

INTEGRATED MULTI-PORTED VALVE ASSEMBLY

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Application No. 63/540,970, filed on September 28, 2023. The entire disclosure of the application
5 referenced above is incorporated herein by reference.

FIELD

[0002] The present disclosure relates generally to substrate processing systems and more particularly to an integrated multi-ported valve assembly for substrate processing systems.

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BACKGROUND

[0003] The background description provided here is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor
15 impliedly admitted as prior art against the present disclosure.

[0004] Substrate processing systems (also called tools) typically comprise one or more processing chambers. In a processing chamber, a substrate is arranged on a substrate support for processing. In some applications such as chemical vapor deposition (CVD), one or more gases and a vaporized precursor are supplied through a
20 showerhead into the processing chamber to process the substrate. In some applications such as plasma-enhanced CVD (PECVD), to process the substrate, a plasma is generated by supplying radio-frequency (RF) power to the showerhead or the substrate support.

SUMMARY

25 [0005] A multiport valve assembly for a substrate processing system comprises a manifold block and a plurality of valves mounted to the manifold block. The manifold block comprises N first inputs connected to N sources of N vaporized precursors, where N is an integer greater than 1; an outlet connectable to a showerhead of a processing chamber; and a plurality of manifolds enclosed in the manifold block. The valves are

coupled to the N first inputs by the manifolds in the manifold block. The valves are configured to supply the N vaporized precursors through respective supply manifolds in the manifold block. The respective supply manifolds are connected to an output manifold in the manifold block. The output manifold comprises the outlet to supply one
5 or more of the N vaporized precursors to the showerhead.

[0006] In additional features, the manifold block and the plurality of valves are integrated in a single integrated assembly.

[0007] In additional features, the outlet of the output manifold and connections of the supply manifolds to the output manifold are configured to prevent cross-contamination
10 of the N vaporized precursors.

[0008] In additional features, the manifold block comprises N second inputs connected to a plurality of gas sources. The valves are coupled to N second inputs by the manifolds in the manifold block. The valves are configured to supply one or more gases from the gas sources through the supply manifolds.

15 **[0009]** In additional features, the valves are configured to supply the one or more gases with the N vaporized precursors through the supply manifolds to the output manifold.

[0010] In additional features, the valves are configured to supply the one or more gases through the supply manifolds to the output manifold regardless of supplying the
20 N vaporized precursors through the supply manifolds to the output manifold to prevent cross-contamination of the N vaporized precursors.

[0011] In additional features, the one or more gases are the same.

[0012] In additional features, the manifold block comprises N outputs connected to an exhaust system. The valves are coupled to the N outputs by the manifolds in the
25 manifold block. The valves are configured to divert the N vaporized precursors to the exhaust system via the N outputs.

[0013] In additional features, the valves are configured to supply the one or more gases through the supply manifolds to the output manifold regardless of diverting the N vaporized precursors to the exhaust system to prevent cross-contamination of the N
30 vaporized precursors.

[0014] In additional features, the supply manifolds, the output manifold, and the outlet are configured as a removable subassembly.

[0015] In additional features, the manifold block comprises a plurality of heaters configured to heat the respective supply manifolds.

[0016] In additional features, the manifold block comprises a heater configured to heat the output manifold.

5 [0017] In additional features, the valves comprise N 4-port valves and N 2-port valves. First ports of the N 4-port valves are coupled to the N first inputs, respectively. Second ports of the N 4-port valves are coupled to the N second inputs, respectively. Third ports of the N 4-port valves are coupled to the respective supply manifolds. Fourth ports of the N 4-port valves are coupled to first ports of the N 2-port valves; respectively.
10 Second ports of the N 2-port valves are coupled to the exhaust system.

[0018] In additional features, a system comprises the multiport valve assembly and a controller configured to control the valves.

[0019] In additional features, the system further comprises the N sources of N vaporized precursors; N first mass flow controllers coupled to the N sources of N
15 vaporized precursors and to the N first inputs, respectively; the gas sources; and one or more first mass flow controllers coupled to the gas sources and to the N second inputs. The controller is configured to control the flow rates of the N vaporized precursors and the one or more gases.

[0020] In additional features, the controller is configured to control the flow rates of the
20 one or more gases differently when the one or more gases are supplied with the N vaporized precursors through the respective supply manifolds than when the one or more gases are supplied without the N vaporized precursors through the respective supply manifolds.

[0021] In additional features, the manifold block comprises a plurality of heaters
25 configured to heat the supply manifolds, the output manifold, or both. The controller is configured to control the heaters.

[0022] Further areas of applicability of the present disclosure will become apparent from the detailed description, the claims and the drawings. The detailed description and specific examples are intended for purposes of illustration only and are not intended to
30 limit the scope of the disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] The present disclosure will become more fully understood from the detailed description and the accompanying drawings, wherein:

5 [0024] FIG. 1 shows an example of a substrate processing system comprising the integrated multi-ported valve assembly of the present disclosure;

[0025] FIG. 2A schematically shows an example of the integrated multi-ported valve assembly that can be used in the substrate processing system of FIG. 1;

[0026] FIG. 2B schematically shows examples of valves used in the integrated multi-ported valve assembly of FIG. 2A;

10 [0027] FIG. 3A schematically shows the integrated multi-ported valve assembly of FIG. 2A in further detail;

[0028] FIG. 3B schematically shows examples of connections of the valves used in the integrated multi-ported valve assembly of FIGS. 2A and 3A;

15 [0029] FIG. 4 schematically shows an example of the integrated multi-ported valve assembly of FIGS. 2A and 3A further comprising a plurality of heaters;

[0030] FIG. 5 schematically shows a portion of the integrated multi-ported valve assembly of FIGS. 2A-4 illustrating examples of an output manifold and supply manifolds of the integrated multi-ported valve assembly of FIGS. 2A-4;

20 [0031] FIG. 6 schematically shows an example of a removable subassembly of the integrated multi-ported valve assembly of FIGS. 2A-5 comprising an output manifold and supply manifolds; and

[0032] FIG. 7 shows a method of supplying multiple vaporized precursors to a processing chamber of FIG. 1 using the integrated multi-ported valve assembly of FIGS. 2A-6.

25 [0033] In the drawings, reference numbers may be reused to identify similar and/or identical elements.

DETAILED DESCRIPTION

30 [0034] Generally, in a substrate processing system (tool), a valve assembly called an outlet divert valve (ODV) is used to supply a vaporized precursor to a showerhead of the processing chamber and to divert the vaporized precursor to an exhaust system of

the tool when the vaporized precursor is not supplied to the showerhead. For example, the ODV comprises a 4-port valve and a 2-port divert valve. The ODV is integrated with a manifold block comprising a plurality of manifolds (conduits). The manifolds connect the ports of the 4-port valve and the 2-port valve to a gas source, a vaporized precursor source, the showerhead, and the exhaust system of the tool.

[0035] In some applications, more than one (e.g., N, where N is an integer greater than 1) vaporized precursor need to be supplied to the showerhead of the processing chamber. Typically, N ODVs and respective sets of manifolds are needed to supply N vaporized precursors, respectively. However, a top plate of the tool generally does not have sufficient room to arrange multiple ODVs and respective sets of manifolds above the processing chamber.

[0036] The present disclosure provides a single multiport valve (MPV) assembly that can supply N vaporized precursors to a showerhead of a processing chamber. The MPV assembly comprises N ODVs integrated on a single substrate block that is integrated with a manifold block comprising a plurality of manifolds. The plurality of manifolds in the manifold block eliminate multiple manifolds from respective sets of manifolds that would be otherwise needed to supply the N vaporized precursors if the N ODVs are not integrated with the manifold block in the single MPV assembly as described below in detail.

[0037] In the MPV assembly, each of the N ODVs comprises a 4-port valve and a 2-port valve. The manifolds in the manifold block connect the N 4-port valves of the N ODVs to N gas sources and N vaporized precursor sources, respectively. Additionally, the manifolds in the manifold block connect the N 4-port valves through a mixing outlet of the MPV assembly to the showerhead of the processing chamber. The manifolds in the manifold block also connect the N 4-port valves and the N 2-port valves of the N ODVs to the exhaust system of the tool as described below in detail.

[0038] In the manifold block, a supply manifold from each of the 4-port valves in the N ODVs, through which a respective vaporized precursor flows, is connected to an output manifold. A single outlet of the output manifold called a mixing outlet is connected to the showerhead. Depending on the application, the N vaporized precursors can be supplied through the respective N 4-port valves and the respective N supply manifolds in any manner (e.g., sequentially, alternately, concurrently, continuously, in a pulsed manner, and so on).

[0039] When switching from supplying a first vaporized precursor to supplying a second vaporized precursor, a first 4-port valve supplying the first vaporized precursor is toggled to a bypass mode to divert the first vaporized precursor to the exhaust system. A second 4-port valve configured to supply the second vaporized precursor
5 begins supplying the second vaporized precursor. A previously supplied vaporized precursor can flow back (i.e., backstream) from the output manifold into the supply manifold(s) supplying another vaporized precursor(s), which can cause cross-contamination of the vaporized precursors.

[0040] To prevent the backflow (i.e., backstream) and cross-contamination of the
10 vaporized precursors, a carrier gas is continuously supplied through the N 4-port valves and N supply manifolds used to supply the N vaporized precursors to the output manifold. In some applications, a single carrier gas may be compatible with the N vaporized precursors. When a single carrier gas is compatible with the N vaporized precursors, a single carrier gas is supplied through the N 4-port valves and the N
15 supply manifolds supplying the N vaporized precursors. In some applications, a single carrier gas may be incompatible with one or more of the N vaporized precursors. When a single carrier gas is incompatible with one or more of the N vaporized precursors, a different carrier gas or gases may be supplied through one or more of the N 4-port valves and the N supply manifolds supplying the N vaporized precursors. The flow rates
20 of the carrier gases and the vaporized precursors can also be controlled using mass flow controllers upstream of the MPV assembly.

[0041] The mixing outlet of the MPV assembly is also designed to prevent cross-contamination between the multiple vaporized precursors by providing an isolation length of flow between the mixing point and the isolation points (e.g., the points of
25 intersection where the supply manifolds connect with the output manifold) so that backstream diffusion from the mixing point does not reach the isolation points. The mixing outlet is designed to be configurable (e.g., the location of the mixing outlet on the output manifold can be varied) such that the isolation length can be varied to accommodate different flow conditions needed for various processes.

30 [0042] In some applications, a different volume of one of the N vaporized precursors may need to be supplied. Generally, to supply the different volume, one or more manifolds in the manifold block need to be modified (e.g., replaced). For example, a diameter and/or length of a supply manifold may need to be changed. Typically, to

implement such a change, the entire assembly of the ODV and the manifold block or at least the entire manifold block needs to be replaced. Implementing such a change is labor-intensive, increases system downtime, and is expensive.

[0043] The present disclosure provides a portable manifold block in the MPV assembly. Specifically, the supply manifolds that connect the N 4-port valves of the N ODVs to the output manifold and the output manifold are configurable, pluggable, replaceable. The supply manifolds and the output manifold are manufactured as a subassembly that can be unplugged (e.g., removed like a cartridge) and replaced. Accordingly, if one of the supply manifolds needs to be modified, the subassembly installed in the manifold block can be replaced with another subassembly comprising the modified supply manifold(s) and the output manifold. The replacement can be performed quickly, which reduces system downtime. These and other features of the MPV assembly of the present disclosure are described below in detail.

EXAMPLE OF SUBSTRATE PROCESSING SYSTEM

[0044] FIG. 1 shows a block diagram of a substrate processing system 100. The system 100 comprises an MPV assembly 102 of the present disclosure. The MPV assembly 102 supplies multiple vaporized precursors to a showerhead 104 of a processing chamber 106. The processing chamber 106 comprises a substrate support (also called a pedestal) 108. A substrate 110 is arranged on the pedestal 108. For example, the pedestal 108 may use vacuum clamping to clamp the substrate 110 to the pedestal 108. Alternatively, the pedestal may comprise an electrostatic chuck (ESC) to electrostatically clamp the substrate 110 to the pedestal 108. Other clamping mechanisms may be used instead.

[0045] The system 100 comprises a gas delivery system 120. For example, the gas delivery system 120 comprises a plurality of gas sources shown as Gas Source1 122-1, Gas Source2 122-2, and Gas Source3 122-3 (collectively called the gas sources 122). For example, the gas sources 122 supply a plurality gases (e.g., process gases, insert gases, carrier gases, purge gases, cleaning gases, etc.). The gas delivery system 120 comprises a plurality of valves 124-1, 124-2, and 124-3 (collectively called the valves 124). For example, the gas delivery system 120 comprises a plurality of mass flow controllers (MFCs) 126-1, 126-2, and 126-3 (collectively called the MFCs 126). The gas sources 122 are connected to the MFCs 126 via the valves 124. The MFCs 126 control the flow rates of the gases supplied by the gas sources 122. The MFCs126 are

connected to the MPV assembly 102 as described below in detail with reference to FIGS. 2A onwards. While three gas sources 122 are shown as an example, the gas delivery system 120 can comprise any number of gas sources 122.

[0046] The system 100 comprises a vaporized precursor delivery system 130. For example, the vaporized precursor delivery system 120 comprises a plurality of vaporized precursor (VP) sources shown as VP Source1 132-1, VP Source2 132-2, and VP Source3 132-3 (collectively called the VP sources 132). For example, the VP sources 132 supply a plurality of vaporized precursors. For example, each of the VP sources 132 supplies a different vaporized precursor. The VP delivery system 130 comprises a plurality of valves 134-1, 134-2, and 134-3 (collectively called the valves 134). For example, the VP delivery system 130 comprises a plurality of mass flow controllers (MFCs) 136-1, 136-2, and 136-3 (collectively called the MFCs 136). The VP sources 132 are connected to the MFCs 136 via the valves 134. The MFCs 136 control the flow rates of the vaporized precursors supplied by the VP sources 132. The MFCs 136 are connected to the MPV assembly 102 as described below in detail with reference to FIGS. 2A onwards. While three VP sources 132 are shown as an example, the VP delivery system 130 can comprise any number of VP sources 132.

[0047] The MPV assembly 102 is connected to the showerhead 104. The MPV assembly 102 is described below in detail with reference to FIGS. 2A onwards. Briefly, the showerhead 104 receives a mixture of one or more gases and one or more vaporized precursors from the MPV assembly 102. The showerhead 104 supplies the mixture of one or more gases and one or more vaporized precursors to the processing chamber 106.

[0048] The system 100 comprises an RF power supply 140. When plasma is used to process the substrate 110, the RF power supply 140 supplies RF power to the showerhead 104 with the pedestal 108 grounded or to the pedestal 108 with the showerhead 104 grounded. The RF power ignites the mixture of one or more gases and one or more vaporized precursors to generate a plasma 142 in the processing chamber 106 to process the substrate 110.

[0049] The system 100 comprises an exhaust system 150. For example, the exhaust system 150 comprises one or more valves and a vacuum pump (both not shown). The exhaust system 150 maintains a pressure (e.g., vacuum) in the processing chamber 106 during substrate processing. The exhaust system 150 evacuates (purges) the

processing chamber 106 after the substrate 110 is processed. For example, the exhaust system 150 purges a first mixture of a first gas and a first precursor after the substrate 110 is processed using the first mixture and before the showerhead 104 supplies a second mixture of a second gas and a second precursor to the processing chamber 106 to process the substrate 110 or a different substrate. When vacuum clamping is used, the vacuum pump of the exhaust system 150 also provides vacuum clamping through the pedestal 108 to clamp the substrate 110 to the pedestal 108.

[0050] The system 100 comprises a system controller 160. The controller 160 controls the components of the system 100. For example, the controller 160 controls the valves (e.g., 4-port and 2-port valves) in the MPV assembly 102, power supply to heaters (described below) in the MPV assembly 102, the components of the gas delivery system 120 and the VP delivery system 130, the RF power supply 140, and the exhaust system 150.

[0051] While not shown, the showerhead 104 and the pedestal 108 may comprise one or more of a temperature sensor, a heater, and a cooling channel. The controller 160 controls the heaters and the cooling channels in the showerhead 104 and the pedestal 108 based on the temperatures of the showerhead 104 and the pedestal 108 sensed by the respective temperature sensors.

EXAMPLE OF INTEGRATED MULTIPORT VALVE ASSEMBLY

[0052] FIG. 2A schematically shows an example of the MPV assembly 102. While the MFCs 126, 136 shown in FIG. 1 are not shown in FIGS. 2A onwards, the MPV assembly 102 receives the gases and the vaporized precursors supplied by the gas sources 122 and the VP sources from the MFCs 126, 136, respectively. Accordingly, the connections of the input ports of the MPV assembly 102 described below to the gas sources 122 and the VP sources 132 should be understood as connections to the respective MFCs 126, 136. Further, while the following description uses three vaporized precursors for example, the present disclosure is not so limited. The following description of elements related to supplying one vaporized precursor to the showerhead 104 is extendible to supplying any number of vaporized precursors, which are generally denoted as N in number, where N is an integer greater than 1.

[0053] For example, the MPV assembly 102 comprises first, second, and third ODVs ODV1 200-1, ODV2 200-2, and ODV3 200-3 (collectively called the ODVs 200) and a manifold block 220 (shown in FIG. 3A onwards). The ODVs 200 and the manifold block

220 are shown in further detail in FIG. 3A. Briefly, in FIG. 2A, the ODVs 200 are connected to the gas sources 122, the VP sources 132, the showerhead 104, and the exhaust system 150 by various manifolds in the manifold block 220 and by various input and output ports, which are described below in further detail with reference to FIG. 3A. The ODVs 200 are connected to an output manifold 230 (also see FIG. 3A) in the manifold block 220 by respective supply manifolds 210-1, 210-2, and 210-3 (collectively called the supply manifolds 210) in the manifold block 220. The output manifold 230 is connected to the showerhead 104 via an outlet (called a mixing outlet) 232 in the manifold block 220 of the MPV assembly 102. The supply manifolds 210, the output manifold 230, and the outlet 232 are shown and described below in further detail with reference to FIGS. 3A onwards.

[0054] FIG. 2B shows an example of the ODV 200. For example, each ODV 200 comprises a 4-port valve 202 and a 2-port valve 204. Accordingly, as shown in FIG. 3A onwards, ODV1 200-1 comprises a 4-port valve 202-1 and a 2-port valve 204-1; ODV2 200-2 comprises a 4-port valve 202-2 and a 2-port valve 204-2; and ODV3 200-3 comprises a 4-port valve 202-3 and a 2-port valve 204-3. The 4-port valves 202-1, 202-2, and 202-3 are collectively called the 4-port valves 202. The 2-port valves 204-1, 204-2, and 204-3 are collectively called the 2-port valves 204.

[0055] FIG. 3A schematically shows the MPV assembly 102 in further detail. The MPV assembly 102 comprises the ODVs 200 and the manifold block 220 integrated as a single assembly. The ODVs 200 are integrated on a single substrate. The ODVs 200 are integrated with the manifold block 220. For example, the ODVs 200 are mounted to the manifold block 220. Thus, the MPV assembly 102 is a single integrated assembly comprising the ODVs 200 and the manifold 200 integrated with each other.

[0056] The MPV assembly 102 (e.g., the manifold block 200 of the MPV assembly 102) comprises a plurality of inputs and outputs. For example, the plurality of inputs comprise IN1p, IN1g, IN2p, IN2g, IN3p, and IN3g, where p denotes a vaporized precursor received by the MPV assembly 102 from a respective VP source 132, and g denotes a carrier gas received by the MPV assembly 102 from a respective gas source 122. Accordingly, the input IN1p receives the first vaporized precursor from the first VP source 132-1. The input IN1g receives the first carrier gas from the first gas source 122-1. The input IN2p receives the second vaporized precursor from the second VP source 132-2. The input IN2g receives the second carrier gas from the second gas source 122-

2. The input IN3p receives the third precursor from the third VP source 132-3. The input IN3g receives the third carrier gas from the third gas source 122-3. The inputs IN1p, IN2p, IN3p can be collectively called first N inputs that receive the N vaporized precursor from the N VP sources 132, respectively. The inputs IN1g, IN2g, IN3g can be collectively called the second N inputs that receive the N carrier gases from the N gas sources 122, respectively.

[0057] FIG. 3B shows an example of the connections of the 4-port valve 202 and the 2-port valve 204 of the ODV 200. The 4-port valve 202 has four ports P1, P2, P3, and P4. For example, the ports P1 and P2 of the 4-port valve 202 are input ports, and the ports P3 and P4 of the 4-port valve 202 are output ports. For example, the inputs INp and INg are respectively connected to two input ports P1 and P2 of the 4-port valve by respective separate manifolds 212, 214 in the manifold block 220. For example, the first output port P3 of the 4-port valve 202 is connected to the output manifold 230 by the respective supply manifold 210. The second output port P4 of the 4-port valve 202 is connected to an input port P1 of the 2-port valve 204 by a manifold 216 in the manifold block 220 as follows.

[0058] The 2-port valve 204 has two ports P1 and P2. For example, the first port P1 of the 2-port valve 204 is an input port, and the second port P2 of the 2-port valve 204 is an output port. The input port P1 of the 2-port valve 204 is connected to the second output port P4 of the 4-port valve 202 by a respective manifold 216 in the manifold block 220. The output port P2 of the 2-port valve 204 is connected to the exhaust system 150.

[0059] In FIG. 3A, the plurality of inputs IN1p, IN1g, IN2p, IN2g, IN3p, and IN3g are connected to the 4-port valves 202 by respective separate manifolds in the manifold block 220. Specifically, the inputs IN1p, IN1g are connected to the two input ports P1 and P2 of the first 4-port valve 202-1 by respective separate manifolds 212-1, 214-1 in the manifold block 220. The inputs IN2p, IN2g are connected to the two input ports P1 and P2 of the second 4-port valve 202-2 by respective separate manifolds 212-2, 214-2 in the manifold block 220. The inputs IN3p, IN3g are connected to the two input ports P1 and P2 of the third 4-port valve 202-3 by respective separate manifolds 212-3, 214-3 in the manifold block 220.

[0060] The output ports P3 of the 4-port valves 202 are connected to the output manifold 230 by respective supply manifolds 210. For example, the output port P3 of

the first 4-port valve 202-1 is connected to the output manifold 230 by the supply manifold 210-1. The output port P3 of the second 4-port valve 202-2 is connected to the output manifold 230 by the supply manifold 210-2. The output port P3 of the third 4-port valve 202-3 is connected to the output manifold 230 by the supply manifold 210-3. The
5 output manifold 230 comprises the outlet (called the mixing outlet) 232. The outlet 232 is connected to the showerhead 104.

[0061] The output ports P4 of the 4-port valves 202 are connected to the input ports P1 of the 2-port valves 204 by respective separate manifolds 216 in the manifold block 220. For example, the output port P4 of the 4-port valve 202-1 is connected to the input
10 port P1 of the 2-port valve 204-1 by the manifold 216-1. The output port P4 of the 4-port valve 202-2 is connected to the input port P1 of the 2-port valve 204-2 by the manifold 216-2. The output port P4 of the 4-port valve 202-3 is connected to the input port P1 of the 2-port valve 204-3 by the manifold 216-3.

[0062] The supply manifolds 210-1, 210-2, 210-3 are collectively called the supply manifolds 210 and individually called the supply manifold 210. The manifolds 212-1, 212-2, 212-3 are collectively called the manifolds 212 and individually called the manifold 212. The manifolds 214-1, 214-2, 214-3 are collectively called the manifolds 214 and individually called the manifold 214. The manifolds 216-1, 216-2, 216-3 are collectively called the manifolds 216 and individually called the manifold 216.
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[0063] The first vaporized precursor flows from the input IN1p, through the first 4-port valve 202-1, through the supply manifold 210-1, through the output manifold 230, and through the outlet 232 to the showerhead 104. The second vaporized precursor flows from the input IN2p, through the second 4-port valve 202-2, through the supply manifold 210-2, through the output manifold 230, and through the outlet 232 to the showerhead
20 104. The third vaporized precursor flows from the input IN3p, through the third 4-port valve 202-3, through the supply manifold 210-3, through the output manifold 230, and through the outlet 232 to the showerhead 104.
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[0064] To prevent backflow and cross-contamination of the vaporized precursors, carrier gases are supplied through the supply manifolds 210. The carrier gases are supplied through the supply manifolds 210 regardless of whether the vaporized precursors are being supplied through the supply manifolds 210. For example, the first carrier gas flows from the input IN1g, through the first 4-port valve 202-1, through the supply manifold 210-1, through the output manifold 230, and through the outlet 232 to
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the showerhead 104. The second carrier gas flows from the input IN2p, through the second 4-port valve 202-2, through the supply manifold 210-2, through the output manifold 230, and through the outlet 232 to the showerhead 104. The third carrier gas flows from the input IN3p, through the third 4-port valve 202-3, through the supply manifold 210-3, through the output manifold 230, and through the outlet 232 to the showerhead 104. As described above, one or more of the carrier gases may be the same or may be different depending on the compatibility or incompatibility of the carrier gases with the chemistries of the vaporized precursors.

[0065] When supply of a vaporized precursor is stopped (e.g., when switching from supplying one vaporized precursor to supplying another vaporized precursor to the showerhead 104), the vaporized precursor being supplied is diverted by the respective 4-port valve through the respective 2-port valve to the exhaust system 150. The supply of the corresponding carrier gas through the respective 4-port valve and the respective supply manifold 210 to the output manifold 230 is continued. Subsequently, when the supply of the vaporized precursor is to be resumed, the respective 4-port valve stops diverting the vaporized precursor to the exhaust system 150 and supplies the vaporized precursor along with the carrier gas through the respective supply manifold 210 to the output manifold 230.

[0066] The flow rates of the carrier gas or gases through the supply manifolds 210 can be controlled (e.g., by the controller 160) depending on whether the corresponding vaporized precursors are being supplied through the supply manifolds 210 or are being diverted to the exhaust system 150. For example, the carrier gas may be supplied through the supply manifold 210 at a first flow rate when the vaporized precursor is supplied through the supply manifolds 210 and at a second flow rate when the vaporized precursor is not supplied through the supply manifolds 210 but is diverted to the exhaust system 150, where the first flow rate can be different than the second flow rate. The continued supply of the carrier gas through the supply manifolds 210 regardless of whether the corresponding vaporized precursors are supplied through the supply manifolds 210 prevents backflow and cross-contamination of the vaporized precursors in the manifolds of the manifold block 220.

[0067] In addition, the backflow and cross-contamination of the vaporized precursors can be prevented by configuring the following parameters of the output manifold 230 and the supply manifolds 210. For example, the length, size, and shape of the output

manifold 230 and of the supply manifolds 210; the locations at which the supply manifolds 210 connect to the output manifold 230; the location of the outlet 232 on the output manifold 230; and the distances between the outlet 232 and the locations at which the supply manifolds 210 connect to the output manifold 230 can be configured to prevent the backflow and cross-contamination of the vaporized precursors.

[0068] FIG. 4 shows the MPV assembly 102 comprising a plurality of heaters 240-1, 240-2, 240-3, and 240-4 (collectively called the heaters 240). The heaters 240 are arranged in the manifold block 220. For simplicity of illustration, only the output manifold 230 and the supply manifolds 210 of the manifold block 220 are shown. Other elements shown in FIGS. 3A and 3B are omitted but are presumed to be present. The heaters 240 are omitted in other figures but are presumed to be present.

[0069] The heaters 240 heat the respective supply manifolds 210 and the output manifold 230. The heaters 240 ensure that the vaporized precursors in the supply manifolds 210 and the output manifold 230 remain in vapor form and are delivered through the outlet 232 to the showerhead 104 in vapor form. The heaters 240 also ensure that the vaporized precursors do not condense in the supply manifolds 210 and the output manifold 230.

[0070] While four heaters 240 are shown for example, the manifold block 220 may comprise any number of heaters to heat the vaporized precursors. The controller 160 (see FIG. 1) controls the power supply to the heaters 240 to control the temperatures of the vaporized precursors in the supply manifolds 210 according to properties (e.g., boiling point, etc.) of the precursors.

[0071] FIG. 5 shows the MPV assembly 102 with only the output manifold 230 and the supply manifolds 210 shown in the manifold block 220 to describe the output manifold 230 and the supply manifolds 210 in further detail. Other elements of the MPV assembly 102 shown in FIGS. 3A-4 are omitted but are presumed present. For example, the output manifold 230 and the supply manifolds 210 may have the same size and shape. For example, the output manifold 230 and the supply manifolds 210 may have different size and shape. For example, the output manifold 230 and the supply manifolds 210 may have the same diameter. For example, the output manifold 230 may have a different diameter than the supply manifolds 210. For example, at least one of the supply manifolds 210 may have a different diameter than the other supply manifolds 210. For example, the length of the output manifold 230 may be less than the

lengths of the supply manifolds 210. For example, the lengths of the supply manifolds 210 may be same. For example, at least one of the supply manifolds 210 may have a different length than the other supply manifolds 210. The output manifold 230 and the supply manifolds 210 may have any combination of the size and shape.

5 **[0072]** While the output manifold 230 and the supply manifolds 210 are schematically shown as being straight elements, the output manifold 230 and the supply manifolds 210 can be curved, bent, serpentine, or zig-zagged. The output manifold 230 and the supply manifolds 210 can be shaped and the supply manifolds 210 can be connected to the output manifold 230 as described above to prevent backflow and cross-
10 contamination of the vaporized precursors. The output manifold 230 and the supply manifolds 210 can be shaped and the supply manifolds 210 can be connected to the output manifold 230 to shorten the distances (e.g., flow paths of the vaporized precursors) between the 4-port valves 202 and the outlet 232 of the MPV assembly 102. The output manifold 230 and the supply manifolds 210 can also be shaped to fit in
15 the manifold block 220 along with other manifolds and heaters 240.

[0073] FIG. 6 shows a removable assembly 250 comprising the output manifold 230 and the supply manifolds 210. In the removable assembly 250, any of the output manifold 230 and the supply manifolds 210 can be customized (e.g., shaped and sized) for a particular application. For example, diameters and/or lengths of any the output
20 manifold 230 and the supply manifolds 210 can be designed to suit a particular application. For example, to supply a greater volume of one vaporized precursor, the diameter of one of the supply manifolds 210 may be increased. Such a change can be made by swapping an existing removable assembly 250 in the MPV assembly 102 with another removable assembly 250 having the different supply manifold 210.

25 **[0074]** In some applications, the locations at which the supply manifolds 210 connect to the output manifold 230, the location of the outlet 232 on the output manifold 230, and the distances between the outlet 232 and the locations at which the supply manifolds 210 connect to the output manifold 230 can be configured to prevent the backflow and cross-contamination of the vaporized precursors. Such changes can be
30 implemented in the removable assembly 250 and the existing removable assembly 250 in the MPV assembly 102 can be swapped with another removable assembly 250 having the different design.

[0075] For example, before switching operation from a first application to a second application in the system 100 (see FIG. 1), a first removable assembly 250 used with the first application can be pulled out of the MPV assembly 102 and a second removable assembly 250 designed for the second application can be inserted (plugged) into the MPV assembly 102. The removable assembly 250 eliminates the need to replace the entire MPV assembly 102 or to perform modifications to the MPV assembly 102 when switching operation from one application to another. Thus, the removable assembly 250 makes the supply manifolds 210 and the output manifold 230 configurable, modular, and portable. While not shown, in some examples, the removable assembly 250 may also comprise one or more of the heaters 240.

[0076] FIG. 7 shows a method 300 of delivering multiple vaporized precursors to the showerhead 104 using the MPV assembly 102. For example, the controller 160 performs the following steps of the method 300 as described above with reference to FIGS. 2A-6. At 302, the controller 160 controls the ODVs 200 to deliver the vaporized precursors via the MPV assembly 102 to the showerhead 104. At 304, the controller 160 controls the ODVs 200 to supply one or more carrier gases along with the vaporized precursors through the MPV assembly 102 to the showerhead 104.

[0077] At 306, the controller 160 controls the ODVs 200 to continue to supply the one or more carrier gases through the MPV assembly 102 when switching between the vaporized precursors and when one or more of the vaporized precursors are not supplied through the MPV assembly 102 to prevent backflow and cross-contamination of the vaporized precursors in the manifolds in the MPV assembly 102.

[0078] At 308, the controller 160 controls the power supply to the heaters 240 to prevent condensation of the vaporized precursors in the manifolds in the MPV assembly 102 and to supply the vaporized precursors to the showerhead 104 in vapor form. At 310, the controller 160 controls the ODVs to divert one or more vaporized precursors to the exhaust system 150 (e.g., when switching between the vaporized precursors) and to supply the vaporized precursors to the showerhead in any manner (e.g., sequentially, alternatingly, concurrently, continuously, in a pulsed manner, and so on).

[0079] The MPV assembly 102 is not a design choice or a rearrangement of parts such as valves and manifolds. Rather, the MPV assembly 102 is integrated as a single integrated assembly of the ODVs 200 and the manifold block 220 to provide many

advantages. The advantages include the following. The MPV assembly 102 combines a plurality of ODVs 200 and utilizes a set of manifolds in the manifold block 220, which eliminates multiple manifolds that would be otherwise required if the ODVs 200 are implemented with respective separate sets of manifolds. Thus, the MPV assembly 102 is compact and can fit in the limited space in the top plate above the showerhead 104. The MPV assembly 102 comprises the supply manifolds 210, the output manifold 230, and the outlet 232 specifically designed to prevent backflow and cross-contamination of the vaporized precursors in the manifolds in the MPV assembly 102. The MPV assembly 102 also optimizes flow paths of the vaporized precursors between the ODVs 200 and the outlet 232 of the MPV assembly 102, which allows fast and efficient delivery of the vaporized precursors to the showerhead 104 without cross-contamination of the vaporized precursors. The optimized flow paths and the heaters 240 integrated in the manifold block 220 prevent condensation of the vaporized precursors in the manifolds in the manifold block 220 and ensure that the vaporized precursors are delivered to the showerhead 104 in vapor form. The optimized flow paths also allow fast switching between the vaporized precursors, which increases processing speed at which the substrate 110 can be processed using different vaporized precursors, which in turn increases throughput. The optimized flow paths and the fast switching of the vaporized precursors also reduce waste of the expensive vaporized precursors, some of which can be hazardous.

[0080] The foregoing description is merely illustrative in nature and is not intended to limit the disclosure, its application, or uses. The broad teachings of the disclosure can be implemented in a variety of forms. Therefore, while this disclosure includes particular examples, the true scope of the disclosure should not be so limited since other modifications will become apparent upon a study of the drawings, the specification, and the following claims.

[0081] It should be understood that one or more steps within a method may be executed in different order (or concurrently) without altering the principles of the present disclosure. Further, although each of the examples is described above as having certain features, any one or more of those features described with respect to any one of the examples of the disclosure can be implemented in and/or combined with features of any of the other examples, even if that combination is not explicitly described. In other words, the described examples are not mutually exclusive, and permutations of one or more examples with one another remain within the scope of this disclosure.

[0082] Spatial and functional relationships between elements (for example, between modules, circuit elements, semiconductor layers, etc.) are described using various terms, including “connected,” “engaged,” “coupled,” “adjacent,” “next to,” “on top of,” “above,” “below,” and “disposed.” Unless explicitly described as being “direct,” when a
5 relationship between first and second elements is described in the above disclosure, that relationship can be a direct relationship where no other intervening elements are present between the first and second elements, but can also be an indirect relationship where one or more intervening elements are present (either spatially or functionally) between the first and second elements. As used herein, the phrase at least one of A, B,
10 and C should be construed to mean a logical (A OR B OR C), using a non-exclusive logical OR, and should not be construed to mean “at least one of A, at least one of B, and at least one of C.”

[0083] In some implementations, a controller is part of a system, which may be part of the above-described examples. Such systems can comprise semiconductor processing
15 equipment, including a processing tool or tools, chamber or chambers, a platform or platforms for processing, and/or specific processing components (a wafer pedestal, a gas flow system, etc.). These systems may be integrated with electronics for controlling their operation before, during, and after processing of a semiconductor wafer or substrate.

[0084] The electronics may be referred to as the “controller,” which may control various components or subparts of the system or systems. The controller, depending on the processing requirements and/or the type of system, may be programmed to control any of the processes disclosed herein, including the delivery of processing gases, temperature settings (e.g., heating and/or cooling), pressure settings, vacuum
20 settings, power settings, radio frequency (RF) generator settings, RF matching circuit settings, frequency settings, flow rate settings, fluid delivery settings, positional and operation settings, wafer transfers into and out of a tool and other transfer tools and/or load locks connected to or interfaced with a specific system.

[0085] Broadly speaking, the controller may be defined as electronics having various
30 integrated circuits, logic, memory, and/or software that receive instructions, issue instructions, control operation, enable cleaning operations, enable endpoint measurements, and the like. The integrated circuits may include chips in the form of firmware that store program instructions, digital signal processors (DSPs), chips defined

as application specific integrated circuits (ASICs), and/or one or more microprocessors, or microcontrollers that execute program instructions (e.g., software).

5 [0086] Program instructions may be instructions communicated to the controller in the form of various individual settings (or program files), defining operational parameters for carrying out a particular process on or for a semiconductor wafer or to a system. The operational parameters may, in some examples, be part of a recipe defined by process engineers to accomplish one or more processing steps during the fabrication of one or more layers, materials, metals, oxides, silicon, silicon dioxide, surfaces, circuits, and/or dies of a wafer.

10 [0087] The controller, in some implementations, may be a part of or coupled to a computer that is integrated with the system, coupled to the system, otherwise networked to the system, or a combination thereof. For example, the controller may be in the “cloud” or all or a part of a fab host computer system, which can allow for remote access of the wafer processing. The computer may enable remote access to the
15 system to monitor current progress of fabrication operations, examine a history of past fabrication operations, examine trends or performance metrics from a plurality of fabrication operations, to change parameters of current processing, to set processing steps to follow a current processing, or to start a new process.

[0088] In some examples, a remote computer (e.g., a server) can provide process
20 recipes to a system over a network, which may include a local network or the Internet. The remote computer may include a user interface that enables entry or programming of parameters and/or settings, which are then communicated to the system from the remote computer. In some examples, the controller receives instructions in the form of data, which specify parameters for each of the processing steps to be performed during
25 one or more operations. It should be understood that the parameters may be specific to the type of process to be performed and the type of tool that the controller is configured to interface with or control.

[0089] Thus, as described above, the controller may be distributed, such as by comprising one or more discrete controllers that are networked together and working
30 towards a common purpose, such as the processes and controls described herein. An example of a distributed controller for such purposes would be one or more integrated circuits on a chamber in communication with one or more integrated circuits located

remotely (such as at the platform level or as part of a remote computer) that combine to control a process on the chamber.

[0090] Without limitation, example systems may include a plasma etch chamber or module, a deposition chamber or module, a spin-rinse chamber or module, a metal
5 plating chamber or module, a clean chamber or module, a bevel edge etch chamber or module, a physical vapor deposition (PVD) chamber or module, a chemical vapor deposition (CVD) chamber or module, an atomic layer deposition (ALD) chamber or module, an atomic layer etch (ALE) chamber or module, an ion implantation chamber or module, a track chamber or module, and any other semiconductor processing systems
10 that may be associated or used in the fabrication and/or manufacturing of semiconductor wafers.

[0091] As noted above, depending on the process step or steps to be performed by the tool, the controller might communicate with one or more of other tool circuits or modules, other tool components, cluster tools, other tool interfaces, adjacent tools,
15 neighboring tools, tools located throughout a factory, a main computer, another controller, or tools used in material transport that bring containers of wafers to and from tool locations and/or load ports in a semiconductor manufacturing factory.

CLAIMS

What is claimed is:

1. A multiport valve assembly for a substrate processing system, the multiport valve assembly comprising:
 - 5 a manifold block comprising:
 - N first inputs configured to receive N vaporized precursors, respectively, where N is an integer greater than 1;
 - an outlet connectable to a showerhead of a processing chamber; and
 - a plurality of manifolds enclosed in the manifold block; and
 - 10 a plurality of valves mounted to the manifold block, the valves coupled to the N first inputs by the manifolds in the manifold block, the valves configured to supply the N vaporized precursors through respective supply manifolds in the manifold block, the respective supply manifolds connected to an output manifold in the manifold block, the output manifold comprising the outlet to supply one or more of the N vaporized
 - 15 precursors to the showerhead.
2. The multiport valve assembly of claim 1 wherein the manifold block and the plurality of valves are integrated in a single integrated assembly.
3. The multiport valve assembly of claim 1 wherein the outlet of the output manifold and connections of the supply manifolds to the output manifold are configured to
- 20 prevent cross-contamination of the N vaporized precursors.
4. The multiport valve assembly of claim 1 wherein:
 - the manifold block comprises N second inputs configured to receive one or more gases;
 - the valves are coupled to N second inputs by the manifolds in the manifold block;
 - 25 and
 - the valves are configured to supply the one or more gases through the supply manifolds.

5. The multiport valve assembly of claim 4 wherein the valves are configured to supply the one or more gases with the N vaporized precursors through the supply manifolds to the output manifold.
6. The multiport valve assembly of claim 4 wherein the valves are configured to supply the one or more gases through the supply manifolds to the output manifold regardless of supplying the N vaporized precursors through the supply manifolds to the output manifold to prevent cross-contamination of the N vaporized precursors.
7. The multiport valve assembly of claim 4 wherein the one or more gases are the same.
8. The multiport valve assembly of claim 4 wherein:
the manifold block comprises N outputs connected to an exhaust system;
the valves are coupled to the N outputs by the manifolds in the manifold block;
and
the valves are configured to divert the N vaporized precursors to the exhaust system via the N outputs.
9. The multiport valve assembly of claim 8 wherein the valves are configured to supply the one or more gases through the supply manifolds to the output manifold regardless of diverting the N vaporized precursors to the exhaust system to prevent cross-contamination of the N vaporized precursors.
10. The multiport valve assembly of claim 1 wherein the supply manifolds, the output manifold, and the outlet are configured as a removable subassembly.
11. The multiport valve assembly of claim 1 wherein the manifold block comprises a plurality of heaters configured to heat the respective supply manifolds.
12. The multiport valve assembly of claim 1 wherein the manifold block comprises a heater configured to heat the output manifold.

13. The multiport valve assembly of claim 8 wherein the valves comprise:
N 4-port valves; and
N 2-port valves;
wherein first ports of the N 4-port valves are coupled to the N first inputs,
5 respectively;
wherein second ports of the N 4-port valves are coupled to the N second inputs,
respectively;
wherein third ports of the N 4-port valves are coupled to the respective supply
manifolds;
10 wherein fourth ports of the N 4-port valves are coupled to first ports of the N 2-
port valves; respectively; and
wherein second ports of the N 2-port valves are coupled to the exhaust system.
14. A system comprising:
the multiport valve assembly of claim 8; and
15 a controller configured to control the valves.
15. The system of claim 14 further comprising:
N sources configured to supply the N vaporized precursors;
N first mass flow controllers coupled to the N sources and to the N first inputs,
respectively;
20 one or more gas sources configured to supply the one or more gases; and
one or more first mass flow controllers coupled to the one or more gas sources
and to the N second inputs,
wherein the controller is configured to control flow rates of the N vaporized
precursors and the one or more gases.
- 25 16. The system of claim 15 wherein the controller is configured to control the flow
rates of the one or more gases differently when the one or more gases are supplied
with the N vaporized precursors through the respective supply manifolds than when the
one or more gases are supplied without the N vaporized precursors through the
respective supply manifolds.

17. The system of claim 14 wherein:
- the manifold block comprises a plurality of heaters configured to heat the supply manifolds, the output manifold, or both; and
 - the controller is configured to control the heaters.