

MODULAR MULTI-DIRECTIONAL GAS MIXING BLOCK

CROSS-REFERENCE TO RELATED APPLICATIONS

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[0001] This application claims the benefit and priority of U.S. Patent Application No. 17/514,430, filed October 29, 2021, entitled “MODULAR MULTI-DIRECTIONAL GAS MIXING BLOCK”, which is hereby incorporated by reference in its entirety.

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TECHNICAL FIELD

[0002] The present technology relates to semiconductor processes and equipment. More specifically, the present technology relates to substrate processing systems and components.

BACKGROUND

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[0003] Semiconductor processing systems often utilize cluster tools to integrate a number of process chambers together. This configuration may facilitate the performance of several sequential processing operations without removing the substrate from a controlled processing environment, or it may allow a similar process to be performed on multiple substrates at once in the varying chambers. These chambers may include, for example, degas chambers, pretreatment chambers, transfer chambers, chemical vapor deposition chambers, physical vapor deposition chambers, etch chambers, metrology chambers, and other chambers. The combination of chambers in a cluster tool, as well as the operating conditions and parameters under which these chambers are run, are selected to fabricate specific structures using particular process recipes and process flows.

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[0004] Oftentimes, processing systems include gas delivery assemblies that may mix and/or otherwise deliver a number of process gases to the various chambers. The flow of these gases may be carefully controlled to ensure uniform flow of gases into each of the processing chambers.

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[0005] Thus, there is a need for improved systems and methods that can be used to efficiently mix and/or otherwise deliver gases to processing chambers under desired conditions. These and other needs are addressed by the present technology.

SUMMARY

[0006] Exemplary modular gas delivery assemblies may include a plurality of modular gas blocks coupled together to form a gas path along a length and a width of the modular gas delivery assembly. Each of the plurality of modular gas blocks may include a block body having an upper portion and a lower portion. A first end of the upper portion may extend beyond a first end of the lower portion and a second end of the lower portion may extend beyond a second end of the upper portion. A longitudinal axis of the block body may extend from the first end to the second end of the upper portion. The block body may define a first fluid channel that extends along the longitudinal axis. The first fluid channel may include a first fluid port extending through an upper surface of the second end of the lower portion. The first fluid channel may include a second fluid port extending through an upper surface of a medial region of the upper portion. The first fluid channel may include a third fluid port extending through a lower surface of the first end of the upper portion. The block body may define a second fluid channel that extends transversely to the longitudinal axis and the first fluid channel. A first modular gas block of the plurality of modular gas blocks may be coupled with a second modular gas block of the plurality of modular gas blocks and a third modular gas block of the plurality of modular gas blocks such that the first fluid channels of each of the first modular gas block, the second modular gas block, and the third modular gas block are fluidly coupled with one another.

[0007] In some embodiments, the first end of the upper portion of the first modular gas block may be positioned above and coupled with the second end of the lower portion of the second modular gas block. The third fluid port of the first modular gas block may be coupled with the first fluid port of the second modular gas block. The second end of the lower portion of the first modular gas block may be positioned below and coupled with the first end of the upper portion of the third modular gas block. The first fluid port of the first modular gas block may be coupled with the third fluid port of the third modular gas block. The assemblies may include a plurality of valves. Each of the plurality of valves may be coupled with the medial region of the upper portion of a respective one of the plurality of modular gas blocks. Each of the plurality of valves may include a valve port. Each valve port may be coupled with the second fluid port of a respective one of the plurality of modular gas blocks. A fourth modular gas block of the plurality of modular gas blocks may be coupled with first modular gas block in a direction that is transverse to the longitudinal axis of the first modular

gas block. The second fluid channel of the first modular gas block may be fluidly coupled with the second fluid channel of the fourth modular gas block. The modular gas delivery assembly may include a proximal end in a direction of the first end of each of the plurality of modular gas blocks and a distal end in a direction of the second end of each of the plurality of modular gas blocks. The third fluid port of a proximal-most one of the plurality of modular gas blocks may be obstructed. The first fluid port of a distal-most one of the plurality of modular gas blocks may be obstructed. An obstruction of one or both of the first fluid port of the distal-most one of the plurality of modular gas blocks and the third fluid port of the proximal-most one of the plurality of modular gas blocks may be removable to couple an additional plurality of modular gas blocks to the gas delivery assembly along the width of the modular gas assembly. Each of the plurality of modular gas blocks may include an identical geometry. Top surfaces of each of the plurality of modular gas blocks may be generally coplanar. Bottom surfaces of each of the plurality of modular gas blocks may be generally coplanar. Interfaces formed between at least some of the fluid ports of the plurality of modular gas blocks may include C-seals. The modular gas delivery assembly may not include any weldments extending beneath the plurality of modular gas blocks.

[0008] Some embodiments of the present technology may encompass modular gas blocks. The blocks may include a block body having an upper portion and a lower portion. A first end of the upper portion may extend beyond a first end of the lower portion and a second end of the lower portion may extend beyond a second end of the upper portion. A longitudinal axis of the block body may extend from the first end to the second end of the upper portion. The block body may define a first fluid channel that extends along the longitudinal axis. The first fluid channel may include a first fluid port extending through an upper surface of the second end of the lower portion. The first fluid channel may include a second fluid port extending through an upper surface of a medial region of upper portion. The first fluid channel may include a third fluid port extending through a lower surface of the first end of the upper portion. The block body may define a second fluid channel that extends transversely to the longitudinal axis and the first fluid channel.

[0009] In some embodiments, an upper surface of the first end of the upper portion and the upper surface of the second end of the lower portion may each define a plurality of fastener receptacles. The lower surface of the first end of the upper portion and the upper surface of the second end of the lower portion may be substantially coplanar. A thickness of the first

end of the upper portion and the second end of the lower portion may be together substantially as thick as the medial region.

[0010] Some embodiments of the present technology may encompass modular gas delivery assemblies. The assemblies may include a first modular gas block. The assemblies may
5 include a second modular gas block coupled with a first end of the first modular gas block. The assemblies may include a third modular gas block coupled with a second end of the first modular gas block. Each of the first modular gas block, second modular gas block, and third modular gas block may include a block body having an upper portion and a lower portion. A first end of the upper portion may extend beyond a first end of the lower portion and a second
10 end of the lower portion may extend beyond a second end of the upper portion. The block body may define a first fluid channel that extends the first end to the second end. The first fluid channel may include a first fluid port extending through an upper surface of the second end of the lower portion. The first fluid channel may include a second fluid port extending through an upper surface of a medial region of the upper portion. The first fluid channel may
15 include a third fluid port extending through a lower surface of the first end of the upper portion. The block body may define a second fluid channel that extends transversely to the first fluid channel. The first fluid channels of each of the first modular gas block, the second modular gas block, and the third modular gas block may be fluidly coupled with one another.

[0011] In some embodiments, the first end of the upper portion of the first modular gas
20 block may be positioned above and coupled with the second end of the lower portion of the second modular gas block. The third fluid port of the first modular gas block may be coupled with the first fluid port of the second modular gas block. The second end of the lower portion of the first modular gas block may be positioned below and coupled with the first end of the upper portion of the third modular gas block. The first fluid port of the first modular gas
25 block may be coupled with the third fluid port of the third modular gas block. The assemblies may include a fourth modular gas block coupled with first modular gas block in a direction that is transverse to first fluid channel of the first modular gas block.

[0012] Such technology may provide numerous benefits over conventional systems and techniques. For example, the processing systems may provide modular gas assembly
30 components that may be easily assembled to produced customized gas assemblies. Additionally, the modular gas assembly components may facilitate mixing of different gases without the need for complex arrangements of weldments, which may reduce the time, cost,

and complexity of gas delivery assemblies. These and other embodiments, along with many of their advantages and features, are described in more detail in conjunction with the below description and attached figures.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0013] A further understanding of the nature and advantages of the disclosed technology may be realized by reference to the remaining portions of the specification and the drawings.

[0014] FIG. 1 shows a schematic top plan view of an exemplary processing system according to some embodiments of the present technology.

10 **[0015]** FIG. 2 shows a schematic isometric view of a transfer region of an exemplary chamber system according to some embodiments of the present technology.

[0016] FIG. 3 shows a schematic isometric view of a transfer region of an exemplary chamber system according to some embodiments of the present technology.

15 **[0017]** FIG. 4 shows a schematic isometric view of a transfer region of an exemplary chamber system according to some embodiments of the present technology.

[0018] FIG. 5 shows a schematic partial isometric view of a chamber system according to some embodiments of the present technology.

[0019] FIG. 6 shows a schematic isometric view of an exemplary modular gas block according to some embodiments of the present technology.

20 **[0020]** FIG. 6A illustrates a schematic cross-sectional front elevation view of the modular gas block of FIG. 6.

[0021] FIG. 6B illustrates a schematic cross-sectional side elevation view of the modular gas block of FIG. 6.

25 **[0022]** FIG. 7 illustrates a schematic cross-sectional side elevation view of a gas delivery assembly according to some embodiments of the present technology.

[0023] FIG. 8 illustrates a schematic cross-sectional front elevation view of a gas delivery assembly according to some embodiments of the present technology.

[0024] FIG. 9 illustrates a schematic top plan view of a number of gas delivery assemblies according to some embodiments of the present technology.

[0025] FIG. 10 shows a schematic top plan view of a semiconductor processing system according to some embodiments of the present technology.

[0026] Several of the figures are included as schematics. It is to be understood that the figures are for illustrative purposes, and are not to be considered of scale or proportion unless
5 specifically stated to be of scale or proportion. Additionally, as schematics, the figures are provided to aid comprehension and may not include all aspects or information compared to realistic representations, and may include exaggerated material for illustrative purposes.

[0027] In the appended figures, similar components and/or features may have the same reference label. Further, various components of the same type may be distinguished by
10 following the reference label by a letter that distinguishes among the similar components. If only the first reference label is used in the specification, the description is applicable to any one of the similar components having the same first reference label irrespective of the letter.

DETAILED DESCRIPTION

15 [0028] Substrate processing can include time-intensive operations for adding, removing, or otherwise modifying materials on a wafer or semiconductor substrate. Efficient movement of the substrate may reduce queue times and improve substrate throughput. To improve the number of substrates processed within a cluster tool, additional chambers may be incorporated onto the mainframe. Although transfer robots and processing chambers can be
20 continually added by lengthening the tool, this may become space inefficient as the footprint of the cluster tool scales. Accordingly, the present technology may include cluster tools with an increased number of processing chambers within a defined footprint. To accommodate the limited footprint about transfer robots, the present technology may increase the number of processing chambers laterally outward from the robot. For example, some conventional
25 cluster tools may include one or two processing chambers positioned about sections of a centrally located transfer robot to maximize the number of chambers radially about the robot. The present technology may expand on this concept by incorporating additional chambers laterally outward as another row or group of chambers. For example, the present technology may be applied with cluster tools including three, four, five, six, or more processing
30 chambers accessible at each of one or more robot access positions.

[0029] Processing systems may include gas delivery assemblies to deliver various gases to the processing chambers. To eliminate the need to have a different output delivery lumen for

each type of gas being flowed to a given chamber or set of chambers, gas delivery assemblies are often designed to mix and co-flow compatible gases to the chambers. Conventional gas delivery assemblies deliver gases to an output weldment along a length (or y-axis) of the assembly. To facilitate mixing of the various gases, conventional systems utilize an array of
5 different weldments that are typically provided beneath gas blocks on which valves, mass flow controllers, and/or other shut off and/or flow throttling components may be mounted. The network of weldments may be complex, which may lead to issues in designing and fabricating a new gas delivery assembly, altering an existing gas delivery assembly, and/or servicing an existing gas delivery assembly.

10 **[0030]** To design new gas delivery assemblies using conventional components requires engineers to design and/or weldments of a correct shape and size to properly connect various ports of a gas assembly, while ensuring that the weldments positioned beneath the gas blocks do not run into one another. The fabrication may be tedious and may involve the use of significant numbers of different weldments to achieve a functional assembly. Additionally,
15 due to the complexity of the weldment configurations, engineers cannot design base assembly designs that may be easily altered to accommodate new assembly designs. Therefore, engineers must design each assembly from scratch. These issues may cause the design and fabrication of new assemblies to be slow (up to 15 weeks) and very expensive.

[0031] During altering (such as adding or subtracting a new gas source/gas stick) and/or
20 servicing of existing gas delivery assemblies, technicians must remove all upper components (such as valves, mass flow controllers, gas blocks, and the like) to access the weldments. Oftentimes, a majority or entirety of the gas assembly may need to be disassembled to add or remove a gas stick. The network of weldments beneath the gas blocks may need to be completely redesigned and/or replaced to accommodate mixing of newly added gas sticks.
25 Oftentimes, any weldments from a previous iteration of a gas delivery assembly must be scrapped, leading to considerable waste. Additionally, if modification and/or service of a gas assembly impacts a toxic gas stick, the entire toxic gas stick may need to be replaced to prevent any toxic gases from leaking into the environment. These issues may cause the modification or repair of existing assemblies to be slow (up to 18 weeks) and very expensive.

30 **[0032]** The present technology overcomes these issues by utilizing modular gas blocks that include lumens that facilitate gas mixing between adjacent gas sticks in the x-direction. Such lumens may eliminate the need for the network of weldments at the bottom of the gas

delivery assembly and may significantly simplify the design and fabrication of the gas delivery assembly. All or most of the modular gas blocks may have an identical geometry, which may enable alteration of the gas delivery assembly to be as simple as connecting or removing a gas stick to or from an existing gas delivery assembly, without the need to expose other flow paths. This may eliminate the risk of exposing toxic gas sticks and may help reduce waste during alteration operations. Additionally, a purge gas stick may be provided that may be used to flush any toxic gas flow paths to further mitigate any risk of toxic gases during servicing of the gas delivery assembly. Such features may significantly shorten the time (oftentimes to less than 4-5 weeks) and cost associated with designing, fabricating, and/or otherwise altering a gas delivery assembly.

[0033] Although the remaining disclosure will routinely identify specific structures, such as four-position chamber systems, for which the present structures and methods may be employed, it will be readily understood that the systems and methods are equally applicable to any number of structures and devices that may benefit from the structural capabilities explained. Accordingly, the technology should not be considered to be so limited as for use with any particular structures alone. Moreover, although an exemplary tool system will be described to provide foundation for the present technology, it is to be understood that the present technology can be incorporated with any number of semiconductor processing chambers and tools that may benefit from some or all of the operations and systems to be described.

[0034] **FIG. 1** shows a top plan view of one embodiment of a substrate processing tool or processing system 100 of deposition, etching, baking, and curing chambers according to some embodiments of the present technology. In the figure, a set of front-opening unified pods 102 supply substrates of a variety of sizes that are received within a factory interface 103 by robotic arms 104a and 104b and placed into a load lock or low pressure holding area 106 before being delivered to one of the substrate processing regions 108, positioned in chamber systems or quad sections 109a-c, which may each be a substrate processing system having a transfer region fluidly coupled with a plurality of processing regions 108. Although a quad system is illustrated, it is to be understood that platforms incorporating standalone chambers, twin chambers, and other multiple chamber systems are equally encompassed by the present technology. A second robotic arm 110 housed in a transfer chamber 112 may be used to transport the substrate wafers from the holding area 106 to the quad sections 109 and back, and second robotic arm 110 may be housed in a transfer chamber with which each of

the quad sections or processing systems may be connected. Each substrate processing region 108 can be outfitted to perform a number of substrate processing operations including any number of deposition processes including cyclical layer deposition, atomic layer deposition, chemical vapor deposition, physical vapor deposition, as well as etch, pre-clean, anneal, plasma processing, degas, orientation, and other substrate processes.

[0035] Each quad section 109 may include a transfer region that may receive substrates from, and deliver substrates to, second robotic arm 110. The transfer region of the chamber system may be aligned with the transfer chamber having the second robotic arm 110. In some embodiments the transfer region may be laterally accessible to the robot. In subsequent operations, components of the transfer sections may vertically translate the substrates into the overlying processing regions 108. Similarly, the transfer regions may also be operable to rotate substrates between positions within each transfer region. The substrate processing regions 108 may include any number of system components for depositing, annealing, curing and/or etching a material film on the substrate or wafer. In one configuration, two sets of the processing regions, such as the processing regions in quad section 109a and 109b, may be used to deposit material on the substrate, and the third set of processing chambers, such as the processing chambers or regions in quad section 109c, may be used to cure, anneal, or treat the deposited films. In another configuration, all three sets of chambers, such as all twelve chambers illustrated, may be configured to both deposit and/or cure a film on the substrate.

[0036] As illustrated in the figure, second robotic arm 110 may include two arms for delivering and/or retrieving multiple substrates simultaneously. For example, each quad section 109 may include two accesses 107 along a surface of a housing of the transfer region, which may be laterally aligned with the second robotic arm. The accesses may be defined along a surface adjacent the transfer chamber 112. In some embodiments, such as illustrated, the first access may be aligned with a first substrate support of the plurality of substrate supports of a quad section. Additionally, the second access may be aligned with a second substrate support of the plurality of substrate supports of the quad section. The first substrate support may be adjacent to the second substrate support, and the two substrate supports may define a first row of substrate supports in some embodiments. As shown in the illustrated configuration, a second row of substrate supports may be positioned behind the first row of substrate supports laterally outward from the transfer chamber 112. The two arms of the second robotic arm 110 may be spaced to allow the two arms to simultaneously enter a quad

section or chamber system to deliver or retrieve one or two substrates to substrate supports within the transfer region.

[0037] Any one or more of the transfer regions described may be incorporated with additional chambers separated from the fabrication system shown in different embodiments.

- 5 It will be appreciated that additional configurations of deposition, etching, annealing, and curing chambers for material films are contemplated by processing system 100. Additionally, any number of other processing systems may be utilized with the present technology, which may incorporate transfer systems for performing any of the specific operations, such as the substrate movement. In some embodiments, processing systems that may provide access to
- 10 multiple processing chamber regions while maintaining a vacuum environment in various sections, such as the noted holding and transfer areas, may allow operations to be performed in multiple chambers while maintaining a particular vacuum environment between discrete processes.

- [0038]** As noted, processing system 100, or more specifically quad sections or chamber
- 15 systems incorporated with processing system 100 or other processing systems, may include transfer sections positioned below the processing chamber regions illustrated. **FIG. 2** shows a schematic isometric view of a transfer section of an exemplary chamber system 200 according to some embodiments of the present technology. FIG. 2 may illustrate additional aspects or variations of aspects of the transfer region described above, and may include any
- 20 of the components or characteristics described. The system illustrated may include a transfer region housing 205, which may be a chamber body as discussed further below, defining a transfer region in which a number of components may be included. The transfer region may additionally be at least partially defined from above by processing chambers or processing regions fluidly coupled with the transfer region, such as processing chamber regions 108
- 25 illustrated in quad sections 109 of FIG. 1. A sidewall of the transfer region housing may define one or more access locations 207 through which substrates may be delivered and retrieved, such as by second robotic arm 110 as discussed above. Access locations 207 may be slit valves or other sealable access positions, which include doors or other sealing mechanisms to provide a hermetic environment within transfer region housing 205 in some
- 30 embodiments. Although illustrated with two such access locations 207, it is to be understood that in some embodiments only a single access location 207 may be included, as well as access locations on multiple sides of the transfer region housing. It is also to be understood that the transfer section illustrated may be sized to accommodate any substrate size, including

200 mm, 300 mm, 450 mm, or larger or smaller substrates, including substrates characterized by any number of geometries or shapes.

[0039] Within transfer region housing 205 may be a plurality of substrate supports 210 positioned about the transfer region volume. Although four substrate supports are illustrated, it is to be understood that any number of substrate supports are similarly encompassed by embodiments of the present technology. For example, greater than or about three, four, five, six, eight, or more substrate supports 210 may be accommodated in transfer regions according to embodiments of the present technology. Second robotic arm 110 may deliver a substrate to either or both of substrate supports 210a or 210b through the accesses 207. Similarly, second robotic arm 110 may retrieve substrates from these locations. Lift pins 212 may protrude from the substrate supports 210, and may allow the robot to access beneath the substrates. The lift pins may be fixed on the substrate supports, or at a location where the substrate supports may recess below, or the lift pins may additionally be raised or lowered through the substrate supports in some embodiments. Substrate supports 210 may be vertically translatable, and in some embodiments may extend up to processing chamber regions of the substrate processing systems, such as processing chamber regions 108, positioned above the transfer region housing 205.

[0040] The transfer region housing 205 may provide access 215 for alignment systems, which may include an aligner that can extend through an aperture of the transfer region housing as illustrated and may operate in conjunction with a laser, camera, or other monitoring device protruding or transmitting through an adjacent aperture, and that may determine whether a substrate being translated is properly aligned. Transfer region housing 205 may also include a transfer apparatus 220 that may be operated in a number of ways to position substrates and move substrates between the various substrate supports. In one example, transfer apparatus 220 may move substrates on substrate supports 210a and 210b to substrate supports 210c and 210d, which may allow additional substrates to be delivered into the transfer chamber. Additional transfer operations may include rotating substrates between substrate supports for additional processing in overlying processing regions.

[0041] Transfer apparatus 220 may include a central hub 225 that may include one or more shafts extending into the transfer chamber. Coupled with the shaft may be an end effector 235. End effector 235 may include a plurality of arms 237 extending radially or laterally outward from the central hub. Although illustrated with a central body from which the arms

extend, the end effector may additionally include separate arms that are each coupled with the shaft or central hub in various embodiments. Any number of arms may be included in embodiments of the present technology. In some embodiments a number of arms 237 may be similar or equal to the number of substrate supports 210 included in the chamber. Hence, as
5 illustrated, for four substrate supports, transfer apparatus 220 may include four arms extending from the end effector. The arms may be characterized by any number of shapes and profiles, such as straight profiles or arcuate profiles, as well as including any number of distal profiles including hooks, rings, forks, or other designs for supporting a substrate and/or providing access to a substrate, such as for alignment or engagement.

10 **[0042]** The end effector 235, or components or portions of the end effector, may be used to contact substrates during transfer or movement. These components as well as the end effector may be made from or include a number of materials including conductive and/or insulative materials. The materials may be coated or plated in some embodiments to withstand contact with precursors or other chemicals that may pass into the transfer chamber
15 from an overlying processing chamber.

[0043] Additionally, the materials may be provided or selected to withstand other environmental characteristics, such as temperature. In some embodiments, the substrate supports may be operable to heat a substrate disposed on the support. The substrate supports may be configured to increase a surface or substrate temperature to temperatures greater than
20 or about 100° C, greater than or about 200° C, greater than or about 300° C, greater than or about 400° C, greater than or about 500° C, greater than or about 600° C, greater than or about 700° C, greater than or about 800° C, or higher. Any of these temperatures may be maintained during operations, and thus components of the transfer apparatus 220 may be exposed to any of these stated or encompassed temperatures. Consequently, in some
25 embodiments any of the materials may be selected to accommodate these temperature regimes, and may include materials such as ceramics and metals that may be characterized by relatively low coefficients of thermal expansion, or other beneficial characteristics.

[0044] Component couplings may also be adapted for operation in high temperature and/or corrosive environments. For example, where end effectors and end portions are each
30 ceramic, the coupling may include press fittings, snap fittings, or other fittings that may not include additional materials, such as bolts, which may expand and contract with temperature, and may cause cracking in the ceramics. In some embodiments the end portions may be

continuous with the end effectors, and may be monolithically formed with the end effectors. Any number of other materials may be utilized that may facilitate operation or resistance during operation, and are similarly encompassed by the present technology. The transfer apparatus 220 may include a number of components and configurations that may facilitate the
5 movement of the end effector in multiple directions, which may facilitate rotational movement, as well as vertical movement, or lateral movement in one or more ways with the drive system components to which the end effector may be coupled.

[0045] FIG. 3 shows a schematic isometric view of a transfer region of a chamber system 300 of an exemplary chamber system according to some embodiments of the present
10 technology. Chamber system 300 may be similar to the transfer region of chamber system 200 described above, and may include similar components including any of the components, characteristics, or configurations described above. FIG. 3 may also illustrate certain component couplings encompassed by the present technology along with the following figures.

15 [0046] Chamber system 300 may include a chamber body 305 or housing defining the transfer region. Within the defined volume may be a plurality of substrate supports 310 distributed about the chamber body as previously described. As will be described further below, each substrate support 310 may be vertically translatable along a central axis of the substrate support between a first position illustrated in the figure, and a second position
20 where substrate processing may be performed. Chamber body 305 may also define one or more accesses 307 through the chamber body. A transfer apparatus 335 may be positioned within the transfer region and be configured to engage and rotate substrates among the substrate supports 310 within the transfer region as previously described. For example, transfer apparatus 335 may be rotatable about a central axis of the transfer apparatus to
25 reposition substrates. The transfer apparatus 335 may also be laterally translatable in some embodiments to further facilitate repositioning substrates at each substrate support.

[0047] Chamber body 305 may include a top surface 306, which may provide support for overlying components of the system. Top surface 306 may define a gasket groove 308, which may provide seating for a gasket to provide hermetic sealing of overlying components
30 for vacuum processing. Unlike some conventional systems, chamber system 300, and other chamber systems according to some embodiments of the present technology, may include an open transfer region within the processing chamber, and processing regions may be formed

overlying the transfer region. Because of transfer apparatus 335 creating an area of sweep, supports or structure for separating processing regions may not be available. Consequently, the present technology may utilize overlying lid structures to form segregated processing regions overlying the open transfer region as will be described below. Hence, in some
5 embodiments sealing between the chamber body and an overlying component may only occur about an outer chamber body wall defining the transfer region, and interior coupling may not be present in some embodiments. Chamber body 305 may also define apertures 315, which may facilitate exhaust flow from the processing regions of the overlying structures. Top surface 306 of chamber body 305 may also define one or more gasket grooves about the
10 apertures 315 for sealing with an overlying component. Additionally, the apertures may provide locating features that may facilitate stacking of components in some embodiments.

[0048] FIG. 4 shows a schematic isometric view of overlying structures of chamber system 300 according to some embodiments of the present technology. For example, in some embodiments a first lid plate 405 may be seated on chamber body 305. First lid plate 405
15 may be characterized by a first surface 407 and a second surface 409 opposite the first surface. First surface 407 of the first lid plate 405 may contact chamber body 305, and may define companion grooves to cooperate with grooves 308 discussed above to produce a gasket channel between the components. First lid plate 405 may also define apertures 410, which may provide separation of overlying regions of the transfer chamber to form
20 processing regions for substrate processing.

[0049] Apertures 410 may be defined through first lid plate 405, and may be at least partially aligned with substrate supports in the transfer region. In some embodiments, a number of apertures 410 may equal a number of substrate supports in the transfer region, and each aperture 410 may be axially aligned with a substrate support of the plurality of substrate
25 supports. As will be described further below, the processing regions may be at least partially defined by the substrate supports when vertically raised to a second position within the chamber systems. The substrate supports may extend through the apertures 410 of the first lid plate 405. Accordingly, in some embodiments apertures 410 of the first lid plate 405 may be characterized by a diameter greater than a diameter of an associated substrate support.
30 Depending on an amount of clearance, the diameter may be less than or about 25% greater than a diameter of a substrate support, and in some embodiments may be less than or about 20% greater, less than or about 15% greater, less than or about 10% greater, less than or about 9% greater, less than or about 8% greater, less than or about 7% greater, less than or

about 6% greater, less than or about 5% greater, less than or about 4% greater, less than or about 3% greater, less than or about 2% greater, less than or about 1% greater than a diameter of a substrate support, or less, which may provide a minimum gap distance between the substrate support and the apertures 410.

5 **[0050]** First lid plate 405 may also include a second surface 409 opposite first surface 407. Second surface 409 may define a recessed ledge 415, which may produce an annular recessed shelf through the second surface 409 of first lid plate 405. Recessed ledges 415 may be defined about each aperture of the plurality of apertures 410 in some embodiments. The recessed shelf may provide support for lid stack components as will be described further
10 below. Additionally, first lid plate 405 may define second apertures 420, which may at least partially define pumping channels from overlying components described below. Second apertures 420 may be axially aligned with apertures 315 of the chamber body 305 described previously.

[0051] FIG. 5 shows a schematic partial isometric view of chamber system 300 according
15 to some embodiments of the present technology. The figure may illustrate a partial cross-section through two processing regions and a portion of a transfer region of the chamber system. For example, chamber system 300 may be a quad section of processing system 100 described previously, and may include any of the components of any of the previously described components or systems.

20 **[0052]** Chamber system 300, as developed through the figure, may include a chamber body 305 defining a transfer region 502 including substrate supports 310, which may extend into the chamber body 305 and be vertically translatable as previously described. First lid plate 405 may be seated overlying the chamber body 305, and may define apertures 410 producing access for processing region 504 to be formed with additional chamber system components.
25 Seated about or at least partially within each aperture may be a lid stack 505, and chamber system 300 may include a plurality of lid stacks 505, including a number of lid stacks equal to a number of apertures 410 of the plurality of apertures. Each lid stack 505 may be seated on the first lid plate 405, and may be seated on a shelf produced by recessed ledges through the second surface of the first lid plate. The lid stacks 505 may at least partially define
30 processing regions 504 of the chamber system 300.

[0053] As illustrated, processing regions 504 may be vertically offset from the transfer region 502, but may be fluidly coupled with the transfer region. Additionally, the processing

regions may be separated from the other processing regions. Although the processing regions may be fluidly coupled with other processing regions through the transfer region from below, the processing regions may be fluidly isolated, from above, from each of the other processing regions. Each lid stack 505 may also be aligned with a substrate support in some
5 embodiments. For example, as illustrated, lid stack 505a may be aligned over substrate support 310a, and lid stack 505b may be aligned over substrate support 310b. When raised to operational positions, such as a second position, the substrates may deliver substrates for individual processing within the separate processing regions. When in this position, as will be described further below, each processing region 504 may be at least partially defined from
10 below by an associated substrate support in the second position.

[0054] FIG. 5 also illustrates embodiments in which a second lid plate 510 may be included for the chamber system. Second lid plate 510 may be coupled with each of the lid stacks, which may be positioned between the first lid plate 405 and the second lid plate 510 in some embodiments. As will be explained below, the second lid plate 510 may facilitate accessing
15 components of the lid stacks 505. Second lid plate 510 may define a plurality of apertures 512 through the second lid plate. Each aperture of the plurality of apertures may be defined to provide fluid access to a specific lid stack 505 or processing region 504. A remote plasma unit 515 may optionally be included in chamber system 300 in some embodiments, and may be supported on second lid plate 510. In some embodiments, remote plasma unit 515 may be
20 fluidly coupled with each aperture 512 of the plurality of apertures through second lid plate 510. Isolation valves 520 may be included along each fluid line to provide fluid control to each individual processing region 504. For example, as illustrated, aperture 512a may provide fluid access to lid stack 505a. Aperture 512a may also be axially aligned with any of the lid stack components, as well as with substrate support 310a in some embodiments, which
25 may produce an axial alignment for each of the components associated with individual processing regions, such as along a central axis through the substrate support or any of the components associated with a particular processing region 504. Similarly, aperture 512b may provide fluid access to lid stack 505b, and may be aligned, including axially aligned with components of the lid stack as well as substrate support 310b in some embodiments.

30 **[0055]** FIG. 6 shows a schematic isometric view of an exemplary modular gas block 600 according to some embodiments of the present technology. Modular gas block 600 may be used as part of a gas delivery assembly for mixing and/or delivering one or more gases to a semiconductor processing system for performing one or more processing operations, such as

deposition, etching, annealing, cleaning, and/or curing. As will be discussed in greater detail below, a number of modular gas block 600 may be assembled to generate a gas path that extends along both a length and a width (or both an x-axis and a y-axis) of a gas delivery assembly, which enables a number of gases to be mixed and/or otherwise delivered to one or more processing systems.

[0056] Gas block 600 may include a block body 605, with the block body 605 including an upper portion 602 and a lower portion 604. As illustrated, the upper portion 602 and lower portion 604 each has a generally rectangular prism shape, although other shapes may be utilized in various embodiments. The block body 605 (and each of the upper portion 602 and lower portion 604) may have a first end 606 and a second end 608, as well as a medial region 607 that is disposed between the first end 606 and second end 608. A longitudinal axis of the block body 605 may extend through the first end 606 and the second end 608. First end 606 of the upper portion 602 may extend beyond the first end 606 of the lower portion 604 such that the first end 606 of the upper portion 602 forms an overhang with respect to the lower portion 604. Second end 608 of the lower portion 604 may extend beyond second end 608 of the upper portion 602 such that the second end 608 of the lower portion 604 forms a ledge with respect to the upper portion 602. In such a manner, a cross-section of the block body 605 may have a generally z-shape in some embodiments. The shape of the block body 605 may depend on adjacent block geometry (such as the geometry of end blocks). For example, the block body 605 may have a t-shape, a z-shape, an inverted z-shape, a mirrored z-shape, and/or other shape in various embodiments.

[0057] In some embodiments, a lower surface of the first end 606 of the upper portion 602 and the upper surface of the second end 608 of the lower portion 604 may be substantially coplanar. Such a design may enable multiple modular gas blocks 600 to be coupled together along an x direction (with the first end 606 of one modular gas block 600 being coupled with the second end 608 of another modular gas block 600) with the respective top and bottom surfaces of adjacent modular gas blocks 600 being substantially coplanar with one another. In some embodiments, to facilitate such a design, the first end 606 of the upper portion 602 and the second end 608 of the lower portion 604 may be substantially the same thickness, although as long as the lower surface of the first end 606 of the upper portion 602 and the upper surface of the second end 608 of the lower portion 604 are substantially coplanar the first end 606 of the upper portion 602 and the second end 608 of the lower portion 604 may

have different thicknesses while still facilitating the coplanar coupling of multiple modular gas blocks 600.

[0058] FIG. 6A illustrates a schematic cross-sectional front elevation view (such as a cross-section taken along a y-axis) of modular gas block 600. The block body 605 may define a number of fluid channels that may be used to transport process and/or purge gases to a respective processing system. For example, as shown in FIG. 6A, the block body 605 may define a first fluid channel 610 that extends in a direction that is substantially parallel to the longitudinal axis of the block body 605. The first fluid channel 610 may be designed to transport gases between adjacent modular gas blocks 600 along a width (or x-axis) of a gas delivery assembly. The first fluid channel 610 may include and/or be fluidly coupled with a first fluid port 615, a second fluid port 620, and/or a third fluid port 625. The first fluid port 615 may extend through an upper surface of the second end 608 of the lower portion 604. As will be discussed below, the first fluid port 615 may be used to fluidly couple adjacent modular gas blocks 600 along the width of a gas delivery assembly. The second fluid port 620 may extend through an upper surface of the medial region 607 of the upper portion 602. The second fluid port 620 may be interfaced with a flow regulation device, such as a valve, mass flow controller, and/or other device that may be seated atop the modular gas block 600 and which may control, regulate, and/or otherwise impact flow through the gas assembly. The third fluid port 625 may extend through a lower surface of the first end 606 of the upper portion 602. As will be discussed below, the third fluid port 625 may be used to fluidly couple adjacent modular gas blocks 600 along the width of a gas delivery assembly.

[0059] FIG. 6B illustrates a schematic cross-sectional side elevation view (such as a cross-section taken along an x-axis) of modular gas block 600. Block body 605 may define a second fluid channel 630 that extends transversely to the longitudinal axis and the first fluid channel 610 to transport gases between adjacent modular gas blocks 600 along a length (or y-axis) of a gas delivery assembly. The second fluid channel 630 may include and/or be fluidly coupled with second fluid port 620 and a fourth fluid port 635. Each of the second fluid port 620 and the fourth fluid port 635 may extend through an upper surface of the block body 605, such as within the medial region 607. In some embodiments, additional fluid ports may be provided. For example, one or more fluid ports may be defined within sidewalls of the block body 605 and may serve as fluid inlets and/or outlets for the gas delivery assembly. For example, a fluid port formed in a sidewall of the block body 605 may be coupled with a gas source that introduces a gas into the gas delivery assembly and/or may be coupled with a

weldment and/or other gas delivery lumen that directs any gases from the gas delivery assembly to one or more processing chambers and/or manifolds. Along with second fluid port 620, fourth fluid port 635 may be interfaced with a flow regulation device, such as a valve, mass flow controller, and/or other device that may be seated atop the modular gas block 600 and which may control, regulate, and/or otherwise impact flow through the gas assembly. The second fluid channel 630 may be a single channel and/or may be broken up into multiple segments. For example, as illustrated a portion of the second fluid channel 630 extends from the fourth fluid port 635 to the second fluid port 620. The fluid channels 630 of adjacent modular gas blocks 600 may be coupled with one another via a flow regulation device that is coupled with the modular gas block 600 via second fluid port 620 and fourth fluid port 635.

[0060] The first fluid channel 610 and the second fluid channel 630 may be distinct from one another in some embodiments, while in other embodiments the two fluid channels may be fluidly coupled with one another. For example, the first fluid channel 610 and the second fluid channel 630 may intersect at one or more points. In a particular embodiment, the first fluid channel 610 and second fluid channel 630 may intersect within the block body 605 proximate second fluid port 620, which both fluid channels may share. While illustrated with two ports (second fluid port 620 and fourth fluid port 635) that extend through an upper surface of the medial 607 for coupling with a flow regulation device, it will be appreciated that in some embodiments other numbers of fluid ports may be provided, which may facilitate more complex flow designs (e.g., T-junctions, 3-way valves, etc.).

[0061] Turning back to FIG. 6, block body 605 may define a number of fastener receptacles, which may receive fasteners for securing multiple modular gas blocks 600 together and/or for securing flow regulation devices and/or other components to the modular gas block 600. For example, the first end 606 of the upper portion 602 and the second end 608 of the lower portion 604 may define a number of fastener receptacles 655 that may enable fasteners to be inserted through the receptacles 655 to couple the first end 606 of one modular gas block 600 with the second end 608 of another modular gas block 600. The medial region 607 and second end 608 of the upper portion 602 may each define a plurality of fastener receptacles 660 that may enable fasteners to be inserted through the fastener receptacles 660 to couple a flow regulation device to the upper surface of the block body 605.

[0062] FIG. 7 illustrates a schematic cross-sectional front elevation view of a number of modular gas blocks 600 being coupled to form a portion of a gas delivery assembly 700. As illustrated, modular gas blocks 600 are coupled along a width (or x-axis) of the gas delivery assembly 700 to form a fluid path that extends along a width of the gas delivery assembly 700. While shown with three modular gas blocks 600, it will be appreciated that the gas delivery assembly 700 may include any number of modular gas delivery blocks 600 in various embodiments. Additionally, one or more modular gas blocks 600 may be added to or removed from the gas delivery assembly to add or remove different gas sources.

[0063] As illustrated, a first modular gas block 600a may be positioned between a second modular gas block 600b and a third modular gas block 600c. The first end 606 of the upper portion 602 of the first modular gas block 600a may be positioned above and coupled with the second end 608 of the lower portion 604 of the second modular gas block 600b. For example, the third fluid port 625 of the first modular gas block 600a may be coupled with the first fluid port 615 of the second modular gas block 600b. This may fluidly couple the first fluid channels 610 of the first modular gas block 600a and the second modular gas block 600b. The second end 608 of the lower portion 604 of the first modular gas block 600a may be positioned below and coupled with the first end 606 of the upper portion 602 of the third modular gas block 600c. For example, the first fluid port 615 of the first modular gas block 600a may be coupled with the third fluid port 635 of the third modular gas block 600c. When assembled, the modular gas blocks 600 within the gas delivery assembly 700 may have top surfaces that are generally coplanar with one another and bottom surfaces that are generally coplanar with one another.

[0064] As noted above, any number of modular gas blocks 600 may be joined end to end to form a width of the gas delivery assembly 700. The gas delivery assembly 700 may include a proximal end in a direction of the first end 606 of each of the modular gas blocks 600 (shown as a leftmost end here) and a distal end in a direction of the second end 608 of each of the modular gas blocks 600 (shown as a rightmost end here). To seal the joined first fluid channels 610 of the modular gas blocks 600, the third fluid port 625 of a proximal-most modular gas block 600 (here, second modular gas block 600b) and the first fluid port 615 of a distal-most modular gas block 600 (here, third modular gas block 600c) may be obstructed, such as by plugging, capping, and/or otherwise closing off the respective third fluid port 625 and first fluid port 615 with an obstruction 705. To add new gas sticks to the gas delivery assembly 700, the obstruction 705 (such as a cap, plug, and/or other blockage) may be

- removed from a respective fluid port on the modular gas blocks 600 on a given side (e.g., proximal or distal side) of the gas delivery assembly 700. Additional modular gas blocks 600 may then be interfaced with the exposed fluid ports to expand the gas delivery assembly 700 to incorporate additional gas sticks. In some embodiments, interfaces formed between at least some of the fluid ports of the coupled modular gas blocks 600 include sealing mechanisms. For example, couplings between adjacent first fluid ports 615 and third fluid ports 625 may include O-rings, gaskets, C-seals, and/or other sealing mechanisms that may prevent gases from leaking out of the first fluid channels 610 at the various interfaces between adjacent modular gas blocks 600.
- 10 **[0065] FIG. 8** illustrates a schematic cross-sectional side elevation view of a number of modular gas blocks 600 being coupled to form a portion of a gas delivery assembly 800. As illustrated, modular gas blocks 600 are coupled along a length (or y-axis) of the gas delivery assembly 800 to form a fluid path that extends along a length of the gas delivery assembly 800. Each line of modular gas blocks 600 along the y direction may be considered a separate
- 15 gas stick and may be coupled with a different gas source. While shown with three modular gas blocks 600, it will be appreciated that the gas delivery assembly 800 may include any number of modular gas delivery blocks 600 in various embodiments. Additionally, one or more modular gas blocks 600 may be added to or removed from the gas delivery assembly to add or remove different gas sources.
- 20 **[0066]** As illustrated, a first modular gas block 600d may be positioned between a second modular gas block 600e and a third modular gas block 600f. The first sidewall of the first modular gas block 600d may be positioned against the second sidewall of the second modular gas block 600e. For example, the fourth fluid port 635 of the first modular gas block 600d may be coupled with the second fluid port 620 of the second modular gas block 600e, such as
- 25 via valves and/or other flow regulation devices. This may fluidly couple the second fluid channels 630 of the first modular gas block 600d and the second modular gas block 600e. The second sidewall of the first modular gas block 600d may be positioned against the first sidewall of the third modular gas block 600f. For example, the fourth fluid port 635 of the first modular gas block 600d may be coupled with the second fluid port 620 of the third
- 30 modular gas block 600f via a flow regulation device. This may fluidly couple the second fluid channels 630 of the first modular gas block 600d and the third modular gas block 600f. When assembled, the modular gas blocks 600 within the gas delivery assembly 800 may have top surfaces that are generally coplanar with one another and bottom surfaces that are

generally coplanar with one another. The second fluid channels 630 may be fully coupled with one another when valves are interfaced with each modular gas block 600 at second fluid port 620 and fourth fluid port 635.

[0067] As noted above, any number of modular gas blocks 600 may be joined sidewall to sidewall to form a length of the gas delivery assembly 800. The gas delivery assembly 800 may include a proximal end in a direction of the first sidewall of each of the modular gas blocks 600 (shown as a leftmost end here) and a distal end in a direction of the second sidewall of each of the modular gas blocks 600 (shown as a rightmost end here). An exposed second fluid port 620 and/or fourth fluid port 635 of the gas delivery assembly 800 may be coupled with a gas source, a gas outlet, and/or obstructed in various embodiments. In some embodiments, interfaces formed between at least some of the fluid ports of the coupled modular gas blocks 600 include sealing mechanisms. For example, couplings between fourth fluid ports 635 and/or second fluid ports 620 and flow regulation devices may include O-rings, gaskets, C-seals, and/or other sealing mechanisms that may prevent gases from leaking out of the second fluid channels 620 at the various interfaces between adjacent modular gas blocks 600.

[0068] Oftentimes, a number of different gases may be supplied to a processing chamber. Some of the gases may be mixed prior to being introduced to the processing chamber, which may help to reduce the complexity of conduits extending between gas sources and the processing chambers. The use of modular gas blocks 600 may enable the design and assembly of an easily customizable gas delivery assembly that may enable gases from one or more gas sources to be flowed to one or more processing chambers and/or mixed prior to delivery of the gases to the one or more processing chambers. **FIG. 9** illustrates a number of gas delivery assemblies 900 that each incorporate a number of modular gas blocks 600 arranged along both a length and a width of the respective gas delivery assembly 900 to facilitate delivery and/or mixing of a number of gases. Each gas delivery assembly 900 may incorporate any feature of previously described gas delivery assemblies, such as gas delivery assembly 700 and 800. For example, the second fluid channels 630 of the various modular gas blocks 600 may deliver gases from gas sources 905 to an outlet 910 of the gas delivery assembly 900 for subsequent delivery to one or more processing chambers and/or manifolds. The first fluid channels 610 may enable mixing of the gases flowing within some or all of the second fluid channels 610 along a width of the gas delivery assembly 900. The flow and/or mixing of gases through the various fluid channels of the modular gas blocks 600 may be

controlled using one or more flow regulation device, such as valves 915, mass flow controllers 920, and the like, which may be each be coupled with a respective one of the modular gas blocks 600, such as via the second fluid port 620 and/or the fourth fluid port 635. For example, various valves 915 may be utilized to control whether and/or how much of a particular gas (or mixture of gases) flows through a given fluid channel of a given modular gas block 600.

[0069] As illustrated, each gas delivery assembly 900 includes three or four gas sources 905 (e.g., one per gas stick), which may include one or more purge gas sources 905a. However, in other embodiments other numbers of gas sources 905 may be utilized, with some or all of the gas sources 905 being purge gas sources 905a. For example, a given gas delivery assembly 900 may include at least or about one gas source 905, at least or about two gas sources 905, at least or about three gas sources 905, at least or about four gas sources 905, at least or about five gas sources 905, at least or about six gas sources 905, or more. Each gas delivery assembly 900 may include an outlet 910, such as an output weldment, which may deliver any combination of one or more gases from the gas delivery assembly 900 to one or more processing chambers and/or manifolds.

[0070] By using modular gas blocks 600 to generate the gas delivery assembly 900, embodiments of the present invention may facilitate gas mixing between adjacent gas sticks in the x-direction without the use of a network of weldments at the bottom of the gas delivery assembly, which may significantly simplify the design and fabrication of the gas delivery assembly and reduce the time and cost associated therewith. In some embodiments, each block within the gas delivery assembly 900 may have an identical geometry or design, which may simplify the construction of a given gas delivery assembly 900. In other embodiments, gas delivery assembly 900 may include some different modular gas blocks (such as some similar to modular gas blocks 600 that include additional ports on the medial region 607). In some embodiments, modular gas blocks at an extreme proximal and/or distal end of the width and/or length of the gas delivery assembly 900 may be different to accommodate connections with other components, such as weldments from gas sources, outlets, and the like. Such a modular design may enable a single type (or small number of types) of modular gas blocks 900 on hand to generate different configurations of gas delivery assemblies.

[0071] As noted above, each gas delivery assembly may include an outlet that delivers a mixture of one or more gases to one or more processing chambers and/or manifolds. For

example, the gas delivery assembly may be remotely located from the processing chambers (such as below the processing chamber). The outlets may be coupled with fluid lines, such as weldments, that direct the gases from the gas delivery assembly to the processing chambers and/or manifolds. **FIG. 10** shows a schematic top plan view of one embodiment of a semiconductor processing system 1000 according to some embodiments of the present technology. The figure may include components of any of the systems illustrated and described previously, and may also show further aspects of any of the previously described systems. It is to be understood that the illustration may also show exemplary components as would be seen on any quad section 109 described above.

10 **[0072]** Semiconductor processing system 1000 may include a lid plate 1005, which may be similar to second lid plate 510 previously described. For example, the lid plate 1005 may define a number of apertures, similar to apertures 512, which provide access to a number of processing chambers positioned beneath the lid plate 1005. Each aperture of the plurality of apertures may be defined to provide fluid access to a specific lid stack, processing chamber, and/or processing region.

[0073] A gas splitter assembly 1010 may be seated on a top surface of the lid plate 1005. For example, the gas splitter assembly 1010 may be centered between the apertures of the lid plate 1005. The gas splitter assembly 1010 may be fluidly coupled with a number of input weldments 1015 that are each coupled with a respective outlet of a gas delivery assembly, such as gas delivery assemblies 700, 800, and 900. Input weldments 1015 may deliver gases, such as precursors, plasma effluents, and/or purge gases from a number of gas sources to the gas splitter assembly 1010. For example, each of the input weldments 1015 may extend vertically from gas delivery assemblies positioned below the lid plate 1005 and pass through a feedthrough plate 1020. A portion of the input weldments 1015 above the feedthrough plate 1020 may be bent horizontally and may direct the gases toward the gas splitter assembly 1010. In some embodiments, some or all of the input weldments 1015 may be disposed within heater jackets 1019 that help prevent heat loss along the length of the input weldments 1015.

[0074] The gas splitter assembly 1010 may receive gases from the input weldments 1015 and may recursively split the gas flows into a greater number of gas outputs that are each interfaced with one or more valves 1027 that help control flow of gases through the valve block 1025. For example, actuation of the valves 1027 may control whether purge and/or

process gases are flowed to a respective processing chamber or are diverted away from the processing chamber to another location of the system 1000. For example, outlets of gas splitter assembly 1010 may each be fluidly coupled with an output weldment 1030, which may deliver the purge gas and/or process gas to an output manifold 1035 associated with a particular processing chamber. For example, an output manifold 1035 may be positioned over each aperture formed within the lid plate 1005 and may be fluidly coupled with the lid stack components to deliver one or more gases to a processing region of a respective processing chamber.

[0075] In the preceding description, for the purposes of explanation, numerous details have been set forth in order to provide an understanding of various embodiments of the present technology. It will be apparent to one skilled in the art, however, that certain embodiments may be practiced without some of these details, or with additional details.

[0076] Having disclosed several embodiments, it will be recognized by those of skill in the art that various modifications, alternative constructions, and equivalents may be used without departing from the spirit of the embodiments. Additionally, a number of well-known processes and elements have not been described in order to avoid unnecessarily obscuring the present technology. Accordingly, the above description should not be taken as limiting the scope of the technology. Additionally, methods or processes may be described as sequential or in steps, but it is to be understood that the operations may be performed concurrently, or in different orders than listed.

[0078] Where a range of values is provided, it is understood that each intervening value, to the smallest fraction of the unit of the lower limit, unless the context clearly dictates otherwise, between the upper and lower limits of that range is also specifically disclosed. Any narrower range between any stated values or unstated intervening values in a stated range and any other stated or intervening value in that stated range is encompassed. The upper and lower limits of those smaller ranges may independently be included or excluded in the range, and each range where either, neither, or both limits are included in the smaller ranges is also encompassed within the technology, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included.

[0079] As used herein and in the appended claims, the singular forms “a”, “an”, and “the” include plural references unless the context clearly dictates otherwise. Thus, for example,

reference to “a plate” includes a plurality of such plates, and reference to “the aperture” includes reference to one or more apertures and equivalents thereof known to those skilled in the art, and so forth.

- [0080]** Also, the words “comprise(s)”, “comprising”, “contain(s)”, “containing”, “include(s)”, and “including”, when used in this specification and in the following claims, are intended to specify the presence of stated features, integers, components, or operations, but they do not preclude the presence or addition of one or more other features, integers, components, operations, acts, or groups.
- 5

WHAT IS CLAIMED IS:

1. A modular gas delivery assembly, comprising:
a plurality of modular gas blocks coupled together to form a gas path along a length and a width of the modular gas delivery assembly, each of the plurality of modular gas
5 blocks comprising a block body having an upper portion and a lower portion, wherein:
a first end of the upper portion extends beyond a first end of the lower portion and a second end of the lower portion extends beyond a second end of the upper portion;
a longitudinal axis of the block body extends from the first end to the
10 second end of the upper portion;
the block body defines a first fluid channel that extends along the longitudinal axis, the first fluid channel comprising:
a first fluid port extending through an upper surface of the second end of the lower portion;
15 a second fluid port extending through an upper surface of a medial region of the upper portion; and
a third fluid port extending through a lower surface of the first end of the upper portion;
the block body defines a second fluid channel that extends transversely
20 to the longitudinal axis and the first fluid channel; and
a first modular gas block of the plurality of modular gas blocks is coupled with a second modular gas block of the plurality of modular gas blocks and a third modular gas block of the plurality of modular gas blocks such that the first fluid channels of each of the first modular gas block, the second modular gas block, and the
25 third modular gas block are fluidly coupled with one another.
2. The modular gas delivery assembly of claim 1, wherein:
the first end of the upper portion of the first modular gas block is positioned above and coupled with the second end of the lower portion of the second modular gas block;
and
30 the third fluid port of the first modular gas block is coupled with the first fluid port of the second modular gas block.
3. The modular gas delivery assembly of claim 1, wherein:

the second end of the lower portion of the first modular gas block is positioned below and coupled with the first end of the upper portion of the third modular gas block; and the first fluid port of the first modular gas block is coupled with the third fluid port of the third modular gas block.

5 4. The modular gas delivery assembly of claim 1, further comprising:
a plurality of valves, wherein:
each of the plurality of valves is coupled with the medial region of the
upper portion of a respective one of the plurality of modular gas blocks;
each of the plurality of valves comprises a valve port; and
10 each valve port is coupled with the second fluid port of a respective
one of the plurality of modular gas blocks.

5. The modular gas delivery assembly of claim 1, wherein:
a fourth modular gas block of the plurality of modular gas blocks is coupled
with first modular gas block in a direction that is transverse to the longitudinal axis of the
15 first modular gas block.

6. The modular gas delivery assembly of claim 5, wherein:
the second fluid channel of the first modular gas block is fluidly coupled with
the second fluid channel of the fourth modular gas block.

7. The modular gas delivery assembly of claim 1, wherein:
20 the modular gas delivery assembly comprises a proximal end in a direction of
the first end of each of the plurality of modular gas blocks and a distal end in a direction of
the second end of each of the plurality of modular gas blocks;
the third fluid port of a proximal-most one of the plurality of modular gas
blocks is obstructed; and
25 the first fluid port of a distal-most one of the plurality of modular gas blocks is
obstructed.

8. The modular gas delivery assembly of claim 7, wherein:
an obstruction of one or both of the first fluid port of the distal-most one of the
plurality of modular gas blocks and the third fluid port of the proximal-most one of the
30 plurality of modular gas blocks is removable to couple an additional plurality of modular gas
blocks to the gas delivery assembly along the width of the modular gas assembly.

9. The modular gas delivery assembly of claim 1, wherein:
each of the plurality of modular gas blocks comprises an identical geometry.
10. The modular gas delivery assembly of claim 1, wherein:
top surfaces of each of the plurality of modular gas blocks are generally
5 coplanar; and
bottom surfaces of each of the plurality of modular gas blocks are generally
coplanar.
11. The modular gas delivery assembly of claim 1, wherein:
interfaces formed between at least some of the fluid ports of the plurality of
10 modular gas blocks comprise C-seals.
12. The modular gas delivery assembly of claim 1, wherein:
the modular gas delivery assembly does not include any weldments extending
beneath the plurality of modular gas blocks.
13. A modular gas block, comprising:
15 a block body having an upper portion and a lower portion, wherein:
a first end of the upper portion extends beyond a first end of the lower
portion and a second end of the lower portion extends beyond a second end of the
upper portion;
a longitudinal axis of the block body extends from the first end to the
20 second end of the upper portion;
the block body defines a first fluid channel that extends along the
longitudinal axis, the first fluid channel comprising:
a first fluid port extending through an upper surface of the
second end of the lower portion;
25 a second fluid port extending through an upper surface of a
medial region of upper portion; and
a third fluid port extending through a lower surface of the first
end of the upper portion; and
the block body defines a second fluid channel that extends transversely
30 to the longitudinal axis and the first fluid channel.

14. The modular gas block of claim 12, wherein:
an upper surface of the first end of the upper portion and the upper surface of the second end of the lower portion each define a plurality of fastener receptacles.
15. The modular gas block of claim 13, wherein:
5 the lower surface of the first end of the upper portion and the upper surface of the second end of the lower portion are substantially coplanar.
16. The modular gas block of claim 13, wherein:
a thickness of the first end of the upper portion and the second end of the lower portion are together substantially as thick as the medial region.
- 10 17. A modular gas delivery assembly, comprising:
a first modular gas block;
a second modular gas block coupled with a first end of the first modular gas block; and
a third modular gas block coupled with a second end of the first modular gas block, wherein:
15 each of the first modular gas block, second modular gas block, and third modular gas block comprising a block body having an upper portion and a lower portion;
a first end of the upper portion extends beyond a first end of the lower portion and a second end of the lower portion extends beyond a second end of the upper portion;
20 the block body defines a first fluid channel that extends the first end to the second end, the first fluid channel comprising:
a first fluid port extending through an upper surface of the second end of the lower portion;
25 a second fluid port extending through an upper surface of a medial region of the upper portion; and
a third fluid port extending through a lower surface of the first end of the upper portion;
30 the block body defines a second fluid channel that extends transversely to the first fluid channel; and

the first fluid channels of each of the first modular gas block, the second modular gas block, and the third modular gas block are fluidly coupled with one another.

- 5 18. The modular gas delivery assembly of claim 17, wherein:
the first end of the upper portion of the first modular gas block is positioned above and coupled with the second end of the lower portion of the second modular gas block; and
the third fluid port of the first modular gas block is coupled with the first fluid port of the second modular gas block.

- 10 19. The modular gas delivery assembly of claim 17, wherein:
the second end of the lower portion of the first modular gas block is positioned below and coupled with the first end of the upper portion of the third modular gas block; and
the first fluid port of the first modular gas block is coupled with the third fluid port of the third modular gas block.

- 15 20. The modular gas delivery assembly of claim 17, further comprising:
a fourth modular gas block coupled with first modular gas block in a direction that is transverse to first fluid channel of the first modular gas block.