 is a schematic structural diagram of the gas distribution plate in the gas distribution device according to the first embodiment of the present disclosure. As shown in FIG. 4 and FIG. 6, exemplarily, a cross-sectional area of each gas distribution hole 41 perpendicular to an axis of the gas distribution hole 41 is the same at all positions in the vertical direction. For each gas distribution hole 41 in the central region of the gas distribution plate 40, a cross section of the gas distribution hole 41 perpendicular to the axis of the gas distribution hole 41 has a first dimension and a second dimension in a

circumferential direction, the first dimension is greater than or equal to the second dimension, and a direction of the first dimension is perpendicular to that of the second dimension.

[0087] Illustratively, the gas distribution plate has a central region and an edge region around the central region. The second dimensions of the gas distribution holes 41 in the central region increase from a center of the gas distribution plate to the edge region of the gas distribution plate.

[0088] In an embodiment, within the central region of the gas distribution plate 40, the second dimensions of the gas distribution holes 41 in each ring are increased relatively to the gas distribution holes 41 in a radically inner ring. In another implementation, the second dimensions of the gas distribution holes 41 in several adjacent rings are the same, and the second dimensions of the gas distribution holes 41 in several outer rings are greater than those of the gas distribution holes 41 in the several adjacent rings. For example, the second dimensions of the gas distribution holes 41 in the two innermost rings are the same, the second dimensions of the gas distribution holes 41 in the third to fifth rings from the inside are the same and greater than the second dimensions of the gas distribution holes 41 in the two innermost rings, and the second dimensions of the gas distribution holes 41 in the sixth and seventh rings are greater and are the same.

[0089] In some embodiments of the present disclosure, the first dimensions and the second dimensions of the gas distribution holes 41 may be set to be equal in the edge region of the gas distribution plate 40. For example, cross-sectional shapes of the gas distribution holes 41 may be circular in the edge region of the gas distribution plate 40.

[0090] With the cross-sectional area of each gas distribution hole 41 perpendicular to the axis of the gas distribution hole 41 set to be the same at all the positions in the vertical direction, the gas distribution holes 41 are almost uniform in conductance, so that a gas homogenizing effect can be ensured. A double distribution effect of the gas flow and the free radicals is realized, that is, uniformity of gas flow and uniformity of passage of the free radicals are both ensured, so that processing quality of the wafer is improved.

[0091] The plasma free radicals are recombined after contacting a wall surface. Through the auxiliary diffusion by the diffusion plate 50, in the space above the gas distribution plate 40, the free radicals in the gas flow flowing through the diffusion holes 51 in the central region of the diffusion plate 50 inevitably contact the upper surface of the gas distribution plate 40 and are mostly recombined when moving outwards from the center in the second gas

homogenizing sub-chamber, such that a concentration of the free radicals in an outer region is reduced.

[0092] For the free radicals, an efficiency of passing through a hole is mainly determined by a smallest dimension, a narrow and long structure hinders the passage by the free radicals, and the free radicals can easily contact an inner surface of the hole due to molecular collision. In view of this, the second dimensions of the gas distribution holes 41 in the central region of the gas distribution plate 40 are reduced to reduce the passage efficiency of the free radicals through the gas distribution holes 41 in the central region of the gas distribution plate 40. The second dimensions of the gas distribution holes 41 in the edge region are made greater than those of the gas distribution holes 41 in the central region, so that the passage efficiency of the free radicals in the edge region is higher than that of the free radicals in the central region. Thus, an effect that a free radical concentration in the central region is higher than that in the edge region is weakened or even eliminated, so that the concentration of the free radicals which reach the surface of the wafer is uniform in the central region and the edge region as much as possible, and process quality is improved.

[0093] As shown in FIG. 6, exemplarily, the first dimension is a dimension of the gas distribution hole 41 along a radial direction of the gas distribution plate 40.

[0094] The direction of the first dimension is a length direction of the gas distribution hole 41. By setting the length direction as the radial direction of the gas distribution plate 40, an influence of the arrangement of the holes in the gas distribution plate 40 on radial flow of the gas flow can be reduced when the gas flow flows on the surface of the gas distribution plate 40 along the radial direction, so that the gas flow can keep flowing and flow smoothly on the surface of the gas distribution plate 40, which ensures a gas distribution effect of the gas distribution plate 40.

[0095] In another implementation, the first dimension may not be the dimension of the gas distribution hole 41 along the radial direction of the gas distribution plate 40. For example, the first dimension is a dimension of the gas distribution hole 41 along a circumferential direction of the gas distribution plate 40, that is, the length direction of the gas distribution hole 41 is a tangential dimension of the gas distribution plate 40 at the position of the gas distribution hole 41, or even the direction of the first dimension of each gas distribution hole 41 is random as long as a ratio of the first dimension to the second dimension is in accordance with the above description, and an effect of improving the uniformity of the free radical concentration by adjusting the passage efficiency of the free radicals can also be produced.

[0096] FIG. 7 is a schematic diagram illustrating some shapes of the gas distribution holes 41 of the gas distribution plate in the gas distribution device according to the first embodiment of the present disclosure. As shown in FIG. 7, exemplarily, the gas distribution holes 41 in the central region of the gas distribution plate 40 are elliptical holes, slotted holes, or chamfered diamond-shaped holes.

[0097] By setting the gas distribution holes 41 in the above shapes, a flow rate of the free radicals is balanced, and moreover, processability of the gas distribution holes 41 is improved, and manufacturing cost is reduced.

[0098] As shown in FIG. 6, exemplarily, the second dimensions of the plurality of gas distribution holes 41 increase along a direction from the center of the gas distribution plate 40 to the edge of the gas distribution plate 40. For example, length-width ratios of the gas distribution holes 41 gradually decrease from the center of the gas distribution plate 40 to the edge of the gas distribution plate 40. That is, in a case where the cross-sectional area of each gas distribution hole 41 perpendicular to the axis of the gas distribution hole 41 is the same, the second dimensions become greater along the direction from the center of the gas distribution plate 40 to the edge of the gas distribution plate 40.

[0099] By increasing the second dimensions of the plurality of gas distribution holes 41 along the direction from the center of the gas distribution plate 40 to the edge of the gas distribution plate 40, for example, by gradually decreasing the length-width ratios of the gas distribution holes 41, the passage efficiency of the free radicals through the gas distribution holes 41 can be gradually increased from the inside to the outside along the radial direction of the gas distribution plate 40 to be matched with a gradual reduction of density of the free radicals on the upper surface of the gas distribution plate 40, so as to improve density uniformity of the free radicals on the lower surface of the gas distribution plate 40, thereby improving product processing quality.

[0100] Exemplarily, a minimum hole diameter of the diffusion holes 51 (for example, the hole diameter R of the diffusion holes 51 when the diffusion holes 51 are circular holes) is 5 to 30 times the mean free path of gas molecules, and/or the hole depths h of the diffusion holes 51 are 5 to 30 times the mean free path of gas molecules, and/or a minimum hole diameter R_a of the gas distribution holes 41 is 5 to 30 times the mean free path of gas molecules.

[0101] The minimum hole diameter R_a of the gas distribution holes 41 refers to a radius of the gas distribution holes 41 when the gas distribution holes 41 are circular holes, a semi-

minor axis length of an ellipse when the gas distribution holes 41 are elliptical holes, or half a length of shorter opposite sides of a shortest rhombus when the gas distribution holes 41 are chamfered diamond-shaped holes, or half a width of a slotted hole.

[0102] In the present embodiment, the diffusion holes 51 in each ring have the same hole diameter R, while the hole diameters of the diffusion holes 51 in different rings may increase uniformly or non-uniformly. The design of the hole diameters is related to a filtration efficiency of the free radicals, and the free radicals collide greatly in a low-pressure environment. As the hole diameters R become smaller, the probability of the free radicals contacting hole walls while moving in the diffusion holes 51 gradually increases, and a recombination loss generated after the free radicals contact with the hole walls also increases, as shown in FIG. 8. For the same reason, the greater the hole depths h, the greater the recombination loss, as shown in FIG. 9. Therefore, the hole diameters R and the hole depths h need to be set based on the mean free path $\bar{\lambda}$ of gas molecules and are generally set to be 5 to 30 times of $\bar{\lambda}$.

[0103] The mean free path $\bar{\lambda}$ of gas molecules meets the following relational equation:

$$\bar{\lambda} = \frac{kT}{\sqrt{2}\pi\sigma^2 \cdot p}$$

where k is a constant, T is a gas molecule temperature, σ is a gas molecule collision diameter and is related to a gas type, and p is pressure.

[0104] Similarly, the hole diameter R when the gas distribution holes 41 are circular holes or the minimum hole diameter Ra when the gas distribution holes 41 are non-circular holes is also 5 to 30 times the mean free path of gas molecules.

[0105] Taking the gas distribution holes 41 in the central region to be elliptical holes as an example, the design flow of the gas distribution plate 40 is shown in FIG. 10.

[0106] First, estimation is performed based on gas and process parameters (including power, gas amount, pressure, etc.) to determine free radical density (such as a density of the remote plasma free radicals) and a conductance of the gas distribution holes 41 for distributing a gas uniformly; then, the hole diameters and the number of the gas distribution holes 41 at the outermost circular cross section are determined; then, based on the free radical density and recombination loss probability, a minor axis length and a major axis length of an ellipse capable of balancing the loss of the free radicals are calculated; then, samples are prepared, an actual effect is tested, and if the actual effect does not meet design requirements, the

calculated parameters are corrected based on the result, the number or the diameters of the circular gas distribution holes 41 and the elliptical gas distribution holes 41 are adjusted until a process result after sample preparation meets the design requirements, and the cycle is ended.

5 Second Embodiment

[0107] FIG. 11 is a schematic structural diagram of a diffusion plate in a gas distribution device according to a second embodiment of the present disclosure; and FIG. 12 is a half-section view of the diffusion plate in the gas distribution device according to the second embodiment of the present disclosure. As shown in FIG. 11 and FIG. 12, the present
10 embodiment differs from the first embodiment mainly in that the plurality of diffusion holes 51 are distributed on a plurality of circumferences of the diffusion plate 50 which have different radii, and the flow guide angles θ of the diffusion holes 51 on the plurality of circumferences gradually increase along a direction departing from the center of the diffusion plate 50. The flow guide angle θ is the angle between the extension direction of the diffusion
15 hole 51 and the central axis of the diffusion hole 51.

[0108] Exemplarily, in the present embodiment, the diffusion holes 51 are distributed in the diffusion plate 50 along rings. That is, a plurality of diffusion holes 51 may be disposed at a certain distance from the center of the diffusion plate 50. The flow guide angles θ of the diffusion holes 51 gradually increase uniformly or non-uniformly. Uniformly increasing
20 refers to that the flow guide angles θ of the diffusion holes 51 in each ring are increased by a fixed value relative to the flow guide angles θ of the diffusion holes 51 in an adjacent ring, or the axes of the diffusion holes 51 in all rings point to a same point.

[0109] In addition, the flow guide angles θ are always kept to be acute angles, resulting in a smooth flow guide process with small flow resistance and a small influence on the wall
25 surface recombination effect of the plasma free radicals. An effect of efficient distribution of the gas flow and the free radicals can be produced under the condition of small flow resistance and less recombination, which is particularly suitable for requirements of the ALD process and apparatus.

[0110] By gradually increasing the flow guide angles θ of the plurality of the diffusion holes
30 51 on the plurality of circumferences along the direction departing from the center of the diffusion plate 50, the gas flow entering the diffusion holes 51 from above the diffusion plate 50 can be guided to be distributed and deflected, so that auxiliary diffusion is realized. Therefore, an included angle between the gas flow flowing in the diffusion holes 51 at the

positions farther from the center of the diffusion plate 50 and the gas flow flowing in the diffusion holes 51 in the central region of the diffusion plate 50 can be increased gradually, and a capability of the gas flow at the above positions to further diffuse outwards after passing through the diffusion plate 50 is improved, so that a concentration of the gas flow in the edge region of the gas distribution plate 40 is increased, uniformity of gas distribution above the gas distribution plate 40 is improved, and the processing quality is improved.

[0111] As shown in FIG. 4, FIG. 11, and FIG. 12, exemplarily, the lower surface of the diffusion plate 50 is a convex downward curved surface, and the upper surface of the gas distribution plate 40 is a flat surface.

[0112] Since the lower surface of the diffusion plate 50 is the convex downward curved surface and the upper surface of the gas distribution plate 40 is the flat surface, the fluid space sandwiched between the diffusion plate 50 and the gas distribution plate 40 is not uniform, and the gas flow flowing out of the diffusion holes 51 can be easily squeezed outwards to further diffuse towards the edge region.

[0113] As shown in FIG. 11 and FIG. 12, exemplarily, the upper surface of the diffusion plate 50 is a flat surface.

[0114] By arranging the diffusion plate 50 such that the upper surface is the flat surface and the lower surface is the convex downward curved surface, effective hole lengths of the diffusion holes 51 in the central region can be made consistent with those of the diffusion holes 51 in the edge region, or the effective hole lengths of the diffusion holes 51 in the edge region can be made smaller.

[0115] FIG. 13 is a half-section view of the diffusion plate in the gas distribution device provided in the second embodiment of the present disclosure according to another implementation. As shown in FIG. 13, exemplarily, the hole diameter of each diffusion hole 51 gradually increases along a direction in which the gas flow flows in the diffusion hole 51.

[0116] By setting the diffusion hole 51 in the form of a horn hole, the gas flow can diffuse within the diffusion hole 51 instead of flowing along an unchanged direction within the hole, which can further enhance a diffusion effect, and improve the uniformity of the gas flow.

Third Embodiment

[0117] FIG. 14 is a half-section view of a diffusion plate in a gas distribution device according to a third embodiment of the present disclosure. As shown in FIG. 14, the present embodiment differs from the second embodiment in that the upper surface of the diffusion plate 50 in the present embodiment is a convex upward curved surface.

[0118] With the upper surface of the diffusion plate 50 being the convex upward curved surface and the lower surface of the diffusion plate 50 being the convex downward curved surface, the effective hole lengths h of the diffusion holes 51 in the central region of the diffusion plate 50 are greater. Since the flow resistance is related to the effective hole length h , the greater the effective hole length h , the greater the flow resistance. Therefore, the gas amount of the diffusion holes 51 in the central region of the diffusion plate 50 are smaller. Thus, the adjustment to the flow resistance can be achieved by adjusting the effective hole lengths of the diffusion holes 51 in the central region and those of the diffusion holes 51 in the edge region.

Fourth Embodiment

[0119] FIG. 15 is a half-section view of a diffusion plate in a gas distribution device according to a fourth embodiment of the present disclosure. As shown in FIG. 15, the present embodiment differs from the third embodiment in that the upper surface of the diffusion plate 50 in the present embodiment is a concave downward curved surface.

[0120] With the upper surface of the diffusion plate 50 being the concave downward curved surface and the lower surface of the diffusion plate 50 being the convex downward curved surface, the effective hole lengths of the diffusion holes 51 in the central region can be made consistent with those of the diffusion holes 51 in the edge region, so under the same conditions, the flow resistance is uniform, and the flow rate is also uniform, which facilitates improving the uniformity of the gas flow.

[0121] In summary, whether the upper surface of the diffusion plate 50 is horizontal or is upwardly convex or downwardly concave, the plate thicknesses of the diffusion plate 50 at different positions can be adjusted, that is, the effective hole lengths h of the diffusion holes 51 in the central region or those of the diffusion holes 51 in the edge region can be adjusted, so as to further adjust the flow resistance in the central region and that the edge region, thereby adjusting the gas intake.

[0122] By adjusting the flow guide angles θ of the diffusion holes 51, orientations of the diffusion holes 51 can be changed to adjust the effective hole lengths h of the diffusion holes 51 in the edge region to be smaller than those of the diffusion holes 51 in the central region, so that the flow resistance of the diffusion holes 51 in the edge region is reduced, and more gas flow can pass through the diffusion holes 51 in the edge region, thereby weakening the central accumulation effect of the gas. Further, by adjusting the flow guide angles θ , even if the effective hole lengths h are uniform and the flow rate is uniform, the directions of the

gas flowing out from the diffusion holes 51 can be changed, so that the gas can quickly diffuse to the edge of the upper surface of the gas distribution plate 40, which improves the uniformity of the gas flow.

[0123] The edge holes 511 are set to be outward inclined holes, the diffusion holes 51 in the central ring or the one diffusion hole 51 at the center is disposed vertically downwards, and the remaining diffusion holes 51 gradually increase in a radial manner. With such arrangement, the flow guide angles θ can gradually increase. By adjusting the angles, diffusion directions and the effective hole lengths of the diffusion holes 51 can be changed to further change and adjust a diffusion capability. This solution involves a complex structure and numerous adjustable parameters, and is high in design difficulty, processing requirements, and manufacturing cost, but the solution is applicable to different process types or hardware conditions, and is particularly suitable for the remote plasma free radicals susceptible to wall surface recombination and a gas such as an organic source gas which is hard to diffuse due to a high density. Certainly, the diffusion requirements and the diffusion capability depend on actual demand of the gas flow of a machine, and the flow guide angles θ and a difference between the effective hole lengths h of the diffusion holes 51 in the central region and those of the diffusion holes 51 in the edge region are not the bigger the better, otherwise, the phenomenon that the gas intake in the central region is greater and more gas is likely to accumulate in the central region may be reversed, such that the gas intake in the edge region is more or even more gas accumulates in the edge region. The third embodiment and the fourth embodiment illustrate the solutions for implementing different diffusion capabilities, and there are working conditions respectively applicable to the solutions illustrated by the third embodiment and the fourth embodiment.

Fifth Embodiment

[0124] As shown in FIG. 3, a semiconductor processing apparatus provided in a fifth embodiment of the present disclosure includes the reaction chamber 60, the base 17 disposed in the reaction chamber 60, and the above gas distribution device disposed in the reaction chamber 60.

[0125] A side pumping plate 70 is further disposed in the reaction chamber 60, and a pumping chamber is formed between the side pumping plate 70 and the reaction chamber 60 and is communicated with a pumping port 19 disposed at the bottom of the reaction chamber 60, so as to pump out a gas which enters the reaction chamber 60 from the gas inlet 31 and reacts with a wafer on the base 17. Exemplarily, the gas flow from the gas inlet 31 is distributed by

the gas distribution device, and then flows to a surface of the wafer (not shown) on the base 17 in the reaction chamber 60, and the gas reacting with the wafer on the base 17 is pumped out through the pumping chamber located on a side of the reaction chamber 60 to be gathered at the pumping port 19, and is discharged to the atmosphere.

5 [0126] In some embodiments, the semiconductor processing apparatus is an ALD apparatus, for example.

[0127] By disposing the gas distribution device in the semiconductor processing apparatus, the semiconductor processing apparatus is accordingly endowed with all the advantages of the gas distribution device, and those advantages will not be described in detail here.

10 [0128] Although the present disclosure is disclosed as above, the present disclosure is not limited to the above. Various changes and improvements can be made by those of ordinary skill in the art without departing from the spirit and scope of the present disclosure, so that the scope of the present disclosure is the scope of the appended claims.

[0129] Finally, it should be noted that the relational terms such as “first” and “second” herein
15 are just used to distinguish one entity or operation from another entity or operation, and do not necessarily require or imply that such relationship or order actually exists between the entities or operations. Moreover, the term “include” or any other variation thereof is intended to indicate a non-exclusive inclusion, so that a process, method, article, or device, which includes a series of elements, does not only include those listed elements but also include
20 other elements that are not explicitly listed, or the elements inherent in such process, method, article, or device. If there are no more limitations, limiting an element by “including a...” does not exclude the existence of other identical elements in the process, method, article, or device which includes the element.

[0130] In the above embodiments, the descriptions using the terms such as “up” and “down”
25 is based on the drawings.

[0131] The above description of the embodiments of the present disclosure can enable those of ordinary skill in the art to implement or use the present disclosure. Various modifications to these embodiments are apparent to those of ordinary skill in the art, and the general principle defined herein may be implemented in other embodiments without departing from
30 the spirit or scope of the present disclosure.

[0132] Thus, the present disclosure is not limited to the embodiments described herein, but falls in the widest scope consistent with the principle and novel features disclosed herein.

What is claimed is:

1. A gas distribution device applied to a semiconductor processing apparatus; the semiconductor processing apparatus comprising a reaction chamber, and a cover plate
5 being disposed at a top of the reaction chamber and provided with a gas inlet communicated with an interior of the reaction chamber; wherein the gas distribution device is configured to be disposed below the cover plate, and comprises: a gas distribution plate and at least one diffusion plate;

the gas distribution plate is located below the gas inlet, a gas homogenizing
10 chamber is formed between the gas distribution plate and the cover plate, and the gas distribution plate is provided with a plurality of gas distribution holes penetrating through the gas distribution plate along a plate thickness direction of the gas distribution plate; and

the at least one diffusion plate is disposed in the gas homogenizing chamber, and
15 divides the gas homogenizing chamber into at least two gas homogenizing sub-chambers that are spaced apart along a vertical direction; each diffusion plate of the at least one diffusion plate is provided with a plurality of diffusion holes penetrating through the diffusion plate along a plate thickness direction of the diffusion plate; wherein a gas homogenizing sub-chamber adjacent to the cover plate is communicated with the gas inlet;
20 any two adjacent gas homogenizing sub-chambers are communicated with each other through the diffusion holes; and a gas homogenizing sub-chamber adjacent to the gas distribution plate is communicated with the interior of the reaction chamber through the gas distribution holes.

25 2. The gas distribution device of claim 1, wherein the diffusion plate has a central region and an edge region around the central region; and the central region and the edge region are both provided with the plurality of diffusion holes; and

the diffusion holes located in the edge region are edge holes, and the edge holes gradually move away from a central axis of the diffusion plate from gas inlet ends of the
30 edge holes to gas outlet ends of the edge holes.

3. The gas distribution device of claim 2, wherein flow guide angles of the edge holes are acute angles, and the flow guide angles are angles between extension directions

of the diffusion holes and the central axis of the diffusion plate.

4. The gas distribution device of claim 3, wherein the flow guide angles of the diffusion holes in the central region are 0° .

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5. The gas distribution device of claim 4, wherein an upper surface and a lower surface of the diffusion plate are both flat and arranged in parallel.

6. The gas distribution device of claim 1, wherein the plurality of diffusion holes are distributed on a plurality of circumferences of the diffusion plate which have different radii, flow guide angles of the diffusion holes on the plurality of circumferences gradually increase along a direction departing from a center of the diffusion plate, and the flow guide angles are included angles between extension directions of the diffusion holes and a central axis of the diffusion plate.

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7. The gas distribution device of claim 1 or 6, wherein a hole diameter of each diffusion hole increases gradually along a direction in which gas flow flows in the diffusion hole.

8. The gas distribution device of claim 6, wherein a lower surface of the diffusion plate is a convex downward curved surface, and an upper surface of the gas distribution plate is a flat surface.

9. The gas distribution device of claim 8, wherein an upper surface of the diffusion plate is a flat surface, a convex upward curved surface, or a concave downward curved surface.

10. The gas distribution device of any one of claims 1 to 6, wherein the cover plate has a first recess on a side facing the gas distribution device, and the gas homogenizing chamber is formed by an upper surface of the gas distribution plate and the first recess;
or

an upper surface of the gas distribution plate is provided with a second recess, and the gas homogenizing chamber is formed by the second recess and a lower surface of the

cover plate; or

the cover plate has a first recess on a side facing the gas distribution device, an upper surface of the gas distribution plate is provided with a second recess, and the gas homogenizing chamber is formed by the first recess and the second recess.

5 11. The gas distribution device of any one of claims 1 to 6, wherein one diffusion plate is provided, and the diffusion plate divides the gas homogenizing chamber into a first gas homogenizing sub-chamber and a second gas homogenizing sub-chamber; and the first gas homogenizing sub-chamber is communicated with the gas inlet; and

10 the first gas homogenizing sub-chamber has a first funnel-shaped portion and a first cylindrical portion, the gas inlet, the first funnel-shaped portion, and the first cylindrical portion are sequentially arranged from top to bottom, and a cross-sectional area of the first funnel-shaped portion perpendicular to a central axis of the diffusion plate gradually increases from top to bottom.

15 12. The gas distribution device of any one of claims 1 to 6, wherein one diffusion plate is provided, and the diffusion plate divides the gas homogenizing chamber into a first gas homogenizing sub-chamber and a second gas homogenizing sub-chamber; and the first gas homogenizing sub-chamber is communicated with the gas inlet; and

20 the second gas homogenizing sub-chamber has a second funnel-shaped portion and a second cylindrical portion, the gas inlet, the first gas homogenizing sub-chamber, the second funnel-shaped portion, and the second cylindrical portion are sequentially arranged from top to bottom, and a cross-sectional area of the second funnel-shaped portion perpendicular to a central axis of the diffusion plate gradually increases from top
25 to bottom.

13. The gas distribution device of any one of claims 1 to 6, wherein a cross-sectional area of each gas distribution hole perpendicular to an axis of the gas distribution hole is the same at all positions in the vertical direction; and

30 for the gas distribution holes in a central region of the gas distribution plate, cross sections of the gas distribution holes perpendicular to axes of the gas distribution holes have first dimensions and second dimensions in a circumferential direction, the first dimensions are greater than or equal to the second dimensions, and directions of the first

dimension are perpendicular to directions of the second dimensions.

14. The gas distribution device of claim 13, wherein the first dimensions are dimensions of the gas distribution holes along a radial direction of the gas distribution
5 plate.

15. The gas distribution device of claim 13, wherein the gas distribution holes in the central region of the gas distribution plate are elliptical holes, slotted holes, or chamfered diamond-shaped holes.
10

16. The gas distribution device of claim 13, wherein the second dimensions of the plurality of gas distribution holes increase along a direction from a center of the gas distribution plate to an edge of the gas distribution plate.

17. The gas distribution device of claim 13, wherein a minimum hole diameter of the diffusion holes is 5 to 30 times the mean free path of gas molecules, and/or hole depths of the diffusion holes are 5 to 30 times the mean free path of gas molecules, and/or a minimum hole diameter of the gas distribution holes is 5 to 30 times the mean free path of gas molecules.
15

18. A semiconductor processing apparatus, comprising a reaction chamber, a base disposed in the reaction chamber, and the gas distribution device of any one of claims 1 to 17 disposed in the reaction chamber.
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