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FLARED SHUTTER LINER FOR CHEMICAL VAPOR DEPOSITION SYSTEM

Abstract

A shutter liner for use in a chemical vapor deposition (CVD) system includes an upper portion that has a cylindrical shape and a lower portion that has an outwardly flared shape. The outwardly flared shape reduces deposition within the reaction chamber by providing an outwardly angled wall surface that occupies a horizontal gap between inner and outer liners that are contained within the reaction chamber.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION [0001] The present application claims priority to and the benefit of U.S. patent application Ser. No. 63/555,738, filed Feb. 20, 2024, which is hereby expressly incorporated by reference in its entirety.

TECHNICAL FIELD

[0002] The present technology is generally related to semiconductor fabrication technology and, more particularly to chemical vapor deposition processing and associated systems having a flared shutter liner for restricting the migration of reactants outwards from the reaction volume.

BACKGROUND

[0003] Certain processes for fabrication of semiconductors can require a complex process for growing epitaxial layers to create multilayer semiconductor structures for use in fabrication of high-performance devices, such as light emitting diodes (LEDs), laser diodes, optical detectors, power electronics, and field effect transistors. In this process, the epitaxial layers are grown through a general process called chemical vapor deposition (CVD). One type of CVD process is called metal organic chemical vapor deposition (MOCVD). In MOCVD, reactant gases are introduced into a reactor chamber within a controlled environment that enables the reactant gas to react on a substrate (commonly referred to as a “wafer”) to grow thin epitaxial layers.

[0004] During epitaxial layer growth, several process parameters are controlled, such as temperature, pressure, and gas flow rate, to achieve desired quality in the epitaxial layers. Different layers are grown using different materials and process parameters. A suitable substrate for the reaction can be in the form of a wafer having metallic, semiconducting, and/or insulating properties.

[0005] In a rotating disk reactor architecture-based CVD process chamber, one or more wafers are positioned within a rapidly rotating carousel, commonly referred to as a “wafer carrier,” so that the top surface of each wafer is exposed, thereby providing a uniform exposure of the top surface of the wafer to the atmosphere within the reactor chamber for the deposition of semiconductor materials. The wafer carriers are typically machined out of a highly thermally conductive material such as graphite and are often coated with a protective layer of a material such as silicon carbide or tantalum carbide. Each wafer carrier has a set of circular indentations, or pockets, in its top surface in which individual wafers are placed. While the wafer carrier is rotated, the reactant gases are introduced into the chamber from a gas distribution device, positioned upstream of the wafer carrier. The flowing gases pass downstream toward the wafer carrier and wafers, desirably in a laminar flow.

[0006] Traditionally, reactor system design utilizes a cylindrical shutter that has a large horizontal gap on the outside to a reactor jar (outer housing). While the flow is directed downwards and to the exhaust, reactants can escape (through diffusion, back-streaming, etc.) in through this large horizontal gap and out to the periphery of the reactor. These reactants can then produce particulate matter through gas flow recirculation, condensation, etc., and produce defects in many locations in the reactor (e.g., within the passthrough, along reactor walls, etc.) that can be transferred to the surface of the wafer. Defects on the wafer can significantly reduce device yield. There is therefore a need to reduce the amount of reactants and particulate matter that can penetrate into the horizontal gap.

SUMMARY

[0007] The present disclosure provides a shutter liner that overcomes the deficiencies associated with traditional shutter liners and in particular, the shape of the shutter liner greatly reduces deposition growth within the horizontal gap.
[0008] More specifically, a shutter liner for use in a chemical vapor deposition (CVD) system comprises an upper portion that has a cylindrical shape and a lower portion that has an outwardly flared shape. The outwardly flared shape reduces the deposition by providing an outwardly angled wall surface that occupies the horizontal gap between the inner and outer liners. The flared shape maintains a desired radial dimension in the upper portion, while providing the dimension in the lower portion for the desired effect.
[0009] The chemical vapor deposition (CVD) system thus includes a reaction chamber and a plurality of walls including an outer liner and an inner liner that is concentric to and located radially inward of the outer liner. A first annular space is defined between the outer liner and the inner liner. The shutter liner is disposed between the outer liner and the inner liner and is movable between a raised position and a lower position. The shutter liner includes an upper portion that has a cylindrical shape and a lower portion that has an outwardly flared shape.
[0010] The raised position of the shutter liner comprises an operating position and the lowered position comprises a non-operating position that allows for insertion and removal of a wafer carrier from the reaction chamber.

Description

BRIEF DESCRIPTION OF THE DRAWING FIGURES
[0011] The disclosure can be more completely understood in consideration of the following detailed description of various embodiments of the disclosure, in connection with the accompanying drawings, in which:
[0012] FIG. **1** is a partial cross-sectional view of a CVD system with a flared shutter liner being shown in a raised position;
[0013] FIG. **2** is a partial cross-sectional view of the CVD system with the flared shutter liner being shown in a lowered position;
[0014] FIG. **3** is a close-up of the flared shutter liner in relation to the outer liner and inner liner;
[0015] FIG. **4** is a top and side perspective view of the flared shutter liner; and
[0016] FIG. **5** is a side elevation view of the flared shutter liner.
[0017] While embodiments of the disclosure are amenable to various modifications and alternative forms, specifics thereof shown by way of example in the drawings will be described in detail. It should be understood, however, that the intention is not to limit the disclosure to the particular embodiments described. On the contrary, the intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the subject matter as defined by the claims.
DETAILED DESCRIPTION OF CERTAIN EMBODIMENTS
[0018] Referring to FIGS. **1-5**, a chemical vapor deposition (CVD) system **100** is illustrated and includes a reaction chamber **101** (occasionally referred to herein as a “process chamber” or “reactor”), configured to define a process environment space. The reactor region of the system **100** is typically formed of vacuum-grade stainless steel or other suitable metal. The reaction chamber **101** is typically defined by a cylindrical wall with an upper end and a lower end remote therefrom. FIGS. **1-2** are partial views of the system **100** that depict one half of the system **100** to illustrate the teachings of the present disclosure.
[0019] The system includes **100** a baseplate **110** that represents the bottom of the system **100**. The baseplate **110** has a number of through holes that permit passage of certain components, such as the drive shaft that rotates a wafer carrier **115**, etc. As is known, the wafer carrier **115** receives one or more wafers for processing thereof.

Multiple Liners

[0020] Between the wafer carrier **115** and the baseplate **110** there are different components that define a wall structure of the system **100**. For example and as described herein, there can be several liners as well as a jar structure. More specifically, to prevent unwanted reactions with the chamber body (reaction chamber **101**), liners are utilized to shield some of the metallic chamber components from the processing region. In the illustrated embodiment, the system **100** includes multiple liners **120**, **130** that shield the processing volume (reaction chamber **101**) from metallic walls, that surround the processing volume (reaction chamber **101**). The metallic walls can include a reactor jar (weldment), generally indicated at **140**, and the multiple liners **120**, **130** are located radially inward from the reactor jar **140**. The multiple liners **120**, **130** and reactor jar **140** are concentric with one another, with the liner **120** comprising an inner liner **120** and the liner **130** comprising an outer liner **130**. These three structures **120**, **130**, **140** can be annular shaped, with the inner liner **120** being spaced a first distance from the outer liner **130**. The inner liner **120** is at a location proximate to (adjacent the wafer carrier **115** and/or related processing equipment).

[0021] FIG. **3** is a close-up view of the top end regions of these three structures **120**, **130**, **140**. In one embodiment, the inner liner **120** has a height greater than the heights of the outer liner **130** and the reactor jar **140** and the outer liner **130** can have a height less than the height of the reactor jar **140**.

Flow Flange

[0022] A flow flange **150** is provided to introduce reactant gases into the reaction chamber **101** at a certain prescribed location. The flow flange **150** thus defines the flow path used to introduce the reactant gases into the reaction chamber **101**. The flow range **150** is located in the upper region of the reaction chamber **101**.

Cold Plate

[0023] The reaction chamber **101** has one or more gas injectors for injecting one or more gases into the reaction chamber **101**. In one embodiment, there can be a gas distribution and injector head that includes a manifold assembly, which may be formed from one plate or, more typically. a plurality of plates superposed on one another. An element **160** referred to herein as a “cold plate” or “diffuser” overlies the downstream surface of the manifold assembly. Cold plate **160** can be provided with coolant passages connected to a source of a circulating coolant Cold plate defines the downstream surface of the distribution and injector head The cold plate **160** defines a plurality of first gas inlets that define ports communicating with the interior of reaction chamber **101** It will be appreciated that other types of gas injectors can be used.

Flared Shutter Liner

[0024] In accordance with the present embodiment, a flared shutter liner **200** that moves between a raised position (FIG. **1**) and a lowered position (FIG. **2**) is provided. The flared shutter liner **200** is disposed within an annular shaped space between the inner liner **120** and the outer liner **130**.

[0025] The system **100** includes a number of pass-through areas which are intended to provide for movement of parts, such as the insertion and removal of a wafer carrier, etc. For example, the system **100** includes a first pass through area **230** that is located radially outward from the cold plate **160**. This first pass through area **230** is the volume inside the passthrough. There is a second area **240** that is located radially outward from the flared shutter liner **200** but within the reactor jar **140**. This second area **240** is configured and intended to accommodate insertion and removal of the wafer carrier **115**. The second area **240** represents the volume outboard of the shutter but before the passthrough.

[0026] Traditional shutter liners do not have a flared bottom portion but instead are straight and have a cylindrical shape, as in the case of the upper portion **210**. This results in a large horizontal gap (annular shaped) on the outside of the shutter to the reactor jar **140**.

[0027] However, Applicant observed that this type of traditional shutter liner allows for deposition growth in and near the second area **240** as well as other areas. In particular, the flared shutter liner

200 disclosed herein is intended to prevent backstreaming into both inside the passthrough **230** and into the volume (area **240**) between the shutter and the jar. Typically, heavy deposition occurs in the first pass through area **230** as well as in some areas of the second area **240**.

[0028] In other words, the straight walled natured of the traditional shutter liner allows deposition growth since while the flow is directed downwards and to the exhaust, reactants can escape (through diffusion and back-streaming) in through this gap (second pass through area **240**) and out to the periphery of the reactor (system **100**). These reactants can then produce particulate matter through gas flow recirculation, condensation, etc., and produce defects in many locations in the reactor (passthrough, reactor walls) that can be transferred to the surface of the wafer. Large particle count and parasitic deposition within the pass-through area **240** were observed. The adverse implications of this are that deposition in and near the second pass through area **240** causes contamination with wafers during insertion and removal of the wafer carrier **115**. Defects on the wafer can significantly reduce device yield.

[0029] This is not desired and therefore, there is a need to greatly reduce such deposition growth especially within the pass-through area that wafers are located during operation.

[0030] More particularly, it is an objective of the present disclosure and system **100** to prevent convection and back diffusion of species contributing to the parasitic growth to the pass-through area **240**. Further, it is an objective to provide for independent control of side/pass through purges and provide for temperature control within the pass-through area **240**.

[0031] The design of the flared shutter liner **200** achieves these objectives. More particularly, the flared shutter liner **200** includes a top edge **202** and an opposite bottom edge **204**. The flared shutter liner **200** has an upper portion **210** that terminates at the top edge **202** and a lower portion **220** that terminates at the bottom edge **204**. The upper portion **210** has a cylindrical shape, while the lower portion **220** has a flared (angled) shape. As shown, the lower portion **220** has an outward taper so as to define a flared or angled end section. The lower portion **220** thus tapers outward toward the outer liner **130** and the bottom edge **204** can be in close proximity to the outer liner **130**. This results in the outer diameter of the flared shutter liner **200** being greater at the bottom edge **204** than the top edge **202**. The angle of the flared lower portion **220** is less than 90 degrees and can be between 40 degrees and 60 degrees, e.g., 45 degrees (as measured relative to a ground plane (horizontal plane containing the bottom edge of liner).

[0032] In one embodiment, the angled end section (flared lower portion **220**) extends from the cylindrical section (upper portion **210**), keeping the overall height the same as a traditional cylindrical shaped shutter/liner. The flared section (flared lower portion **220**) angles outwards and blocks a large amount of species migration into the outer reactor volume. By restricting the migration of reactants outwards from the reaction volume, the propensity of deposition is significantly reduced thereby improving defectivity.

[0033] As also shown, the height of the upper portion **210** is much greater than the height of the lower portion **220** in that the flared portion of the flared shutter liner **200** only occupies a minor section of the overall shutter liner.

[0034] It will be appreciated that the flared shutter liner **200** can be formed as a single part or can be formed of two parts. For example, when the flared shutter liner **200** is formed as two parts, the (cylindrical shaped) upper portion **210** is a formed as a first part and the (flared) lower portion **220** is formed as a second part. In one embodiment, the upper portion **210** can be formed of molybdenum and similarly, the lower portion **220** can be formed of molybdenum. Alternatively, the flared shutter liner **200** can be formed of a single piece and made of different refractory metals. Fasteners, such as rivets, can be used to attach the two parts or other techniques can be used.

[0035] The movement of the flared shutter liner **200** is achieved using conventional devices, such as a motor (not shown) that is operatively coupled to the flared shutter liner **200**. For example, a stepper motor can be used to precisely move the flared shutter liner **200** between the raised and lowered positions.

[0036] As mentioned, and shown in FIGS. **1-2**, the flared shutter liner **200** moves between the raised position and the lowered position. The raised position is the position of the flared shutter liner **200** that results in the flared shutter liner **200** red ng the deposition buildup in the pass-through areas, such as the pass-through area **230** and area **240**. The flared shutter liner **200** in the lowered position allows for the extraction of the wafer carrier. Thus, the raised position of the flared shutter liner **200** is the normal operating position of the flared shutter liner **200**, while the flared shutter liner **200** in the lowered position is a non-operating position meant to define open spaces that allow for insertion and removal of the wafer carrier into the reaction chamber **101**.
[0037] The flared shutter liner **200** is thus configured and moves within the reactor to perform multiple functions. Applicant has discovered that the flared design provides improved results compared to just having say a larger traditional shutter in terms of protection against reactants and particles; but also the flared shutter liner **200** also serves and satisfies additional requirements, which drives the upper and lower configurations of the liner **200**.
EXAMPLE
[0038] Applicant observed, based on modeling, that when a traditional straight shutter liner was used in the CVD system, the deposition was 3 microns per hour (μm/hr) (within the second pass through area **240**). In contrast, when the flared shutter liner **200** was used in system **100**, the deposition rate was 0.25 microns per hour. This is a more than 91% reduction in the deposition rate and accordingly, far less material is deposited over the same amount of time.
Baffle
[0039] The disclosed reactor can include a baffle assembly **250** that is illustrated in the figures, e.g., FIG. **1**. The baffle assembly **250** includes an integrated reflective shield that can be made of a 304 stainless steel sheet with a mirror-like one side polished or similar reflective material. The baffle assembly **250** is disposed between the water-cooled reactor baseplate **110** and the reactor's heater assembly. The baffle assembly **250** is intended and constructed to reflect thermal radiation back up into the heater cavity allowing for faster carrier heating rates with minimized heat loses.
[0040] Various embodiments of systems, devices, and methods have been described herein. These embodiments are given only by way of example and are not intended to limit the scope of the claimed inventions. It should be appreciated, moreover, that the various features of the embodiments that have been described may be combined in various ways to produce numerous additional embodiments. Moreover, while various materials, dimensions, shapes, configurations and locations, etc. have been described for use with disclosed embodiments, others besides those disclosed may be utilized without exceeding the scope of the claimed inventions.
[0041] Persons of ordinary skill in the relevant arts will recognize that the subject matter hereof may comprise fewer features than illustrated in any individual embodiment described above. The embodiments described herein are not meant to be an exhaustive presentation of the ways in which the various features of the subject matter hereof may be combined. Accordingly, the embodiments are not mutually exclusive combinations of features; rather, the various embodiments can comprise a combination of different individual features selected from different individual embodiments, as understood by persons of ordinary skill in the art. Moreover, elements described with respect to one embodiment can be implemented in other embodiments even when not described in such embodiments unless otherwise noted.
[0042] Although a dependent claim may refer in the claims to a specific combination with one or more other claims, other embodiments can also include a combination of the dependent claim with the subject matter of each other dependent claim or a combination of one or more features with other dependent or independent claims. Such combinations are proposed herein unless it is stated that a specific combination is not intended.
[0043] Any incorporation by reference of documents above is limited such that no subject matter is incorporated that is contrary to the explicit disclosure herein. Any incorporation by reference of documents above is further limited such that no claims included in the documents are incorporated

by reference herein. Any incorporation by reference of documents above is yet further limited such that any definitions provided in the documents are not incorporated by reference herein unless expressly included herein.

[0044] For purposes of interpreting the claims, it is expressly intended that the provisions of 35 U.S.C. § 112 (f) are not to be invoked unless the specific terms “means for” or “step for” are recited in a claim.

Claims

1. A shutter liner for use in a chemical vapor deposition (CVD) system comprising: an upper portion that has a cylindrical shape; and a lower portion that has an outwardly flared shape.
2. The shutter liner of claim 1, wherein the shutter liner is formed of a metal.
3. The shutter liner of claim 1, wherein the shutter liner is formed of molybdenum.
4. The shutter liner of claim 1, wherein the shutter liner comprises a single piece.
5. The shutter liner of claim 1, wherein the shutter liner comprises two pieces, with the lower portion being separate from and coupled to the upper portion.
6. The shutter liner of claim 5, wherein the two pieces are formed of the same material.
7. The shutter line of claim 1, wherein a height of the upper portion is greater than a height of the outwardly flared lower portion.
8. A chemical vapor deposition (CVD) system comprising: a reaction chamber; a plurality of walls including an outer liner and an inner liner that is concentric to and located radially inward of the outer liner, wherein a first annular space is defined between the outer liner and the inner liner; and a shutter liner that is disposed within the first annular space between the outer liner and the inner liner and is movable between a raised position and a lower position, wherein the shutter liner includes an upper portion that has a cylindrical shape and a lower portion that has an outwardly flared shape.
9. The CVD system of claim 8, wherein the plurality of walls includes a reactor jar that is concentric to the outer liner and the inner liner and is located radially outward from the outer liner.
10. The CVD system of claim 8, wherein the shutter liner is formed of a metal.
11. The CVD system of claim 8, wherein the shutter liner is formed of molybdenum.
12. The CVD system of claim 8, wherein the shutter liner comprises a single piece.
13. The CVD system of claim 8, wherein the shutter liner comprises two pieces, with the lower portion being separate from and coupled to the upper portion.
14. The CVD system of claim 13, wherein the two pieces are formed of the same material.
15. The CVD system of claim 13, wherein a bottom edge of the shutter liner is in close proximity to the outer liner.
16. The CVD system of claim 8, wherein the raised position comprises an operating position of the shutter liner and the lowered position comprises a non-operating position that allows for insertion and removal of a wafer carrier from the reaction chamber.
17. The CVD system of claim 16, wherein in the lowered position a top edge of the shutter liner is disposed below the wafer carrier.
18. The CVD system of claim 16, wherein in the raised position, the lower portion of the shutter liner is disposed below the wafer carrier.
19. The CVD system of claim 8, further including a rotatable wafer carrier disposed within the reaction chamber, the inner liner being disposed radially outward from the wafer carrier.