

ADJUSTABLE GAS DISTRIBUTION SYSTEM

Cross References to Related Applications

This application claims the benefit of and priority to U.S. Provisional Application No. 60/475,079 filed May 30, 2003, the disclosure of which is hereby incorporated by reference in its entirety.

Field of the Invention

The present invention relates generally to the field of semiconductor equipment and processing. More specifically, the present invention relates to an adjustable gas distribution apparatus useful in semiconductor fabrication.

Background of the Invention

Wafer processing reactor systems and methods are widely used in the manufacture of semiconductors and integrated circuits. One particular type of wafer processing system utilizes chemical vapor deposition (CVD) to deposit films or layers on the surface of a substrate as a step in the manufacture of semiconductors and integrated circuits. As described in the prior art, in chemical vapor deposition in semiconductor device fabrication (or other chemical reactors in which reaction products are desired to deposit or form in certain geometric manifestations), it is often required to modify a gas dispersion device from a simple basic design that imparts changes necessary to achieve a desired end result. Examples of such systems are shown for instance in U.S. Patent Nos. 6,415,736, 6,410,089, 6,284,673, 6,050,506, 6,184,986 and 6,126,753, among others.

Atomic layer deposition (ALD) is an alternative to CVD processes to deposit very thin films. ALD can be performed at comparatively lower temperatures which is compatible with the industry's trend toward lower temperatures, has high precursor utilization efficiency, and can produce conformal thin film layers. More advantageously, ALD can control film thickness on an atomic scale, and can be used to "nano-engineer" complex thin films. In an ALD process cycle, each reactant gas is introduced independently into a reaction chamber through, for example a showerhead, so that no gas phase intermixing occurs. A monolayer of

a first reactant is physi- or chemisorbed onto a substrate surface. Excess first reactant is evacuated from the reaction chamber preferably with the aid of an inert purge gas. A second reactant is then introduced to the reaction chamber and reacted with the first reactant to form a monolayer of the desired thin film via a self-limiting surface reaction. The self-limiting reaction stops once the initially adsorbed first reactant fully reacts with the second reactant. Excess second reactant is evacuated, preferably with the aid of an inert purge gas. A desired film thickness is obtained by repeating the deposition cycle as necessary. The film thickness can be controlled to atomic layer accuracy by simply counting the number of deposition cycles.

In many CVD or ALD applications, a simple basic geometry of outlet holes in a gas distribution apparatus does not achieve the required deposition thickness specifications. It has been demonstrated that a constant array of outlet holes or "pitch" does not necessarily create a uniform deposition on a wafer. It is therefore desirable to alter the outlet hole pattern or size to create the desired end effect. One prior art approach is to alter the location and/or size of the outlets to achieve the desired deposition pattern. This approach has had limited success however, as it does not allow for adjustment if further changes are necessary, such as in utilizing the same apparatus for more than one particular process or recipe which may be effected by the outlet configuration. Therefore, further development in gas distribution apparatus useful in CVD and ALD are needed.

Summary of the Invention

An adjustable gas distribution apparatus useful in semiconductor fabrication is provided. The adjustable gas distribution apparatus of the present invention allows one to alter the size and/or direction of gases exiting the gas distribution apparatus and thus selectively tailor the configuration of the apparatus to achieve a desired end response.

In one aspect, the present invention provides a gas distribution apparatus comprising a plurality of outlets and at least one replaceable insert placed in at least one of the outlets. The insert is provided with a passageway adapted to alter the size of and/or the direction of gases

exiting the at least one of the outlets. The insert can be placed in the outlet by threading. Alternatively, the insert can be placed in the outlet by press fit.

In one embodiment, the insert is provided with a passageway that is substantially straight and cylindrical. The passageway may have a first portion with a smaller diameter and a second portion with a larger diameter to selectively alter the size of the outlet passage in the gas distribution apparatus.

In another embodiment, the insert is provided with a main passageway and plurality of secondary passageways branched and angled from the main passageway. The angle between the main and branch passageways is in the range from about 10 to about 90 degrees. In one embodiment, the angle between the main and branch passageways is about 90 degrees.

In another aspect, the present invention provides a gas distribution apparatus comprising a unitary body having a surface facing a processing region and a plurality of outlet passages formed within the unitary body and extending through the surface for providing gases into the processing region. At least one replaceable insert is placed in at least one of the outlet passages to allow altering the size of at least one of the outlet passages and/or the direction of gases exiting the at least one of the outlet passages into the processing region.

Brief Description of the Drawings

Other objects and advantages of the present invention become apparent upon reading of the detailed description of the invention provided below and upon reference to the drawings in which:

FIG. 1 is external view of a showerhead showing a plurality of through outlet holes in which one or more replaceable inserts of the present invention can be installed.

FIG. 2 shows an internal gas distribution network within the showerhead as illustrated in FIG. 1.

FIG. 3 is a front view of a screw type insert according to one embodiment of the present invention.

FIG. 4 is a top view of the screw type insert illustrated in FIG. 3 according to one embodiment of the present invention.

FIG. 5 is a cross-sectional view along line A-A of the screw type insert illustrated in FIG. 4 according to one embodiment of the present invention.

FIG. 6 is a partial cross-sectional view of a showerhead installed with the insert illustrated in FIGS. 3-5 according to one embodiment of the present invention.

FIG. 7 is a front view of a press-fit type insert having multiple branch passageways angled from a main passageway according to one embodiment of the present invention.

FIG. 8 is a top view of the press-fit type insert illustrated in FIG. 7 according to one embodiment of the present invention.

FIG. 9 is a cross-sectional view along line B-B of the press-fit type insert illustrated in FIG. 8 according to one embodiment of the present invention.

FIG. 10 is a partial cross-sectional view of a showerhead installed with the press-fit type insert illustrated in FIGS. 7-9 according to one embodiment of the present invention.

FIG. 11 is a front view of a press-fit type of insert having multiple branch passageways perpendicular to a main passageway according to one embodiment of the present invention.

FIG. 12 is a top view of the press-fit type insert illustrated in FIG. 11 according to one embodiment of the present invention.

FIG. 13 is a cross-sectional view along line C-C of the press-fit type insert illustrated in FIG. 12 according to one embodiment of the present invention.

FIG. 14 is a partial cross-sectional view of a showerhead installed with the press-fit type insert illustrated in FIGS. 11-13 according to one embodiment of the present invention.

FIG. 15 is a front view of a press-fit type insert showing details of press fit engagement region according to one embodiment of the present invention.

FIG. 16 is a top view of the press-fit type insert illustrated in FIG. 15 according to one embodiment of the present invention.

FIG. 17 is a cross-sectional view along line D-D of the press-fit type insert illustrated in FIG. 16 according to one embodiment of the present invention.

FIG. 18 is a partial cross-sectional view of a showerhead showing engagement details between the press-fit type insert illustrated in FIGS. 15-17 and the outlet in the showerhead according to one embodiment of the present invention.

FIG. 19 is a front view of a press-fit type insert showing details of press fit engagement region according to one embodiment of the present invention.

FIG. 20 is a top view of the press-fit type insert illustrated in FIG. 19 according to one embodiment of the present invention.

FIG. 21 is a front view of a screw type insert showing multiple passageways according to one embodiment of the present invention.

FIG. 22 is a top view of the screw type insert illustrated in FIG. 21 according to one embodiment of the present invention.

FIG. 23 is a cross-sectional view along line F-F of the screw type insert illustrated in FIG. 22 according to one embodiment of the present invention.

FIG. 24 is a partial cross-sectional view of a showerhead installed with the screw type insert illustrated in FIGS. 21-23 according to one embodiment of the present invention.

Detailed Description of the Invention

An adjustable gas distribution apparatus useful in semiconductor fabrication is provided. In general, the adjustable gas distribution apparatus of the present invention comprises a plurality of gas outlets and one or more inserts installed in one or more of the outlets which allow altering of the size of the outlets and/or the direction of gases exiting the gas distribution apparatus and thus selectively tailoring the gas flow velocity and pattern to specific process requirements.

Referring to the drawings where like components are designated by like reference numerals, the present adjustable gas distribution apparatus is described in more detail.

FIG. 1 shows a showerhead 10 in which one or more inserts of the present invention can be used. It should be noted that the showerhead 10 shown in FIG. 1 is for illustrative purpose only and not intended to limit the scope of the invention in any way. The inserts described below can be used in any other gas distribution apparatus where adjustment of flow velocity and/or direction of gases exiting the apparatus is desired. Generally, in a showerhead, a plurality of channels, passages or holes are created to form an internal gas distribution network in a member. The member can be a single unitary block within which an internal gas distribution network is formed. The member can also be comprised of several individual blocks, within each of which a plurality of channels, passages or holes are formed. These individual blocks are then connected and assembled as a unit, for example by a plurality of bolts. The channels, passages or holes can be formed by any suitable machining methods such as drillings, reaming and electrical discharge machining, etc.

In particular, FIG. 1 shows an external view of a showerhead 10. FIG. 2 shows an internal gas distribution network 12 formed within the showerhead 10. A plurality of horizontal channels 14 are formed in a unitary cylindrical member 16. The unitary member 16 can be comprised of an aluminum, steel, or nickel-based alloy block, or any other suitable materials. These horizontal channels 14 converge at a converging point 18 and extend radially and outwardly to the periphery surface 20 of the cylindrical member 16. The periphery surface 20 is closed. The horizontal channels 14 can be formed by drilling from the periphery surface 20. The unnecessary openings on the periphery surface are closed, for example by sealing plugs after the channels 14 are formed. A vertical inlet passage 22 is formed and connected with the converging point 18. The inlet passage 18 extends upwardly and through the upper surface 24 of the unitary member 16 and connected to a gas source (not shown). Gases are introduced through the inlet passage 22 and distributed into the horizontal channels 14 via the converging point 18.

A plurality of outlet passages or holes 26 are formed along the path of the horizontal channels 14. These outlet holes 26 extend downwardly and through the bottom surface 28 of the unitary member 16. For clarity and simplicity, only some outlet holes are shown in FIGS. 1 and 2. It should be noted that numerous horizontal channels and outlet passages or holes along the horizontal channels can be formed. Various patterns and configurations of outlet

holes can be designed according to process specifications. The diameter of the outlet holes can be uniform throughout the bottom surface of the showerhead. Alternatively, the diameters of the outlet holes may differ. For example, the diameter of the outlet holes can be larger in the inner region and smaller in the outer region of the showerhead bottom surface to provide uniform back pressure. Any or all of the through outlet holes in the showerhead may include an insert described below to allow modification of the outlet size or diameter and/or the directions of gases exiting the showerhead.

The insert is designed to be installed onto, for example, a showerhead as illustrated in FIGS. 1 and 2, to provide a known diameter passageway leading from the internal gas distribution network within the showerhead to the process chamber or region. The insert may be a small precision machined part. The insert can be made of the same material as the showerhead body. Alternatively, the insert is made of a different material to capitalize on differences in physical properties that is desirable, such as different coefficients of thermal expansion to improve sealing between the insert and the showerhead body when used at elevated temperatures. The insert is provided with passageways by any suitable machining method such as drilling, reaming, electrical discharge machining, and the like.

FIGS. 3 to 6 show a screw type insert 30 according to one embodiment of the invention. The insert 30 is provided with threads 32 for engaging the insert 30 with an outlet passage 26 which, in this embodiment, is also provided with threads for receiving the insert 30. The installation is accomplished by screwing the insert 30 into the showerhead outlet 26 until the insert is sufficiently seated to ensure that the gases from the upstream side, i.e., outlet passages, find no route except that through the precision passageway in the insert 30. A cylindrical passageway 34 is formed in the insert 30 and extends through the bottom surface 36 of the insert 30. When installed, the insert passageway 34 is coaxial and in fluid communication with the outlet passage 26. Gases from the internal distribution network 12 exit the showerhead 10 via the insert 30 in a direction perpendicular to the bottom surface 28 of the showerhead 10. The diameter of the insert passageway 34 can be varied to tailor gas flow velocity to specific process requirements. For example, the insert passageway may have a first portion 38 with a smaller diameter proximate to the gas distribution channel 14 and a second portion 39 with a larger diameter distal to the distribution channel 14. The smaller

diameter in the first portion 38 provides a metering function to create uniform back pressure. The larger diameter in the second portion 39 allows the reduction of a "jetting" effect of the gas stream and facilitate installation and removal of the insert 30.

FIGS. 7 to 10 show a press fit type insert 40 according to another embodiment of the invention. Press fit installation alleviates the need for threaded joining. A main passageway 42 is formed in the insert 40 and branched into a plurality of secondary passageways 44. In this embodiment, four branch passageways 44 are formed. The branch passageways 44 extend through the side surface 46 of the insert 40. Each of the branch passageways 44 are angled from the main passageway 42 in the range from about 10 to 89 degrees. After the insert 40 is installed, the insert main passageway 42 is coaxial with the outlet passage 26. The insert 40 extends out of the bottom surface 28 of the showerhead 10 so that the openings of the branch passageways 42 on the side surface 46 of the insert 40 are positioned outside of the plane of the bottom surface 28 of the showerhead 10 to direct gases into a processing region. In this embodiment, gases exit the branch passageways 44 in a direction non-perpendicular to the bottom surface 28 of the showerhead 10 or non-perpendicular to a substrate in a process region, for example, in an angle from about 10 to about 89 degrees with respect to the bottom surface 28. This flow pattern minimizes prior art problems of "spotting," or varying deposition thickness that matches the outlet spacing. By modifying the flow directions, the downward momentum of the gas stream entering the process region is reduced, and as a result gases are more evenly distributed in the process region. Accordingly, the gas flow direction or flow pattern can be altered by selectively choosing the angle between the branch passageways 44 and the main passageway 42.

FIGS. 11-14 show another press-fit type insert 50 according to one embodiment of the present invention. As compared to the insert 40 illustrated in FIGS. 7-10, the insert 50 shown in FIGS. 11-14 has a main passageway 52 and four branch passageways 54 intersecting with the main passageway 52 in 90 degrees. When the insert 50 is installed, gases from distribution channels 14 exit the openings of the branch passageways 54 in a direction parallel to the bottom surface 28 of the showerhead 10.

FIGS. 15 to 20 show in detail the engagement of a press-fit type insert 60 of the present invention with the outlet 26 in the showerhead 10. In the engagement region 62, the outer diameter (D2) of the insert 60 is slightly larger than the outer diameter (D1) in the non-engagement region 64. In a testing or trial stage, a preliminary insert can be sized so that the section in the engagement region is substantially shorter than the section in the non-engagement region ($L2 < L1$) to ease installation and removal of the insert. Threading 70 can be provided in the preliminary insert to facilitate installation and removal of the insert 60. Once the desired insert passageway size is determined, the preliminary insert may be removed and replaced with a final insert 72 that has a larger engagement section as illustrated in FIGS. 19 and 20. In the final insert 72, the engagement section is substantially longer than the non-engagement section ($L2 > L1$). A large engagement region between an insert and an outlet minimizes internal gaps or pocket volume and ensure enhanced sealing between the insert and the showerhead.

FIGS. 21 to 24 show another screw type insert 80 according to one embodiment of the invention. The insert 80 has a hexagonal section 82 and cylindrical section 84. The cylindrical section 84 is provided with threads 86 for engaging the insert 80 with the outlet 26 in the showerhead 10, which is also provided with threads for receiving the insert 80. A main passageway 88 is formed within the cylindrical section 84 and extends into the hexagonal section 82. The main passageway 88 is branched in the hexagonal section 82 into multiple horizontal passageways 90 which extend radially and outwardly. The horizontal passageways 90 extend through the side surfaces 92 of the hexagonal section 82 to direct gases into a processing region. The hexagonal configuration also provides a tool engagement means for installation and removal of the insert 80. Once the insert 80 is installed, the hexagonal section 82 of the insert extends out of the bottom surface 28 of the showerhead 10. The insert 80 main passageway 88 is coaxial with the outlet passage 26 in the showerhead 10. Gases flow through the main passageway 88 and change flow directions from vertical to horizontal with respect to the bottom surface 28 of the showerhead 10 as indicated by the arrows in FIG. 24.

Advantageously, the inserts of the invention can be placed in any selected outlets to alter the size and/or direction of the gases exiting the apparatus. Process results can be used as feedback to change the corresponding inserts to achieve the desired end response. The

resulting configuration can then be used as is, or used to provide the design criteria to replicate the showerhead in a fixed, non-adjustable version that may be preferred in a production environment in which a minimum of process variables is desired.

As described above, an adjustable gas distribution apparatus has been provided by the present invention. The foregoing description of specific embodiments of the invention have been presented for the purpose of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications, embodiments, and variations are possible in light of the above teaching. It is intended that the scope of the invention be defined by the claims appended hereto and their equivalents.

CLAIMS

We Claim:

1. A gas distribution apparatus, comprising:
a body having a surface facing a processing region,
a plurality of outlet passages formed within the body and extending through the surface for providing gases into the processing region; and
at least one replaceable insert placed in at least one of the outlet passages, said insert is provided with a passageway adapted to alter the size of the at least one of the outlet passages and/or the direction of gases exiting the at least one of the outlet passages into the processing region.
2. The apparatus of Claim 1 wherein said insert passageway is substantially cylindrical.
3. The apparatus of Claim 1 wherein the insert passageway comprises a first portion having a smaller diameter and a second portion having a greater diameter.
4. The apparatus of Claim 1 wherein said insert passageway is coaxial with the passage of the outlet placed with the insert.
5. The apparatus of Claim 1 wherein the insert passageway comprises a first portion coaxial with the passage of the outlet placed with the insert and a plurality of second portions branched and angled from the first portion for directing the gases into the processing region.
6. The apparatus of Claim 5 wherein said second portions of the insert passageway are angled from the first portion in the range from about 10 to about 90 degrees.
7. The apparatus of Claim 5 wherein said second portions of the insert passageway are perpendicular to the first portion.
8. The apparatus of Claim 5 wherein said second portions of the insert passageway are in parallel to the surface of the unitary body.
9. The apparatus of Claim 1 wherein said outlet passages are substantially cylindrical.

10. The apparatus of Claim 9 wherein said outlet passages comprises a first portion having a smaller diameter and a second portion having a greater diameter.
11. The apparatus of Claim 1 wherein the insert is placed in the outlet passage by press fit.
12. The apparatus of Claim 1 wherein the outlet passage and insert are provided with threads and the insert is placed in the outlet passage by threading.
13. The apparatus of Claim 12, wherein the insert comprises means for engaging installment tools.
14. A gas distribution apparatus, comprising a plurality of outlets and at least one replaceable insert placed in at least one of the outlets, said insert is provided with a passageway adapted to alter the size of and/or the direction of gases exiting the at least one of the outlets.
15. The apparatus of Claim 14 wherein the insert passageway is substantially cylindrical.
16. The apparatus of Claim 14 wherein the insert passageway is coaxial with the outlet placed with the insert.
17. The apparatus of Claim 15 wherein the insert passageway comprises a first portion having a smaller diameter and a second portion having a greater diameter.
18. The apparatus of Claim 14 wherein the insert passageway comprises a first portion coaxial with the outlet placed with the insert and a plurality of second portions branched and angled from the first portion.
19. The apparatus of Claim 18 wherein said second portions of the insert passageway are angled from the first portion in the range from about 10 to about 90 degree.
20. The apparatus of Claim 18 wherein said second portions of the insert passageway are perpendicular to the first portion.
21. The apparatus of Claim 14 wherein the insert is placed in the outlet by press fit.

22. The apparatus of Claim 14 wherein the outlet and insert are provided with threads and the insert is placed in the outlet by screwing.

23. The apparatus of Claim 22, wherein the insert is provided with means for engaging installation tools.