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Yang et al.

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(54) **SYSTEMS AND METHODS FOR PROCESSING A SUBSTRATE**

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H01L 21/324 (2006.01)
H01L 21/67 (2006.01)

(52) **U.S. Cl.**
CPC ***H01L 21/324*** (2013.01); ***H01L 21/67017*** (2013.01); ***H01L 21/67115*** (2013.01)

(58) **Field of Classification Search**
CPC H01L 21/67393; H01L 21/67389; H01L 21/324; H01L 21/67017; H01L 21/67115; H01L 21/67248; H01L 21/67196
See application file for complete search history.

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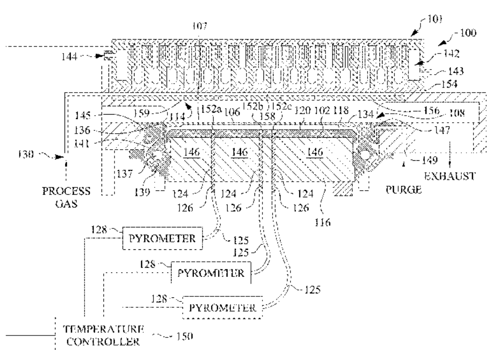
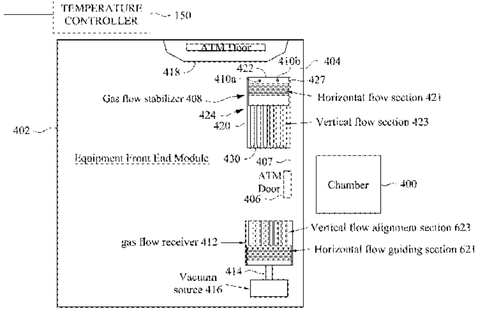
(57) **ABSTRACT**

A system and method for generating a gas curtain over an access port of a processing chamber for a semiconductor substrate. A gas flow stabilizer and a gas flow receiver, each including a horizontal flow section and a vertical flow section cooperate to generate a gas curtain that impedes gas, e.g., oxygen, from outside the processing chamber, from flowing into the chamber, for example, when the access port is opened to add/or to remove a workpiece from the processing chamber.

20 Claims, 8 Drawing Sheets





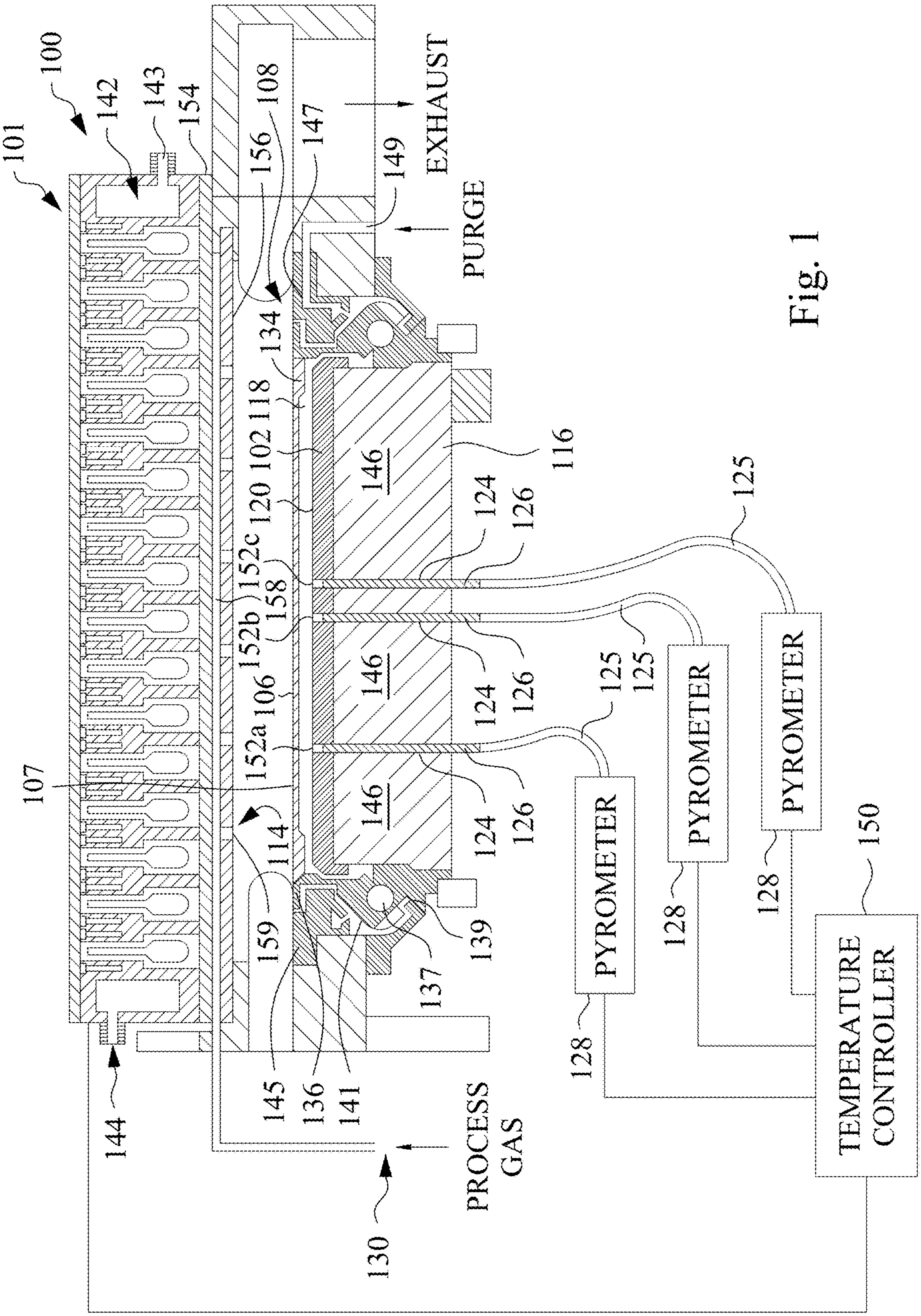

EXHAUST
PURGE
PROCESS GAS
PYROMETER
PYROMETER
PYROMETER
TEMPERATURE CONTROLLER

Fig. 1

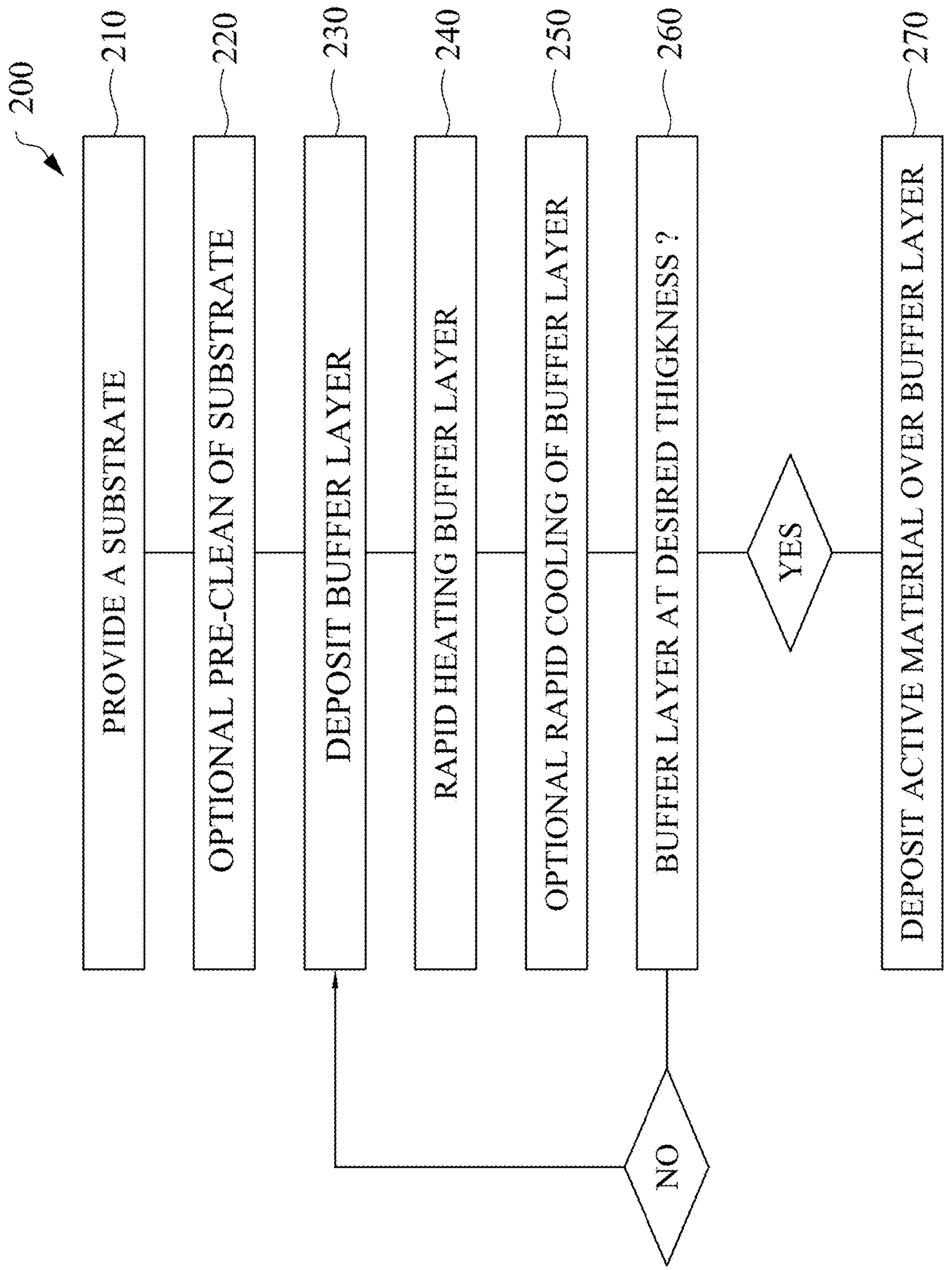

200
210
PROVIDE A SUBSTRATE
220
OPTIONAL PRE-CLEAN OF SUBSTRATE
230
DEPOSIT BUFFER LAYER
240
RAPID HEATING BUFFER LAYER
250
OPTIONAL RAPID COOLING OF BUFFER LAYER
260
BUFFER LAYER AT DESIRED THICKNESS ?
NO
YES
270
DEPOSIT ACTIVE MATERIAL OVER BUFFER LAYER

Fig. 2

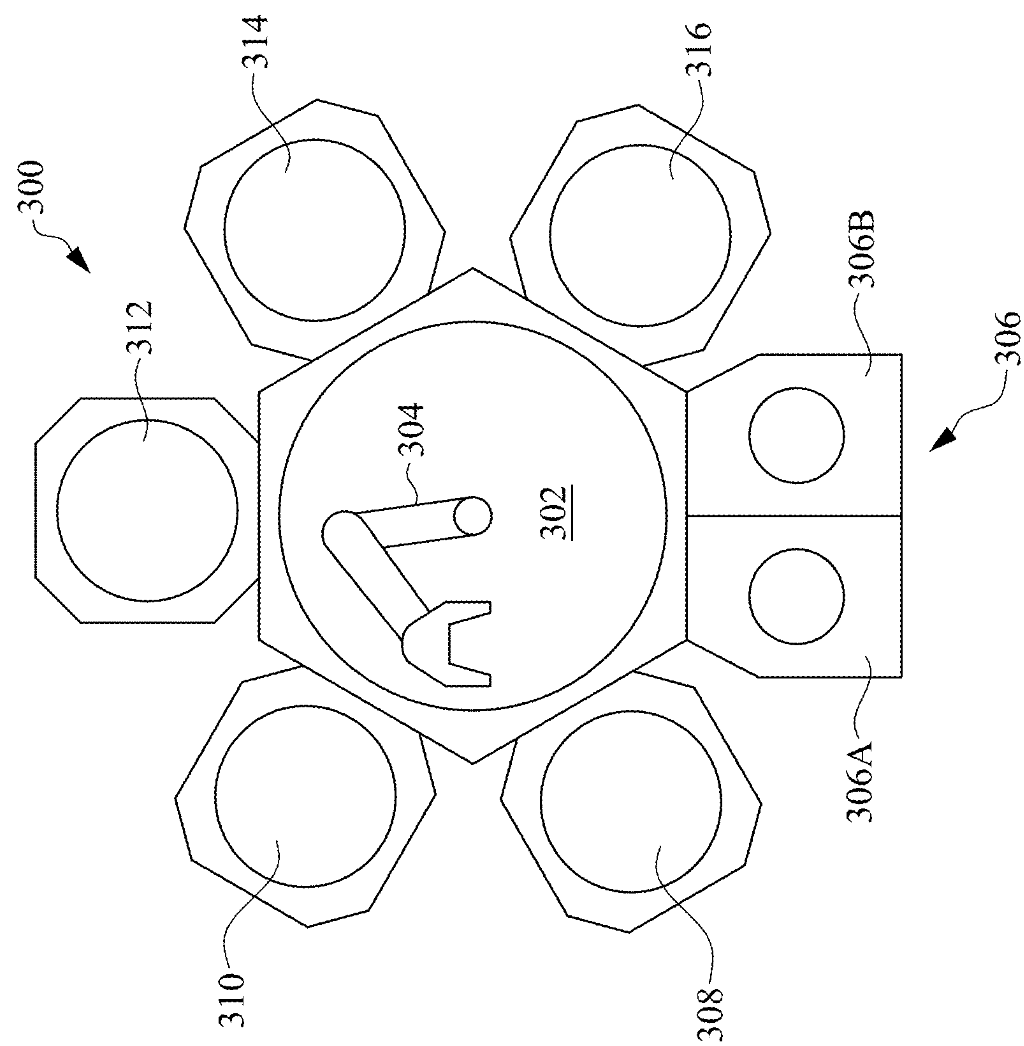


Fig. 3

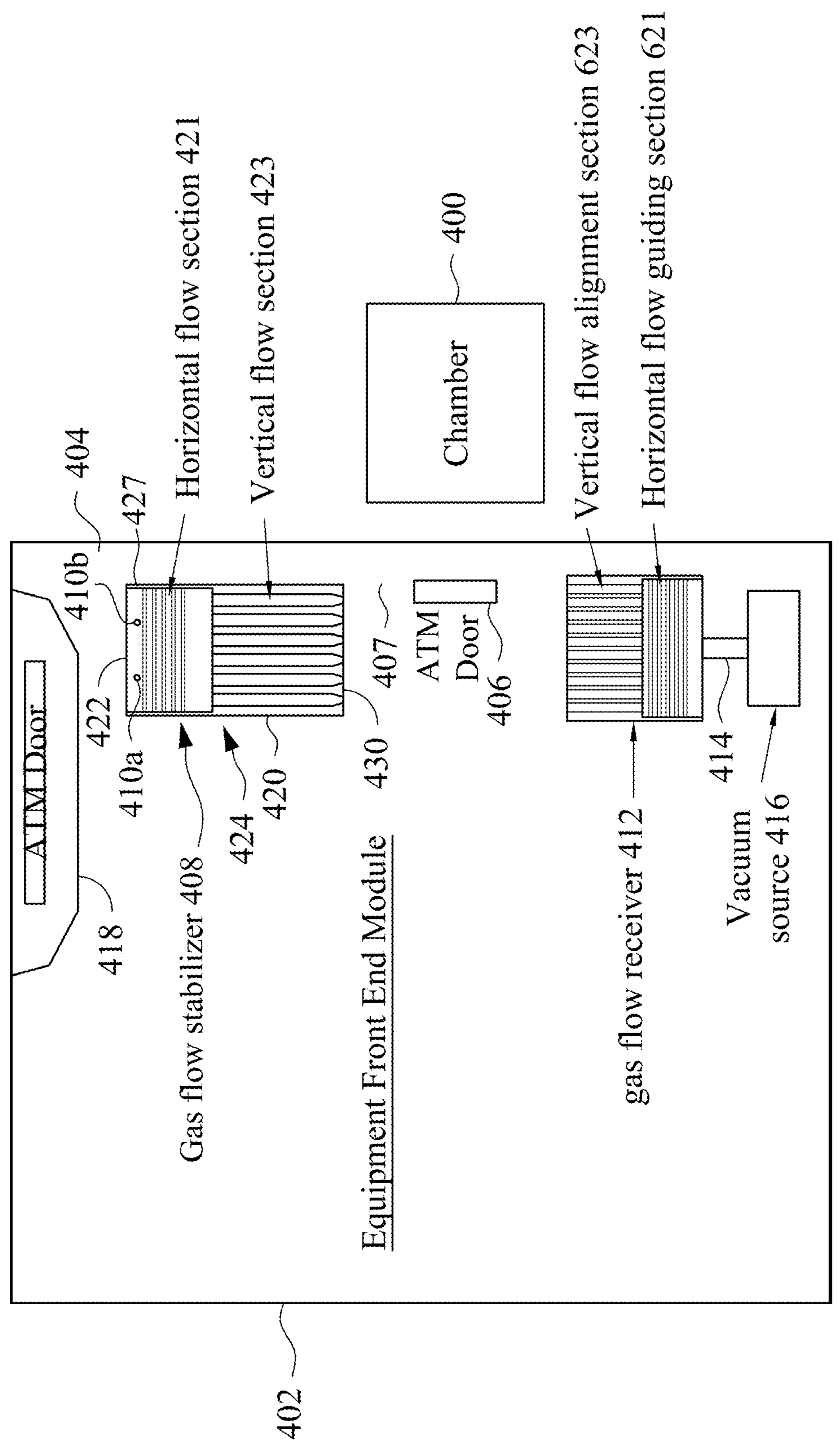

Horizontal flow section 421
Vertical flow section 423
Chamber
400
Vertical flow alignment section 623
Horizontal flow guiding section 621
404
427
410b
422
410a
ATM Door
418
Gas flow stabilizer 408
424
420
430
407
ATM Door
406
Equipment Front End Module
gas flow receiver 412
414
Vacuum source 416
402

Fig. 4

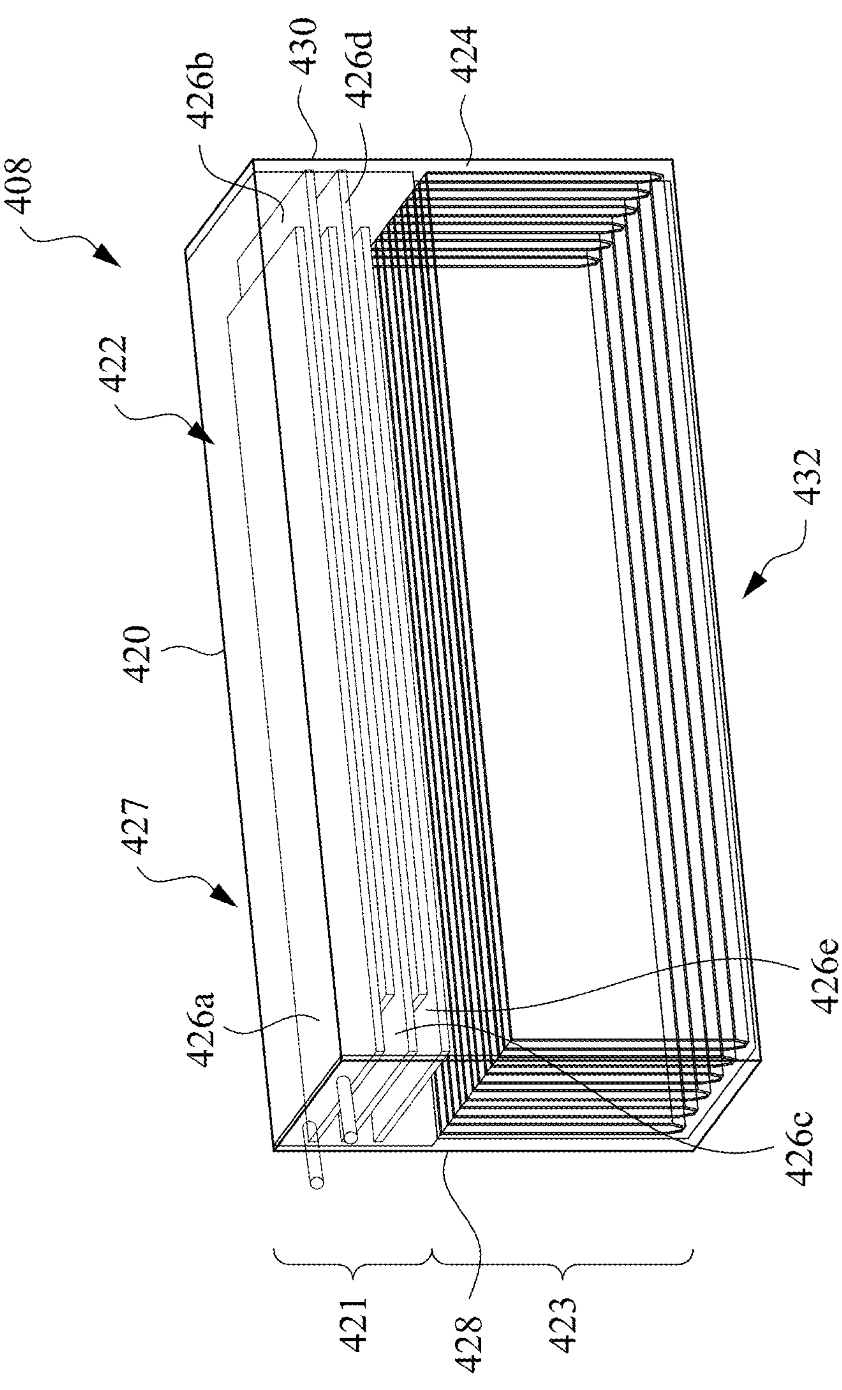

408
426b
430
426d
424
422
432
420
427
426e
426a
426c
421
428
423

Fig. 5

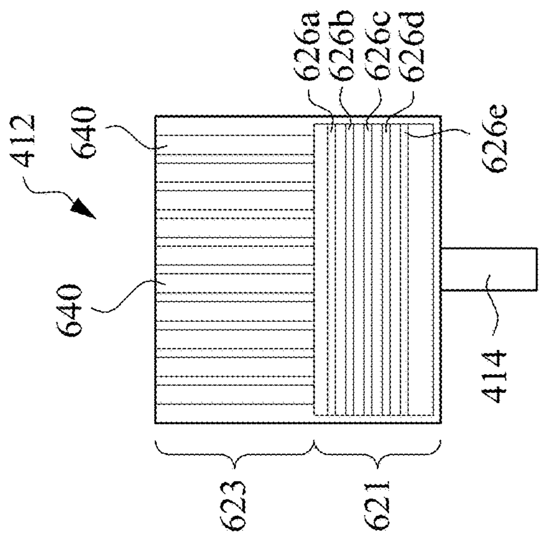

412
640
640
626a
626b
626c
626d
626e
414
623
621

Fig. 6B

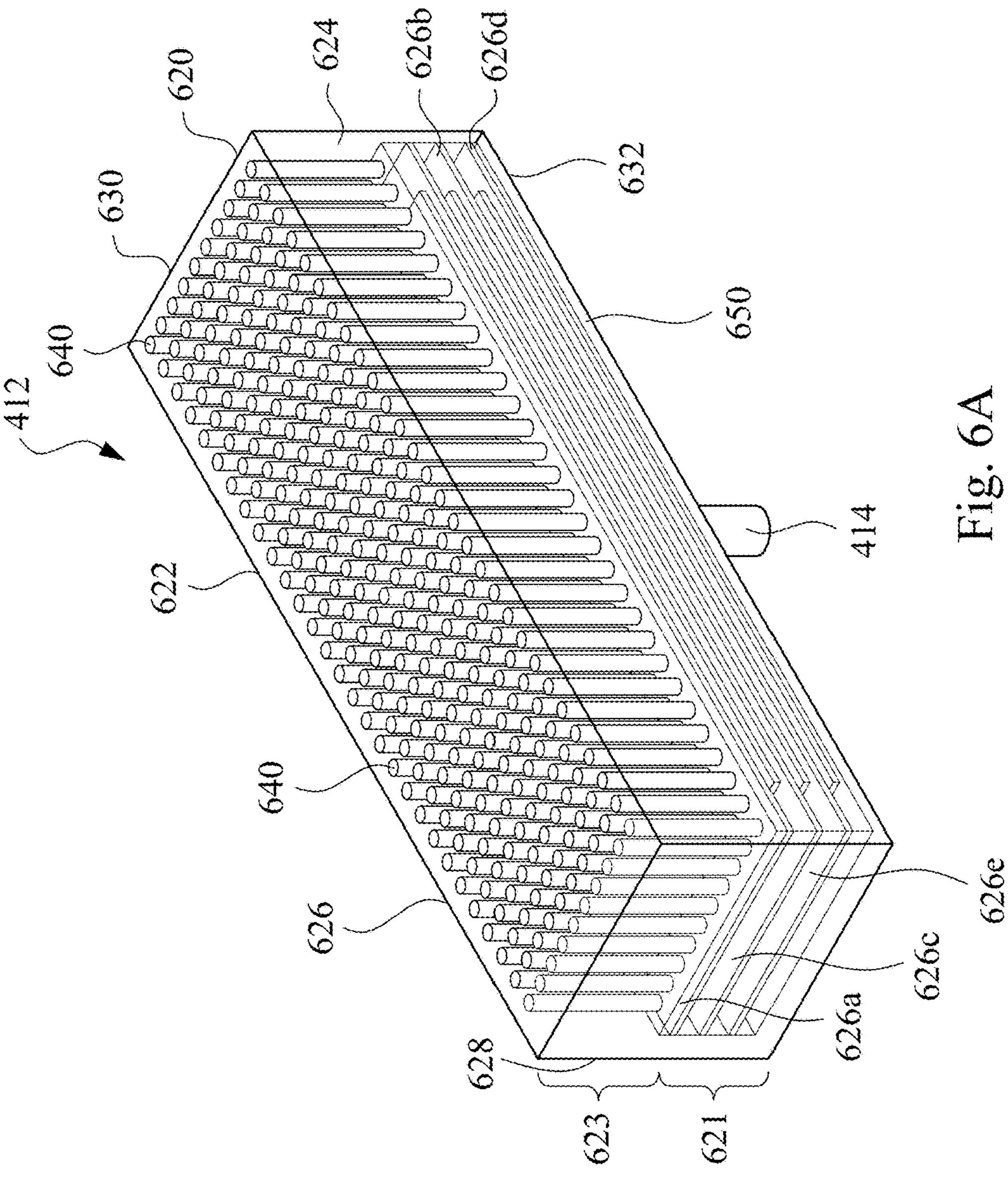

412
620
630
640
624
626b
626d
632
650
622
414
640
626
626e
626c
626a
628
623
621

Fig. 6A

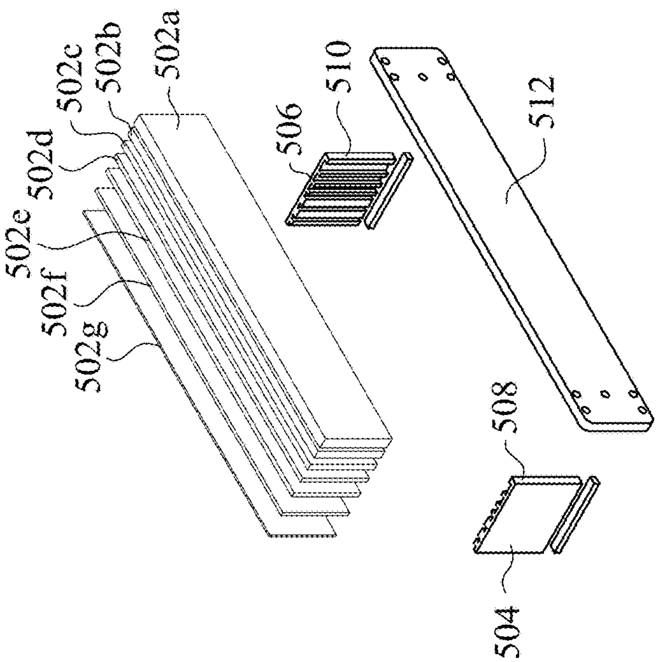


Fig. 7B

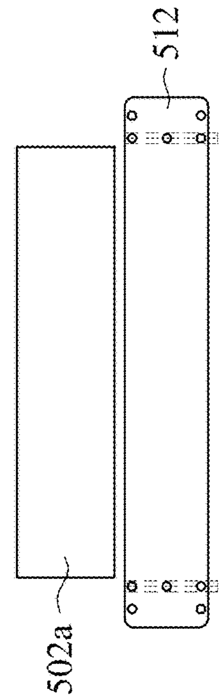


Fig. 7D

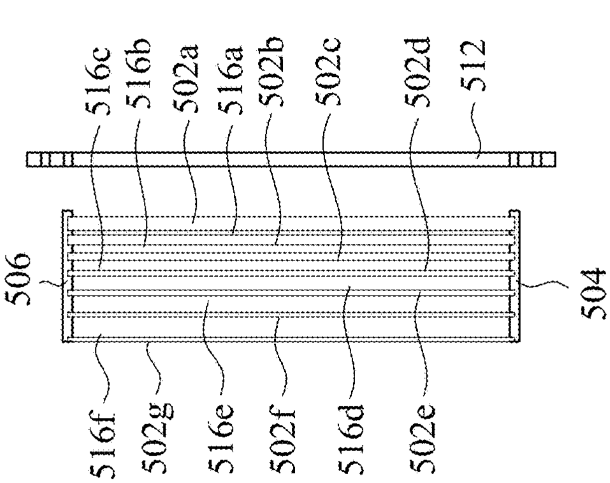


Fig. 7A

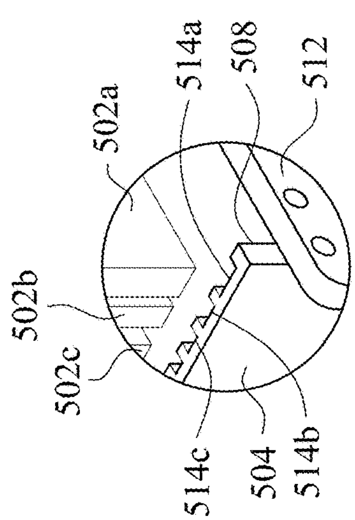


Fig. 7C

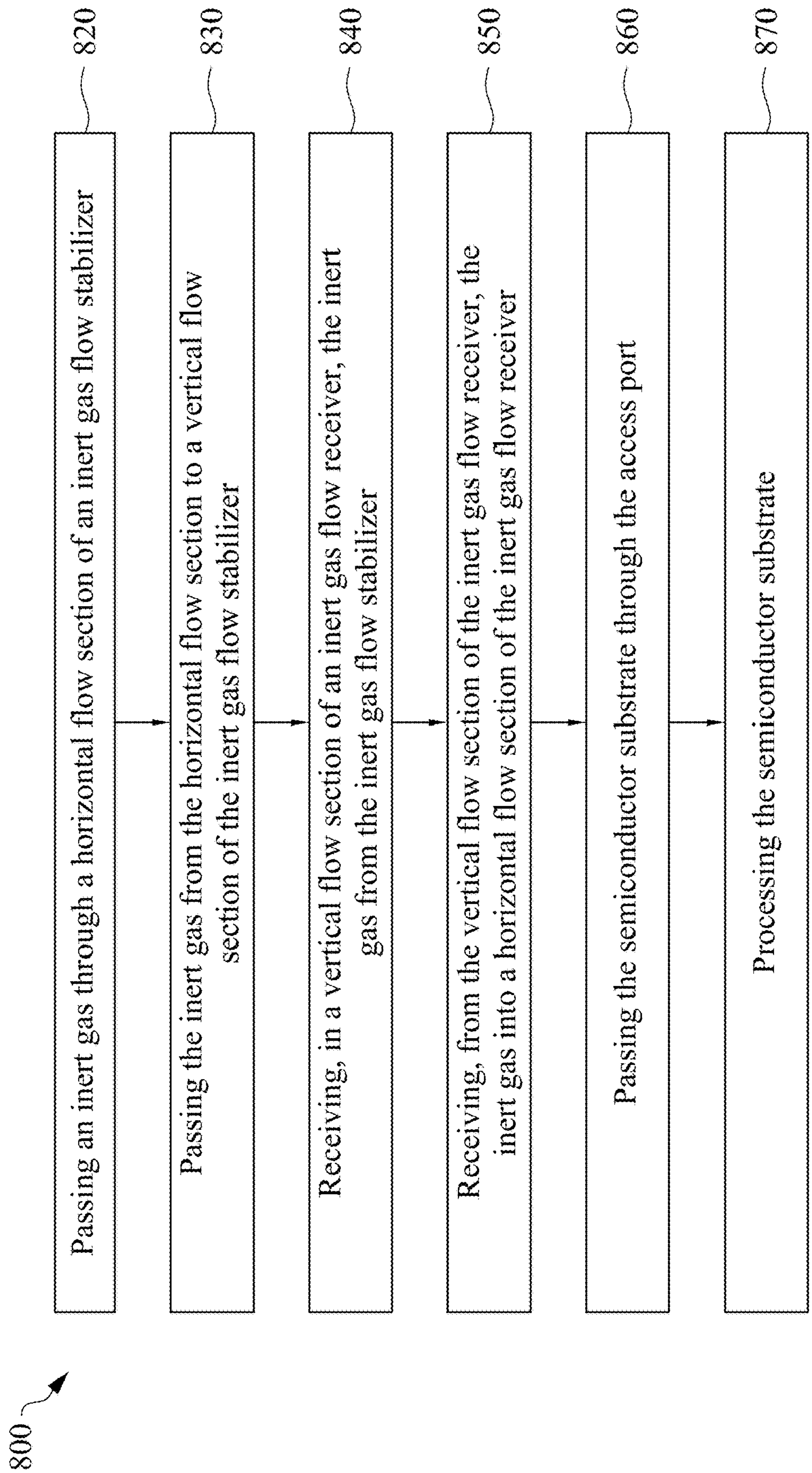

800
820
Passing an inert gas through a horizontal flow section of an inert gas flow stabilizer
830
Passing the inert gas from the horizontal flow section to a vertical flow section of the inert gas flow stabilizer
840
Receiving, in a vertical flow section of an inert gas flow receiver, the inert gas from the inert gas flow stabilizer
850
Receiving, from the vertical flow section of the inert gas flow receiver, the inert gas into a horizontal flow section of the inert gas flow receiver
860
Passing the semiconductor substrate through the access port
870
Processing the semiconductor substrate

Fig. 8

SYSTEMS AND METHODS FOR PROCESSING A SUBSTRATE

BACKGROUND

In the semiconductor industry, rapid thermal annealing (RTA) is a semiconductor process step used for the activation of dopants and the interfacial reaction of metal contacts. In principle, the operation involves rapid heating of a wafer from ambient to approximately 1000-1500 K. As soon as the wafer reaches the desired temperature, it may be held at such temperature before being quenched. Some implementations of RTA utilize an indirect infrared lamp to heat the wafer. The temperature of the wafer is determined with an indirect sensor, based on the radiation emitted by the wafer. After the RTA is completed the wafer is removed from the process chamber through an access port and prepared for further processing.

BRIEF DESCRIPTION OF THE DRAWINGS

Aspects of the present disclosure are best understood from the following detailed description when read with the accompanying figures. It is noted that, in accordance with the standard practice in the industry, various features are not drawn to scale. In fact, the dimensions of the various features may be arbitrarily increased or reduced for clarity of discussion.

FIG. **1** is a schematic cross-sectional view of a rapid thermal processing (RTP) system for use with embodiments of the present disclosure.

FIG. **2** is a plan view of a tool according to an embodiment in accordance with the present disclosure.

FIG. **3** is a flow diagram depicting a method for forming a structure using heteroepitaxial deposition according to one implementation described herein.

FIG. **4** is a schematic side view of a gas flow system in accordance with an embodiment of the present disclosure.

FIG. **5** is a perspective view of a gas flow stabilizer in accordance with an embodiment of the present disclosure.

FIG. **6**A is a perspective view of a gas flow receiver in accordance with an embodiment of the present disclosure.

FIG. **6**B is a cross-sectional view of the gas flow receiver of FIG. **6**A.

FIG. **7**A-**7**D are views from different perspectives of a gas flow stabilizer in accordance with an embodiment of the present disclosure.

FIG. **8** is a flow chart of an embodiment of a method in accordance with the present disclosure.

DETAILED DESCRIPTION

The following disclosure provides many different embodiments, or examples, for implementing different features of the provided subject matter. Specific examples of components and arrangements are described below to simplify the present disclosure. These are, of course, merely examples and are not intended to be limiting. For example, the formation of a first feature over or on a second feature in the description that follows may include embodiments in which the first and second features are formed in direct contact, and may also include embodiments in which additional features may be formed between the first and second features, such that the first and second features may not be in direct contact. In addition, the present disclosure may repeat reference numerals and/or letters in the various examples. This repetition is for the purpose of simplicity and

clarity and does not in itself dictate a relationship between the various embodiments and/or configurations discussed.

Further, spatially relative terms, such as "beneath," "below," "lower," "above," "upper" and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. The spatially relative terms are intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. The apparatus may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein may likewise be interpreted accordingly.

One embodiment described herein is a system for processing a substrate that includes a processing chamber including an access port. This embodiment includes a staging module for staging the substrate prior to delivering the substrate to the processing chamber through the access port and/or for receiving the substrate from the processing chamber through the access port. The system further includes an inert gas stabilizer positioned adjacent the access port. The inert gas flow stabilizer includes a horizontal flow guiding section and a vertical flow guiding section. In accordance with some embodiments, the system promotes a gas curtain outside the processing chamber and over the access port. The gas curtain serves to prevent or reduce the inflow of unwanted gases, e.g., oxygen, into the process chamber, especially when substrates are being introduced into or remove from the processing chamber. Preventing oxygen from entering process chambers is desirable because oxygen can damage sensors within the processing chamber and/or can interact with materials, e.g., aluminum, making up various components within the processing chamber and form unwanted films.

In other embodiments, a gas flow system is provided that includes a gas flow stabilizer and a gas flow receiver. The gas flow stabilizer and the gas flow receiver cooperate to promote the flow of a gas, e.g., an inert gas such as nitrogen, there between, thus forming a gas curtain of the type described in the previous paragraph. The gas flow stabilizer includes a horizontal flow guiding section through which gas flows and a vertical flow alignment section through which gas flows. The horizontal flow guiding section of the gas flow stabilizer overlies the vertical flow alignment section of the gas flow stabilizer. The horizontal flow guiding section of the gas flow stabilizer includes a plurality of overlapping horizontal gas flow paths and the vertical flow alignment section of the gas flow stabilizer includes a plurality of vertical gas flow pass. The gas flow receiver includes a vertical flow alignment section and a horizontal flow guiding section with the vertical flow alignment section of the gas flow receiver overlying the horizontal flow guiding section of the gas flow receiver. The vertical flow alignment section of the gas flow receiver includes a plurality of vertical gas flow paths in the horizontal flow guiding section of the gas flow receiver includes a plurality of overlapping horizontal gas flow paths.

Gas flow systems in accordance with some embodiments of the present disclosure are useful in methods for processing semiconductor substrates.

FIG. **1** illustrates a Rapid Thermal Processing system (RTP) in accordance with some embodiments of the present disclosure. The illustrated RTP system includes a processing chamber **100** having a lamp head **101** for processing a substrate **106**. The lamp head **101** may include an array of lamps as depicted in FIG. **1**.

The substrate **106** is mounted inside the chamber **100** on a substrate support **108** and is heated by the lamp head **101**, which is disposed in a position opposing the substrate support **108**. The lamp head **101** generates radiation which is directed to a front side **107** of the substrate **106**. Alternatively (not shown), the lamp head **101** may be configured to heat the back side of the substrate **106**, for example, such as by being disposed below the substrate **106**, or by directing the radiation to the back side of the substrate **106**. The radiation enters the processing chamber **100** through the window assembly **114**. The window assembly **114** may be a water-cooled quartz window assembly **114**. Beneath the substrate **106** is a reflector **102**, which is mounted on a water-cooled, base **116**. The base **116** may be a stainless steel base. The base **116** includes a circulation circuit **146** through which coolant circulates to cool the reflector **102**. In some implementations, the reflector **102** is made of aluminum and has a highly reflective surface coating **120**. Water is an example of a coolant that is circulated through the base **116** to keep the temperature of the reflector **102** below that of the heated substrate **106**. Alternatively, other coolants may be provided at the same as the water coolant or at different temperatures that the water coolant. For example, antifreeze (e.g., ethylene glycol, propylene glycol, or the like) or other heat transfer fluids may be circulated through the base **116** and/or the base **116** may be coupled to a chiller (not shown). An underside or backside of the substrate **106** and the top of the reflector **102** form a reflecting cavity **118**. The reflecting cavity **118** enhances the effective emissivity of the substrate **106**.

The temperatures at localized regions of the substrate **106** are measured by a plurality of temperature sensors, such as **152***a*, **152***b*, and **152***c*. Each temperature sensor includes a light pipe **126** that passes through a conduit **124** that extends from the backside of the base **116** through the top of the reflector **102**. The light pipe **126** may be a sapphire light pipe **126**. The light pipe **126** is positioned within the conduit **124** so that its uppermost end is flush with or slightly below the upper surface of the reflector **102**. The other end of light pipe **126** couples to a flexible optical fiber **125** that transmits sampled light from the reflecting cavity **118** to a pyrometer **128**.

The pyrometer **128** is connected to a controller **150** which controls the power supplied to the lamp head **101** in response to a measured temperature. In some implementations, the lamp head **101** uses a plurality of lights to deliver highly collimated radiation from tungsten-halogen lamps to the processing chamber **100**.

As indicated above, the described implementations use measurement or temperature sensors distributed over the reflector **102** so as to measure the temperature at different radii of the substrate **106**. During the thermal processing, the substrate **106** is rotated. Thus, each sensor actually samples the temperature profile of a corresponding annular ring area on the substrate **106**.

The concentration of various gases within the chamber **100** can be monitored by various sensors capable of detecting such gases. For example, the chamber may include an oxygen sensor or a nitrogen sensor or sensors capable of detecting other gases.

The substrate support **108** may be configured to be stationary or may rotate the substrate **106**. The substrate support **108** includes a support or an edge ring **134** which contacts the substrate **106** around the substrate's outer perimeter, thereby leaving the entire underside of the substrate **106** exposed except for a small annular region about the outer perimeter.

The support ring **134** rests on a rotatable tubular quartz cylinder **136** that is coated with silicon to render it opaque in the frequency range of the pyrometer **128**. The silicon coating on the quartz cylinder **136** acts as a baffle to block out radiation from the external sources that might contaminate the intensity measurements. The bottom of the quartz cylinder **136** is held by an annular upper bearing **141** which rests on a plurality of ball bearings **137** that are, in turn, held within a stationary, annular, lower bearing race **139**. The annular upper bearing **141** is magnetically coupled to an actuator (not shown) which rotates the quartz cylinder **136**, the edge ring **134** and the substrate **106** during the thermal processing.

A purge ring **145**, which is fitted into the chamber body, surrounds the quartz cylinder **136**. In some implementations, the purge ring **145** has an internal annular cavity **147** which opens up to a region above the annular upper bearing **141**. The internal annular cavity **147** is connected to a gas supply (not shown) through a passageway **149**. During processing, a purge gas is flowed into the chamber through the purge ring **145**. Gases are exhausted through an exhaust port, which is coupled to a vacuum pump (not shown). These purge gases can be relied upon to maintain the pressure within the chamber above pressure outside the chamber and thereby reduce the likelihood that unwanted gases from outside the chamber will enter the chamber, e.g., when the substrate is introduced into the chamber or removed from the chamber; however, in some instances purge gases can carry unwanted particles into the chamber and/or cause the substrate to shift from a desired position within the chamber.

The window assembly **114** is disposed in an upper portion of the processing chamber **100** to allow light energy provided by the lamp head **101** to enter the processing chamber **100**. In some implementations, the window assembly **114** includes an upper window **154** and a lower window **156**. The upper window **154** and the lower window **156** each comprise a material, e.g., quartz, transparent to the energy provided by the lamp head **101** to allow radiation from the lamp head **101** to enter the processing chamber **100** there through.

During processing, a processing gas is introduced into the processing chamber **100** above the substrate **106** through the window assembly **114**. The window assembly **114** may be used to more uniformly distribute the processing gas to the substrate **106** from overhead.

In some implementations, the lower window **156** is disposed below the upper window **154** and is spaced apart therefrom, to define a gap **158** there between. The gap **158** forms a plenum for receiving and flowing the processing gas therein from the inlet **130**. The lower window **156** includes one or more outlets **159** for delivering a processing gas from the plenum (e.g., the gap **158**) into the processing volume of the processing chamber **100**.

In some embodiments, the lamp heads heat a buffer layer formed on the substrate **106** to a temperature sufficient to cause the buffer layer to relax. The temperature sufficient to cause the buffer layer to relax may be dependent upon factors including but not limited to the buffer materials and substrate materials used, the relative strain with respect to the substrate material and the duration of the process. The lamp head **101** may be adapted to heat the buffer layer formed on the substrate **106** to a temperature within a range of about 10 degrees Celsius to about 1800 degrees Celsius, such as about 400 degrees Celsius to about 600 degrees Celsius. The lamp head **101** may be coupled to a power distribution board (not shown) through which power is supplied to each lamp of the lamp head **101**. The lamp head **101** may be cooled during or after processing by, for example, a cooling fluid. A cooling chamber **142** is defined by upper and lower chamber walls and a cylindrical wall. A coolant such as water may be introduced into the chamber via inlet **143** and removed via outlet **144**.

FIG. **2** is a flow diagram depicting a method **200** for forming a structure utilizing the chamber of FIG. **1** and the tool of FIG. **3** described below. Method **200** begins by providing a substrate to a reaction chamber at step **210**. The substrate may be any substrate that an epitaxial layer can be formed on. These may include, for example, substrate wafers made from sapphire (Al_2O_3), silicon (Si) (doped and undoped), silicon carbide (SiC), spinel, zinc oxide, as well as compound semiconductor substrates such as gallium-arsenide (GaAs), lithium gallate, indium phosphide (InP), single-crystal GaN, aluminum nitride (AlN), $GdScO_3$ (GSO), $MoSe_2$, $Ge_2Sb_2Te_5$ (GST) and other chalcogenide materials, among other substrates.

At step **220**, the substrate is pre-cleaned. The pre-clean process may be used to remove native oxides from the surface of the substrate. Prior to formation of the buffer layer, the substrate may be subjected to a pre-clean process and/or a degas process. In some implementations where processing of the substrate is performed ex-situ to the processing cluster tool, the substrate may be subjected to a pre-clean and/or degas process upon entering the cluster tool. The pre-clean process may be performed in a processing chamber positioned on a cluster tool, for example, cluster tool **300** (see FIG. **3**).

At block **230** a buffer layer is deposited on the surface of the substrate. In some implementations, the buffer layer may be a single-layer, multi-layer or graded buffer layer. The buffer layer may comprise any material that helps accommodate the lattice mismatch between the substrate and materials to be deposited onto or formed on the substrate. The buffer layer may be deposited using any suitable deposition technique. Suitable deposition techniques include epitaxial deposition processes, metal organic chemical vapor deposition (MOCVD) processes, hydride vapor phase epitaxial (HYPE) processes, physical vapor deposition (PVD) processes, chemical vapor deposition (CVD) processes, atomic layer deposition (ALD) processes, Atomic Layer Epitaxy (ALE) and/or any other suitable process.

At step **240**, the buffer layer is exposed to a rapid heating process. The rapid heating process may be an annealing process. The conditions of the annealing process are typically selected such that the buffer layer is heated to a temperature below the buffer layer's melting point but high enough to allow diffusion of dopants (when present) and rearrangement of lattice atoms to relax the buffer layer. Exemplary annealing processes include soak anneals, spike anneals, nanosecond anneals, millisecond anneals, laser annealing and combinations thereof.

The rapid heating process may be performed in the same chamber as the deposition process of block **230**. For example, the rapid heating process and the deposition process may be performed in the same processing chamber. The rapid heating process may be performed in a separate chamber than the deposition process of step **230**. In implementations where the rapid heating process is performed in a separate chamber, the separate chamber may be integrated on the same platform as the deposition chamber. In some implementations where the rapid heating process is performed in a separate chamber, the separate chamber may be positioned ex-situ from the integrated platform on which the deposition chamber is positioned. When the rapid heating process is carried out in a separate chamber, the substrate is removed from the chamber in which the deposition occurred and is transferred to a heating chamber.

The annealing process may be any high temperature thermal annealing process that is sufficient to cause the buffer layer to relax. The annealing process may be any high temperature thermal annealing process that is capable of heating the substrate to a temperature below the substrate's melting point but high enough to allow diffusion of dopants (when present) and rearrangement of lattice atoms. The temperature sufficient to cause the buffer layer to relax may be dependent upon factors including but not limited to the buffer materials and substrate materials used, the relative strain with respect to the substrate material, the type of anneal process used, the duration of the process, the temperature ramp-up rates and the temperature ramp-down rates. In some implementations, the annealing temperature is from about 200 degrees Celsius to about 2,000 degrees Celsius. In some implementations, the annealing temperature is about 900 degrees Celsius or above, for example, about 1,100 degrees Celsius to about 1,300 degrees Celsius. In some embodiments, depending on the buffer layer materials and the dopant, annealing temperatures within such ranges provide desired relaxation of the buffer layer and desired levels of diffusion of dopants into the substrate.

In some implementations the rapid heating process is a laser annealing process. The laser annealing process may be a pulsed laser annealing process. The pulsed laser annealing process as described herein may be performed by delivering electromagnetic radiation energy in a series of sequential pulses of energy to allow for diffusion and rearrangement of lattice atoms. The buffer layer may be exposed to multiple pulses of energy from a laser that emits radiation at one or more appropriate wavelengths for a desired period of time. The intensity and wavelength may be tuned depending on the amount of movement strain relaxation desired. Wavelengths of energy used may range generally from the microwave into the deep ultraviolet.

At step **250**, the substrate is exposed to an optional rapid cooling process. The rapid cooling process of step **250** may occur in the same chamber as the rapid heating process of step **240**. In other embodiments the cooling process is carried out in a chamber different from the chamber in which the heating process was conducted. In such embodiments, the substrate is removed from the chamber in which the heating process was conducted and is allowed to cool outside the chamber in which the heating process was conducted or is transferred to another chamber where it is allowed to cool. The rapid cooling process of step **240** may be an active cooling process or a passive cooling process. The rapid cooling process of step **250** may be performed by flowing a coolant through a portion of the chamber in which the cooling process is performed, for example, flowing a coolant through the substrate support on which the substrate is positioned in order to rapidly cool the substrate and/or using a coolant to cool the heating source used during the rapid heating process of step **240**. In some implementations where rapid cooling and rapid heating are performed in the same chamber, the chamber may have a chamber liner configured to rapidly dissipate heat.

At step **260** when the buffer layer has achieved a desired thickness, the method **200** proceeds to step **270** where an active material layer is deposited over the buffer layer. If the buffer layer has not achieved the desired thickness, the method **200** proceeds back to step **230** where additional buffer layer material may be deposited on the previously deposited buffer layer material. The additional buffer layer material may be exposed to the rapid heating process of step **240** and the optional rapid cooling process of step **250**.

While not discussed in detail here, at step **270**, one or more device layers and/or active material layers may be formed over the buffer layer. The active material layer may include for example, a p-n junction which is necessary for the fabrication of the desired semiconductor device, such as light emitting diodes (LEDs), laser diodes (LDs), or other electronic applications such as transistors.

FIG. **3** is a plan view of an example of a cluster tool **300** in which the RTP described with reference to FIG. **1** may be included and which, in operation, carries out the process described above with reference to FIG. **2**. In the embodiment of FIG. **3**, a transfer robot **304** is disposed in a transfer chamber **302** or and equipment front end module of the cluster tool. A load-lock **306**, with two load-lock chambers **306**A, **306**B are coupled to the transfer chamber **302**. A plurality of processing chambers **308**, **310**, **312**, **314**, and **316** are also coupled to the transfer chamber **302**. The plurality of processing chambers **308**, **310**, **312**, **314**, and **316** may include at least one of: a pre-clean chamber, a material deposition chamber such as an epitaxial deposition chamber, and a thermal processing chamber, such as an anneal, degas, or oxidation chamber.

Processing chamber **308** may be a pre-clean chamber configured to clean the substrate prior to deposition of a buffer layer and/or device layer. Processing chamber **310** and/or **314** may be a material deposition chamber such as an epitaxial deposition chamber capable of performing an epitaxial growth process. Processing chamber **312** and/or **316** may be a thermal treatment chamber capable of performing a thermal treatment process.

The cluster tool **300** may be used to perform the method **200** described above. During processing, a substrate that is to be processed may arrive to the cluster tool **300** in a pod (not shown). The substrate is transferred from the pod to the vacuum compatible load-lock chambers **306**A, **306**B by the factory interface robot (not shown). The substrate is then picked by the transfer robot **304** in the transfer chamber **302** which is generally kept in a vacuum state. The transfer robot **304** then loads the substrate into the processing chamber **308** for cleaning as described in block **220**. The transfer robot **304** then picks up the substrate from the processing chamber **308** and loads the substrate into the processing chamber **310** or **314**, whichever is available, for epitaxial deposition. An epitaxial buffer layer may be grown on the cleaned substrate in the processing chamber **310** or **314**. The transfer robot **304** then picks up the substrate from the processing chamber **310** or **314** and transfers the substrate into the thermal processing chamber **312** or **316** whichever is available. The epitaxial buffer layer is then exposed to a rapid heating/cooling process as described in block **240** and block **250**. The transfer robot **304** then picks the substrate from the thermal processing chamber **312** or **316** and transfers the substrate to processing chamber **314** for deposition of active material over the buffer layer as described in block **270**.

An embodiment of the present disclosure, is described below with respect to a thermal processing chamber, such as thermal processing chambers **312** or **316** of FIG. **3**; however, embodiments of the present disclosure are not limited to use with a thermal processing chamber. For example, embodiments of the present disclosure can be utilized in combination with other processing chambers that include load ports that open to atmospheric environments and receive therefrom substrates and open to atmospheric environments into which substrates from the processing chamber are delivered.

Referring to FIG. **4**, a system for processing a substrate in accordance with an embodiment of the present disclosure includes a processing chamber **400** and a substrate staging module **402** (sometimes referred to as an equipment front end module (EFEM). The processing chamber **400** is separated from the substrate staging module **402** by a wall **404** of the substrate staging module **402**. In some embodiments, the substrate staging module **402** is at atmospheric pressure. Access to the process chamber **400** is provided through an access port **406** in the wall **404**. Substrates or workpieces in the substrate staging module **402** are transferred (e.g., by a robot not shown) through the access port **406** and received in the chamber **400** for processing. When processing in chamber **400** is completed, the substrate is removed from the chamber and passed through the access port **406** into the substrate staging module **402**. In some embodiments of the present disclosure the processing chamber **400** is a chamber for carrying out a rapid thermal process as described above with reference to FIGS. **1**-**3**. Embodiments in accordance with the present disclosure are not limited to a processing chamber **400** that carries out a rapid thermal process. Embodiments in accordance with the present disclosure include a processing chamber **400** capable of carrying out a process different from a rapid thermal process.

Continuing to refer to FIG. **4**, rather than deliver a substrate from the substrate staging module **402** into a buffer zone before delivering the substrate to the processing chamber **400**, in accordance with embodiments of the present disclosure, the substrate is delivered from the substrate staging module **402** into the processing chamber without passing through a buffer zone. A buffer zone can be utilized for a number of different reasons, including isolating the environment within the substrate staging module **402** from the environment within the processing chamber. By utilizing the buffer zone, gas within the substrate staging module **402** can be isolated from the processing chamber **400** and thereby prevented from entering the processing chamber **400**. Preventing gas in a substrate staging module **402** from entering a processing chamber **400** can also be accomplished by maintaining the processing chamber **400** at a pressure that is greater than the pressure within the substrate staging module **402**. Thus, when the access port **406** of the substrate staging module **402** is opened, gas from within the processing chamber **400** flows out of the chamber into the substrate staging module **402** while the pressure differential precludes gas in the substrate staging module **402** from flowing into the chamber **400**. Such elevated pressure in the substrate staging module **402** can be achieved by supplying a purge gas into the process chamber **400**. Drawbacks of utilizing a purge gas in this manner include carrying particles into the process chamber **400**, causing particles in the process chamber to become mobile, causing the workpiece to shift or causing damage to gas sensors within the chamber.

Still referring to FIG. **4**, a substrate staging module **402** in accordance with an embodiment of a system for processing a substrate in accordance with the present disclosure includes, a gas flow stabilizer **408** located above the access port **406** on an inner surface **407** of wall **404** of substrate staging module **402**. Gas flow stabilizer **408** includes two gas inlets **410***a* and **410***b* that are in fluid communication with a source of gas, e.g., an inert gas such as nitrogen. Further details of gas flow stabilizer **408** are described below with reference to FIGS. **5** and **7**A-**7**D. Substrate staging module **402** further includes a gas flow receiver **412** located below the access port **406** on the same inner surface **407** of wall **404** upon which gas flow stabilizer **408** is located. Gas flow receiver **412** includes an outlet **414** in fluid communication with a source of vacuum **416**. Further details of gas flow receiver **412** are described below with reference to FIGS. **6**A and **6**B. In the embodiment illustrated in FIG. **4**, substrate staging module **402** includes a second access port **418**. Second access port **418** is a loading port and is configured to cooperate with a FOUP which supplies substrates or workpieces to the substrate staging module **402**. In operation, the system for processing a substrate illustrated in FIG. **4**, receives substrates from a FOUP through access port **418**. The substrates received into substrate staging module **402** are delivered through access port **406** into chamber **400**. In accordance with some embodiments of the present disclosure, gas is delivered to gas flow stabilizer **408** via gas inlets **410***a* and **410***b*. Such gas exits from a bottom of gas flow stabilizer **408** and flows downward along wall **404** towards gas flow receiver **412**. Gas that exits gas flow stabilizer **408** is drawn towards gas flow receiver **412**, due to the reduced pressure at the top of gas flow receiver created by the gas flow receiver being in fluid communication with vacuum source **416**. Substrate staging module **402** can further include other components (not shown) such as a wafer transfer robot, cooling station and clean gas delivery system, e.g., a gas filter fan unit.

In some embodiments of the present disclosure, the flow of gas between gas flow stabilizer **408** and gas flow receiver **412** along inner surface **407** of wall **404** is laminar, in which the gas travels smoothly and/or in regular paths, in contrast to turbulent flow, in which the fluid undergoes irregular fluctuations in mixing. In laminar flow, sometimes referred to as streamlined flow, the velocity, pressure and other flow properties at each point in the fluid remain constant. Laminar flow can be characterized by fluid particles following in smooth paths in layers, with each layer moving smoothly past the adjacent layers with little or no mixing. At low velocities, the fluid tends to flow without lateral mixing, and adjacent layers slide past one another. There are no cross-currents perpendicular to the direction of flow, nor eddies or swirls of fluids. In laminar flow, the motion of the particles of the fluid is very orderly with particles close to a solid surface moving in straight lines parallel to that surface. The dimensionless Reynolds number is a parameter that describes whether fully developed flow conditions lead to laminar or turbulent flow. The Reynolds number is the ratio of the inertial to the shearing of the fluid, i.e., how fast the fluid is moving relative to how viscous the fluid is, irrespective of the scale of the fluid system. Laminar flow generally occurs when the fluid is moving slowly or the fluid is very viscous. As the Reynolds number increases, such as by increasing the flow rate of the fluid, the flow will transition from laminar to turbulent flow at a specific range of Reynolds numbers. In accordance with embodiments of the present disclosure, when the gas flowing between the gas flow stabilizer and the gas flow receiver is nitrogen, in accordance with embodiments of the present disclosure, the Reynolds number is at or below a value that indicates the nitrogen gas flow between gas flow stabilizer **408** and gas flow receiver **412** is laminar. For example, in some embodiments of the present disclosure, the Reynolds number for a flow of nitrogen gas between gas flow stabilizer **408** and gas flow receiver **412** is in the range of less than 2000, e.g., 1000 to 160. Within such range of Reynolds numbers, the flow of nitrogen gas will provide a desired gas curtain in accordance with the present disclosure. Embodiments in accordance with the present disclosure are not limited to this range of Reynolds numbers. For example, in other embodiments of the present disclosure, the Reynolds number is less than about 3000. In other embodiments the Reynolds number can be above the range recited in the previous sentence or below the range recited in the previous sentence. In addition, if the gas is a gas other than nitrogen, the Reynolds number is a value that is below the Reynolds number associated with a transition from laminar flow to turbulent flow.

Referring to FIGS. **4** and **5**, gas stabilizer **408** includes housing **420** that includes a top side **422**, front side **424**, back side **427**, left end **428** and right end **430**. The bottom side **432** of housing **420** is open, i.e., not closed in. Housing **420** is made of any suitable rigid material such as metal or plastic that is inert to any gas that housing **420** might come in contact with. Gas stabilizer **408** includes a horizontal flow section **421** comprising an upper section of housing **420** overlying a vertical flow section **423** comprising a lower section of housing **420**. Horizontal flow section **421** includes a gas flow path designed to promote a uniform gas pressure (e.g., a gas pressure free of pressure pulses that would otherwise negatively affect the ability of vertical flow section **423** to provide a laminar flow of gas along inner surface **407** of wall **404**). Horizontal flow section **421** includes a plurality of horizontal plates **426***a*-**426***e* made from any rigid material such as metal or plastic. Horizontal plates **426***a*-**426***e* have a width that is substantially the same as the width of the interior of housing **420**, such that long edges of horizontal plates **426***a*-**426***e* abut the inside surface of housing **420** along the front side **424** and backside **427** of housing **420**. The long edges of horizontal plates **426***a*-**426***e* are sealed to the inside surface of housing **420** such that gas flowing through the horizontal flow section **421** cannot flow between the long edges of horizontal plates **426***a*-**426***e* where they are abutted or sealed to inner surface of housing **420**. In the illustrated embodiment, the length of horizontal plates **426***a*-**426***e* is less than the length of the interior of housing **420**. In the illustrated embodiment, the left hand ends of horizontal plates **426***a*, **426***c* and **426***e* are abutted with and sealed to the left-hand end of the interior of housing **420**. The right hand end of horizontal plates **626***a*, **626***c*, and **626***e* are abutted with and sealed to the right hand end of the interior of housing **420**. In this manner, horizontal plates **426***a*-**426***e* define a serpentine path through which gas flows from the top of the horizontal flow section **421** to the bottom of the horizontal flow section **421**. In the embodiment illustrated in FIG. **5**, gas that enters gas inlets **410***a* and **410***b* flows to the right above horizontal plate **426***a*. When the gas reaches the right hand end of horizontal plate **426***a*, it changes direction by 180 degrees and flows to the left between horizontal plate **426***a* and horizontal plate **426***b*. When the gas reaches the left-hand end of horizontal plate **426***b*, it changes direction by 180 degrees and flows to the right between horizontal plate **426***b* and horizontal plate **426***c*. The gas continues this serpentine path until it reaches the right hand end of horizontal plate **426***e*, where the gas flows downward into the top of vertical flow section **423**.

Referring to FIGS. **5** and **7**A-**7**D, vertical flow section **423**, in accordance with an embodiment of the present disclosure is defined by a lower portion of housing **420** in which a plurality of vertical plates **502***a*-**502***g* are arranged and supported. Vertical plates **502***a*-**502***g* are made from any rigid material, such as metal or plastic. Horizontal plates **426***a*-**426***e* have a length (L) that is substantially equal to the length of the inner surface of housing **420**. The height (H) of vertical plates **502***a*-**502***g* is sufficient such that vertical plates **502***a*-**502***g* occupy a portion of the housing below the horizontal plates **426***a*-**426***e* of the horizontal flow section **421**. In accordance with embodiments of the present disclosure, the vertical plates **502***a*-**502***g* can have a height or length different from that depicted in FIGS. **5** and **7**A-**7**D. In other words, the vertical plates **502***a*-**502***g* can be taller or shorter than depicted in FIGS. **5** and **7**A-**7**D. Also, vertical plates **502***a*-**502***g* can be shorter than depicted in FIGS. **5** and **7**A-**7**D. Referring to FIGS. **7**A-**7**D, in the illustrated embodiment, the left-hand end of vertical plates **502***a*-**502***g* are received and held in place by a plurality of grooves **514** in a retainer **504**. The right hand end of vertical plates **502***a*-**502***g* are received and held in place by a plurality of grooves provided in retainer **506**. Referring to FIG. **7**A-**7**D, front edge **508** of retainer **504** and front edge **510** of retainer **506** are secured to mounting plate **512** by fasteners (not shown). In the embodiment of FIG. **4**, mounting plate **512** is secured to inner wall **404** of substrate staging module **402**. When the vertical flow section **423** of gas flow stabilizer **408** is formed in accordance with FIGS. **7**A-**7**D, the vertical plate **502***g* can form the back side **427** of housing **420**. In such a configuration, the lower edge of the backside of housing **420** forming the backside of horizontal flow section **421** is connected to the upper edge of vertical plate **502***g*.

Referring to FIGS. **7**A-**7**D, the width of vertical plates **502***a*-**502***g* decreases as the plates move further away from mounting plate **512**. This results in the width (W) of the gap or space between adjacent plates increasing moving away from mounting plate **512**. More specifically, gap **516***a* is wider than gap **516***b* which is wider than gap **516***c* which is wider than gap **516***d* which is wider than gap **516***e* which is wider than gap **516***f*. The minimum width of gaps **516***a*-**516***f* can vary. In some embodiments, the minimum width of gaps **516***a*-**516***f* is at least 2 mm; however, in other embodiments, the minimum width can be less than 2 mm. The amount that the gap spacing increases moving away from the mounting plate **512** can vary. In some embodiments, adjacent gaps vary in width by about 2 mm or more. In other embodiments the adjacent gaps vary in width by an amount that is less than 2 mm. Providing a gas flow stabilizer **408** including gaps of the foregoing widths contributes to the ability of the gas flow stabilizer **408** to create a gas flow exiting gas flow stabilizer **408** that supports a laminar gas flow between gas flow stabilizer **408** and gas flow receiver **412**. In accordance with some embodiments of the present disclosure, the ratio of the width of the gaps **516***a*-**516***f* (W) to the length (L) of vertical plates **502***a*-**502***g* ranges between about 0.02 to 0.05. In accordance with some embodiments of the present disclosure, the ratio of the width of the gaps **516***a*-**516***f* (W) to the width of the vertical flow section **423** (measured from the exterior of plate **502***g* and the exterior of plate **502***a* ranges from about 0.04 to 0.1. When gas flow stabilizer **408** includes gaps **516** that satisfy these width to length ratios, gas flow stabilizer is able to create a gas flow exiting gas flow stabilizer that supports a laminar gas flow between gas flow stabilizer **408** and gas flow receiver **412**.

Referring to FIG. **7**C, retainer **504** includes grooves **514***a*-**514***c*. In the illustrated embodiment, the width of grooves and **514***a* is greater than the width of groove **514***b* which is greater in width than groove **514***c*. The width of these grooves corresponds to the width of the respective vertical plates **502***a*-**502***g* that will be received in the respective grooves.

In operation, gas that flows out of the bottom of horizontal flow section **421** enters the top of vertical flow section **423** and is dispersed across the top of the gaps **516***a*-**516***f* and enters respective gaps and begins to flow in a vertical direction. The gas leaves the vertical flow section **423** at the bottom of housing **420**. This gas is drawn towards gas flow receiver **412** due to the suction produced by the vacuum connected to gas flow receiver **412**. As noted above, in some embodiments, the gas flow between gas flow stabilizer **408** and gas flow receiver **412** is laminar across the inner surface **407** of wall **404**. This laminar flow of gas across access port **406** creates a barrier to gas from within substrate staging module **402** entering chamber **400** when access port **406** is open.

Referring to FIG. **6**A, an embodiment of a gas flow receiver **412** in accordance with the present disclosure is illustrated. Gas flow receiver **412** includes housing **620** that includes a bottom side **632**, front side **624**, back side **626**, left end **628** and right end **630**. The top side **622** of housing **620** is open. Housing is made of any suitable rigid material such as metal or plastic. Gas flow receiver **412** includes a horizontal flow section **621** within housing **620**. Horizontal flow section **621** is below vertical flow section **623** which is also within housing **620**. Horizontal flow section **621** includes a gas flow path which creates a uniform gas pressure e.g., a gas pressure free of pressure pulses that would otherwise negatively affect the ability of vertical flow section **623** to promote a laminar flow of gas along inner surface **407** of wall **404**. Horizontal flow section **621** includes a plurality of horizontal plates **626***a*-**626***e* made from any rigid material such as metal or plastic. In the embodiment illustrated in FIGS. **6**A and **6**B, horizontal plates **626***a*-**626***e* are supported within a horizontal flow chamber **650** that is contained within housing **620**. In the illustrated embodiment, horizontal flow chamber **650** is a rectangular box having a width and length slightly less than the width and length of the interior surface of housing **620** such that horizontal flow chamber **650** fits within housing **620**. A top surface of horizontal flow chamber **650** includes a plurality of orifices for receiving the bottom of vertical flow conduits (**640** described below). The bottom surface of horizontal flow chamber **650** includes an orifice that is in fluid communication with outlet **414** which is in fluid communication with vacuum source **416**. Horizontal plates **626***a*-**626***e* have a width that is substantially the same as the width of the interior of horizontal flow chamber **650**, such that the long edges of horizontal plates **626***a*-**626***e* abut the inside surface of horizontal flow chamber **650** along the front side and backside of horizontal flow chamber **650**. Gas within horizontal flow chamber **650** cannot flow between the long edges of horizontal plates **626***a*-**626***e* and the interior surface of horizontal flow chamber **650** where horizontal plates **626***a*-**626***e* are abutted or sealed to inner surface of horizontal flow chamber **650**. The length of horizontal plates **626***a*-**626***e* is less than the length of the interior horizontal flow chamber **650**. In the illustrated embodiment, the left hand ends of horizontal plates **626***a*, **626***c*, and **626***e* are sealed to the left-hand end of horizontal flow chamber **650**. The right hand end of horizontal plates **426***b* and **426***d* are sealed to the right hand end of horizontal flow chamber **650**. In this manner, horizontal plates **626***a*-**626***e* define a serpentine gas flow path within the horizontal flow section **621** of gas flow receiver **412**. In the embodiment illustrated in FIG. **6**A, gas that enters horizontal flow section **621** from vertical flow section **623** flows to the right above horizontal plate **626***a*. When the gas reaches the right hand end of horizontal plate **626***a*, it changes direction by 180° and flows to the left between horizontal plate **626***a* and horizontal plate **626***b*. When the gas reaches the left-hand end of horizontal plate **626***b*, it changes direction by 180° and flows to the right between horizontal plate **626***b* and horizontal plate **626***c*. The gas continues this serpentine path until it reaches the right hand end of horizontal plate **626***e*, where the gas flows downward below plate **626***e* and is removed from horizontal flow chamber **650** via outlet **414**.

Continuing to refer to FIGS. **6**A and **6**B, vertical flow section **623** in accordance with an embodiment of the present disclosure is defined in an upper portion of housing **620**. Vertical flow section **623** includes a plurality of vertically oriented conduits **640** having a round cross-section. As noted above, the bottoms or vertically oriented conduits **640** are received into the top of horizontal gas flow chamber **650**. The vertical conduits **640** are made from any rigid material, such as metal or plastic. In the embodiment illustrated in FIGS. **6**A and **6**B, vertical conduits **640** are arranged in 10 rows, each row including 29 vertical conduits, with the position of the vertical conduits of adjacent rows being offset in a direction along the length of the housing **620**. The length of the vertical conduits is approximately equal to the distance between upper surface of horizontal flow chamber **650** and the top of housing **620**. In accordance with other embodiments, the length of vertical conduits **640** is less than the distance between upper surface of horizontal flow chamber **650** and the top of housing **620**. The diameter of the vertically oriented conduits **640** can vary. In some embodiments, the diameter of vertically oriented conduits **640** is about 2 mm. In other embodiments, the diameter of vertically oriented conduits **640** is greater than 2.2 mm and in other embodiments, the diameter of vertically oriented conduits **640** is less than 1.8 mm. Vertically oriented conduits having inner diameters that fall within the ranges described above are able to provide sufficient open cross-sectional area to allow gas flow receiver **412** to draw a sufficient amount of gas from gas flow stabilizer **408** into gas flow receiver **412** to support the formation of a gas curtain, which in some embodiments is a laminar gas flow. In the illustrated embodiment, vertical flow section **623** includes about 290 vertical conduits. In other embodiments in accordance with the present disclosure, vertical flow section **623** includes more than 290 vertical conduits. In other embodiments in accordance with the present disclosure, vertical flow section **623** includes less than 290 vertical conduits. The ratio of the combined surface area of the openings of the vertical conduits **640** to the surface area of the top of housing **620** ranges between about 0.5 to about 0.9. A ratio of the combined surface area of the openings of the vertical conduits to the surface area of the top of housing **620** within the foregoing ranges provides sufficient open cross-sectional area to allow gas flow receiver **412** to draw a sufficient amount of gas from gas stabilizer **408** into gas flow receiver **412** to support the formation of a gas curtain, which in some embodiments is a laminar gas flow. The pattern of the spacing between vertical conduits **640** and the distance between adjacent vertical conduits **640** is chosen depending on the gas flow rate that is desired to support a laminar flow between gas flow stabilizer **408** and gas flow receiver **412**. For example, vertical conduits spaced more closely together can support a larger gas flow compared to vertical conduits that are not spaced as closely together. Embodiments in accordance with the present disclosure are not limited to the foregoing ratio of combined surface area of the openings of the vertical conduits **642** the surface area of the top of housing **620**. For example in other embodiments, the ratio of combined surface area of the openings of the vertical conduits **642** the surface area of the top of housing **620** can be above or below the range of ratios recited above.

In accordance with embodiments of the present disclosure, in other embodiments in accordance with the present disclosure, instead of vertical conduits **640**, gas flow receiver **412** includes vertical plates similar to the vertical plates described above with reference to FIGS. **5** and **7**A-**7**D. In accordance with embodiments of the present disclosure, the vertical plates utilized in gas flow receiver **412** can have different thicknesses so as to provide gas flow paths of different widths or the vertical plates may have equal widths and provide gas flow paths that are of equal widths.

In accordance with some embodiments of the present disclosure, the gas flow stabilizer **408** includes the vertical flow section **423** and not the horizontal flow section **421**. Similarly, gas flow receiver **412** includes the vertical flow section **623** and not the horizontal flow section **621**.

Referring to FIG. **8**, a method **800** in accordance with an embodiment of the present disclosure includes step **820** of passing an inert gas through a horizontal flow section of an inert gas flow stabilizer that is located above and access port to a processing chamber. Step **830** of the method **800** includes passing the inert gas from the horizontal gas flow section to a vertical flow section of the inert gas flow stabilizer, wherein the horizontal flow section of the inert gas flow stabilizer overlies the vertical flow section of the inert gas flow stabilizer. Step **840** of the method includes receiving, in a vertical flow section of the inert gas flow receiver, the inert gas from the inert gas flow stabilizer. Step **850** involves receiving, from the vertical flow section of the inert gas flow receiver, the inert gas into a horizontal flow section of the inert gas flow receiver. The vertical flow section of the inert gas flow receiver overlying the horizontal flow section of the inert gas flow receiver. At step **860**, the semiconductor substrate is passed through the access port. At step **870**, the semiconductor substrate is processed in the processing chamber.

In accordance with one embodiment, a system for processing a substrate or work piece is described. The system includes a processing chamber and a staging module for staging the substrate prior to delivering the substrate to the processing chamber. The system further includes an access port between the processing chamber and the staging module through which the substrate is passed between the staging module and the processing chamber. A gas flow stabilizer is positioned adjacent the access port. The gas flow stabilizer includes a horizontal flow section and a vertical flow section. In some embodiments, gas flowing out of the gas flow stabilizer flows in a laminar state across the access port.

In another embodiment of the present disclosure, a method of processing a semiconductor substrate includes receiving a semiconductor substrate into a processing chamber via an access port and processing the semiconductor substrate in the processing chamber. The method provides an inert gas flow outside the processing chamber and over the access port. The inert gas flow is created by passing an inert gas through an inert gas flow stabilizer positioned above the access port. The inert gas flow stabilizer includes a horizontal flow section and a vertical flow section, with the horizontal flow section of the inert gas flow stabilizer overlying the vertical flow section of the inert gas flow stabilizer. The inert gas flow is received in an inert gas flow receiver that includes a vertical flow section overlying a horizontal flow section.

In another embodiment, the present disclosure describes a gas flow system that includes gas flow stabilizer, the gas flow stabilizer including a horizontal flow section and a vertical flow section. In accordance with this embodiment, the horizontal flow section of the gas flow stabilizer overlies the vertical flow section of the gas flow stabilizer. The horizontal flow section of the gas flow stabilizer includes a plurality of overlapping horizontal gas flow paths and the vertical flow section of the gas flow stabilizer includes a plurality of vertical gas flow paths. The system further includes a gas flow receiver including a vertical flow section and a horizontal flow section. The vertical flow section of the gas flow receiver overlies the horizontal flow section of the gas flow receiver. The vertical flow section of the gas flow receiver includes a plurality of vertical gas flow paths and the horizontal flow section of the gas flow receiver includes a plurality of overlapping horizontal gas flow paths.

The foregoing outlines features of several embodiments so that those skilled in the art may better understand the aspects of the present disclosure. Those skilled in the art should appreciate that they may readily use the present disclosure as a basis for designing or modifying other processes and structures for carrying out the same purposes and/or achieving the same advantages of the embodiments introduced herein. Those skilled in the art should also realize that such equivalent constructions do not depart from the spirit and scope of the present disclosure, and that they may make various changes, substitutions, and alterations herein without departing from the spirit and scope of the present disclosure.

The invention claimed is:

1. A system, comprising:

a substrate staging module including a wall, the wall having an access port;

a gas flow stabilizer proximate to a first side of the access port, the gas flow stabilizer including a horizontal flow section and a vertical flow section, the horizontal flow section of the gas flow stabilizer overlying the vertical flow section of the gas flow stabilizer, the horizontal flow section of the gas flow stabilizer including a plurality of overlapping horizontal gas flow paths and the vertical flow section of the gas flow stabilizer including a plurality of vertical gas flow paths; and

a gas flow receiver proximate to a second side of the access port, the gas flow receiver including a vertical flow section and a horizontal flow section, the vertical flow section of the gas flow receiver overlying the horizontal flow section of the gas flow receiver, the vertical flow section of the gas flow receiver including a plurality of vertical gas flow paths, and the horizontal flow section of the gas flow receiver including a plurality of overlapping horizontal gas flow paths,

wherein each of the plurality of overlapping horizontal gas flow paths in the gas flow stabilizer is opposite in horizontal direction to a preceding horizontal gas flow path.

2. The system of claim **1**, wherein the plurality of overlapping horizontal gas flow paths of the gas flow stabilizer are defined between a plurality of overlapping horizontal plates.

3. The system of claim **1**, wherein the plurality of vertical gas flow paths of the gas flow stabilizer are defined between a plurality of vertical plates.

4. The system of claim **3**, wherein at least two pairs of the plurality of vertical plates are spaced apart unequally.

5. The system of claim **1**, wherein the plurality of vertical gas flow paths of the gas flow receiver are defined by a plurality of vertical conduits.

6. The system of claim **5**, wherein the vertical conduits have a round cross-section.

7. The system of claim **1**, further comprising a plurality of gas inlets coupled to the horizontal flow section of the gas flow stabilizer, the plurality of gas inlets being in fluid communication with the gas flow stabilizer.

8. The system of claim **1**, further comprising a source of a vacuum in fluid communication with the gas flow receiver.

9. The system of claim **4**, wherein plurality of vertical plates are spaced apart at least 2 mm.

10. The system of claim **1**, wherein each of the plurality of overlapping horizontal gas flow paths in the gas flow receiver is opposite in horizontal direction to a preceding horizontal gas flow path.

11. The system of claim **1**, wherein the gas flow receiver is equipped with vertical conduits having a round cross-section and a diameter of about 2 mm.

12. The system of claim **7**, wherein the plurality of gas inlets are in fluid communication with a source of gas.

13. The system of claim **1**, wherein the vertical flow section of the gas flow receiver is equipped with a plurality of conduits arranged in rows, each row including a plurality of vertical conduits, with the position of the vertical conduits of adjacent rows being offset from each other.

14. A system, comprising:

a substrate staging module including a wall with an access port;

a gas flow stabilizer included above the access port and coupled to a surface of the wall interior to the substrate staging module, the gas flow stabilizer including a horizontal flow section and a vertical flow section, the horizontal flow section of the gas flow stabilizer overlying the vertical flow section of the gas flow stabilizer, the horizontal flow section of the gas flow stabilizer including a plurality of horizontal gas flow paths and the vertical flow section of the gas flow stabilizer including a plurality of vertical gas flow paths, wherein the plurality of horizontal gas flow paths is serpentine; and

a gas flow receiver included below the access port and coupled to the surface of the wall interior to the substrate staging module, the gas flow receiver including a vertical flow section and a horizontal flow section, the vertical flow section of the gas flow receiver overlying the horizontal flow section of the gas flow receiver, the vertical flow section of the gas flow receiver including a plurality of vertical gas flow paths, and the horizontal flow section of the gas flow receiver including a plurality of horizontal gas flow paths.

15. The system of claim **14**, wherein the plurality of horizontal gas flow paths of the gas flow stabilizer are defined between a plurality of horizontal plates.

16. The system of claim **14**, wherein the plurality of vertical gas flow paths of the gas flow stabilizer are defined between a plurality of vertical plates.

17. The system of claim **14**, wherein the plurality of vertical gas flow paths of the gas flow receiver are defined by a plurality of vertical conduits that have a round cross-section.

18. A system, comprising:

a substrate staging module including a wall, the wall having an access port;

a gas flow stabilizer proximate to a first side of the access port and coupled to the wall, the gas flow stabilizer including a horizontal flow section and a vertical flow section, the horizontal flow section of the gas flow stabilizer overlying the vertical flow section of the gas flow stabilizer, the horizontal flow section of the gas flow stabilizer including a plurality of overlapping horizontal gas flow paths and the vertical flow section of the gas flow stabilizer including a plurality of vertical gas flow paths, wherein the plurality of overlapping horizontal gas flow paths of the gas flow stabilizer are defined between a plurality of overlapping horizontal plates, and the plurality of vertical gas flow paths of the gas flow stabilizer are defined between a plurality of vertical plates; and

a gas flow receiver proximate to a second side of the access port and coupled to the wall, the gas flow receiver including a vertical flow section and a horizontal flow section, the vertical flow section of the gas flow receiver overlying the horizontal flow section of the gas flow receiver, the vertical flow section of the gas flow receiver including a plurality of vertical gas flow paths, and the horizontal flow section of the gas flow receiver including a plurality of overlapping horizontal gas flow paths.

19. The system of claim **18**, wherein at least two pairs of the plurality of vertical plates are spaced apart unequally.

20. The system of claim **18**, wherein the plurality of vertical gas flow paths of the gas flow receiver are defined by a plurality of vertical conduits.

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