

PUMP APPARATUS FOR SEMICONDUCTOR PROCESSING

DESCRIPTION OF THE INVENTION

Field of the Invention

[001] The invention relates to a pump apparatus for use in semiconductor processing. The apparatus may include a single pump configured to transition a substance flow from about molecular pressure to about atmospheric pressure.

Background of the Invention

[002] Semiconductor wafers are used to form a number of different types of devices. For example, wafers, or portions of wafers, may be used to form memory devices, microprocessor unit devices, or combinations of the two devices. The devices may be very small, (e.g., on the order of only one micron), and thus these devices are often manufactured in large batches. In some instances, a single wafer may have hundreds of devices manufactured on it.

[003] In order to manufacture a device on a wafer, a number of discrete steps are performed. Although the number of steps may vary greatly depending on the type and complexity of the device, a typical manufacturing process may include anywhere between 100 and 300 individual steps between the initial step of providing an initial substrate and the final step of extracting individual devices from the wafer and installing them in personal computers, telephones, mobile phones, or other electronic equipment.

[004] Some of the steps in semiconductor wafer processing may include etching away selected material, depositing selected materials, and performing selective ion implantation in the silicon wafer. Many of these steps are performed by tools especially designed for the particular step, but several steps may also be performed by a single tool. Because these steps may be performed in a variety of locations, the wafer may often be moved. For example, the wafer may be placed in and taken out of ion implanter tools, transported by cassettes, placed in and taken out of deposition tools, and placed in and taken out of etch tools, etc.

[005] As mentioned above, etching is one form of processing that may be performed on a wafer. The wafer may be etched a number of different times at a number of different levels for a number of different reasons. For example, one type of etching step includes placing a photoresist type material over an area of the wafer. The photoresist on the wafer may be then be exposed to a light source with a specific wavelength and a specific pattern. The exposure of the photoresist to the light source may alter the chemical composition of the exposed area such that the photoresist either "hardens" so that when a chemical is applied, the "hardened" photoresist remains, or "softens" so that when a chemical is applied, the "softened" photoresist is removed. In either case, a desired photoresist pattern remains on the wafer. Using this remaining photoresist as a mask, chemical substances may be applied to the wafer so as to etch away or remove exposed portions of the wafer. Thus, a desired pattern may be "etched" into the silicon wafer.

[006] The devices and/or patterns that are etched into the wafer often have dimensions that are on the order of one micron. Because the dimensions being dealt with are so small, etching processes are especially susceptible to contaminants. For example, foreign molecules may become lodged in the channels etched into the wafers, and the existence of such flaws may prevent a device or portions of the device from working properly. Accordingly, in order to minimize these flaws, much attention is paid to the method by which the etching is performed, specifically by working to minimize the number of contaminants in the system.

[007] The most common method of controlling the etching is by etching in a vacuum chamber using a plasma. The vacuum chamber is, by definition, kept at a low pressure (e.g., molecular pressure), for example, between pressures of about 10^{-3} millibar and about 10^{-1} millibar. The plasma used to etch the wafers may include the addition of any number of substances, such as fluorocarbons or perfluorocarbons, which within the plasma may be broken up into smaller portions, such as fluorine and fluorine radicals. These smaller portions react with the exposed portions of the wafer and "etch away" that portion of the wafer through the formation of volatile reactant by-products. Other substances may be used depending on the substrate to be etched. Performing this procedure under vacuum substantially prevents contaminants from entering the system (as the chemicals present are normally only those specifically introduced into the system) and moderates the reaction rate as the molecular density is lower.

[008] In a number of current etching procedures, a large amount of reactants are conveyed past the wafer at high speeds, for example, on the order of thousands of liters per second. This runs contrary to the desire to minimize the number of contaminants by keeping the pressure in the vacuum chamber low. What results is a desire to pass etching substances through the vacuum chamber at high speeds, but low pressures, and thus specialized pumps are often desired.

[009] Currently, there are two discrete, completely separate, unintegrated pumps used in conjunction with each other to provide a high flow rate of etching substances at low pressures. The pumps have, among things, separate housings, separate controllers, separate electrical connections, and separate fluid connections, and are located long distances away from one another in different rooms of a wafer processing facility.

[010] In some current configurations, an inlet of a first pump is bolted to the bottom of the vacuum chamber and receives the substances from the vacuum chamber that are flowing at the low pressures. The first pump then gradually increases the pressure of the substance flow from the molecular level (at the inlet) to about the transition level (at the outlet). The substance flow is then sent through a tube or pipe to a second pump. The second pump is typically located in another room of the wafer processing facility (e.g., a basement) for several reasons, most prominent of which are its size, the amount of noise it generates, and its maintenance. The flow path (e.g., tube) connecting the pumps is typically between 5 and 15 meters in length, with a minimum length of 3 meters and a maximum length of 20 meters. The second

pump gradually increases the pressure of the substance flow from about the transition level (at the inlet) to about atmospheric pressure (at the outlet). The second pump then exhausts the substance flow.

[011] There are some drawbacks associated with the current dual pump arrangement. For example, having the second pump in a room separate from the first pump is often an inefficient use of space. In addition, there are efficiency losses associated with flowing the substances through a long tube connecting the pumps. Accordingly, alternative arrangements and/or configurations of multiple pumps are desired.

SUMMARY OF THE INVENTION

[012] In the following description, certain aspects and embodiments of the invention will become evident. It should be understood that the invention, in its broadest sense, could be practiced without having one or more features of these aspects and embodiments. It should also be understood that these aspects and embodiments are merely exemplary.

[013] One aspect, as embodied and broadly described herein, may relate to an apparatus for use in semiconductor processing.

[014] An exemplary embodiment of the invention may include an apparatus for use in semiconductor processing. The apparatus may include a single pump configured to transition a substance flow having an input pressure less than or equal to about 10^{-1} millibar to an output pressure greater than or equal to about 100 millibar.

[015] Various embodiments of the invention may include one or more of the following aspects: the single pump may be configured to transition a

substance flow having an input pressure less than or equal to about 10^{-3} millibar to an output pressure greater than or equal to about 100 millibar; the single pump may be configured to transition the substance flow to an output pressure greater than or equal to about 1 bar; the single pump may include no more than a single rotatable shaft; the single shaft may consist essentially of a single vertical axis; the single shaft may be continuous; a semiconductor processing tool associated with the single pump; a flow rate of the substance flow may range from about 1,000 liters per second to about 10,000 liters per second; the flow rate of the substance flow may range from about 1,600 liters per second to about 3,000 liters per second; the single pump may include at least one ball bearing; at least one ball bearing may be associated with a portion of the single pump that exhausts substance flow having an output pressure greater than or equal to about 100 millibar; the single pump may include at least one magnetic bearing; the at least one magnetic bearing may be associated with a portion of the single pump that receives substance flow having an input pressure less than or equal to about 10^{-2} millibar; the single pump may include no more than one motor; the single pump may include no more than one bearing suspension unit; the single pump may include at least one magnetic bearing; the at least one ball bearing may be associated with a portion of the single pump that exhausts the substance flow having an output pressure greater than or equal to about 100 millibar; and the at least one magnetic bearing may be associated with a portion of the single pump that receives substance flow having an input pressure less than or equal to about 10^{-2} millibar.

[016] Another exemplary embodiment of the invention may include an apparatus for use in semiconductor processing. The apparatus may include a single pump configured to transition a substance flow from about molecular pressure to about atmospheric pressure.

[017] A further exemplary embodiment of the invention may include an apparatus for use in semiconductor processing. The apparatus may include a single pump configured to transition a substance from turbomolecular flow to atmospheric flow.

[018] Aside from the structural relationships discussed above, the invention could include a number of other forms such as those described hereafter. It is to be understood that both the foregoing description and the following description are exemplary only.

BRIEF DESCRIPTION OF THE DRAWINGS

[019] The accompanying drawings, which are incorporated in and constitute a part of this specification. The drawings illustrate several embodiments of the invention and, together with the description, serve to explain some principles of the invention. In the drawings:

[020] Fig. 1A is a schematic view of an embodiment of an apparatus in accordance with the present invention;

[021] Fig. 1B is a schematic view of another embodiment of the apparatus;

[022] Fig. 2 is a schematic view of a portion of the apparatus of Fig. 1B;

[023] Fig. 3 is a schematic view of a portion of the apparatus of Fig. 1A;

[024] Fig. 4 is a schematic view of a portion of the apparatus of Fig. 1A;

[025] Fig. 5 is a schematic view of a further embodiment of the apparatus disposed in a single room of a semiconductor processing facility;

[026] Fig. 6 is a schematic view of still another embodiment of the apparatus associated with a semiconductor processing tool;

[027] Fig. 7 is a schematic view of a portion of a still further embodiment of the apparatus;

[028] Figs. 8A and 8B are perspective views of portions of yet another embodiment of the apparatus;

[029] Figs. 8C and 8D are schematic views of the portions of Figs 8A and 8B; and

[030] Fig. 9 is a schematic view of a yet further embodiment of the apparatus.

DESCRIPTION OF THE EMBODIMENTS

[031] Reference will now be made in detail to some possible embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

[032] Figs. 1-9 depict exemplary embodiments of an apparatus for use in semiconductor processing. The apparatus may include a pump 1 having one or more of each of a turbomolecular stage 100, a drag stage 200, and a dry stage 300. For example, pump 1 may include all three of turbomolecular stage 100, drag stage 200, and dry stage 300. In another example, pump 1 may

include only one of turbomolecular stage 100, drag stage 200, and dry stage 300. In a further example, as shown in Fig. 9, pump 1 may include a turbomolecular stage 100, a plurality of drag stages 200, and a dry stage 300. In some examples, pump 1 may be configured to receive a substance flow at about molecular pressure, for example, having a pressure of about 5×10^{-3} millibar, at a flow rate ranging from about 1600 liters per second to about 2000 liters per second, and exhaust the substance flow at about atmospheric pressure.

[033] Also or alternatively, pump 1 may be configured to transition a substance flow having an input pressure less than or equal to about 10^{-2} millibar (e.g., about 10^{-3} millibar) to an output pressure greater than or equal to about 100 millibar (e.g., about 1 bar), and/or may be configured to accommodate a flow rate of the substance flow that ranges from about 1,000 liters per second (e.g., about 1,600 liters per second) to about 10,000 liters per second (e.g., about 3,000 liters per second).

[034] Turbomolecular stage 100 may be a stage configured to provide turbomolecular flow of a substance at about molecular pressure such that molecules of the substance are more likely to collide with at least one interior wall 101 (Fig. 4) of turbomolecular stage 100 rather than into other substance molecules. Turbomolecular stage 100 may have an inlet 102 configured to receive a flow of the substance at a first pressure (e.g., from a semiconductor processing chamber) and an outlet 103 to expel the substance flow at a second pressure, for example, to one or more of drag stage 200, dry stage 300, or the atmosphere. As shown in Fig. 1, turbomolecular stage 100 may include blades

104 configured to rotate together to transition substance flow from an input pressure of about 10^{-3} millibar to about 10^{-1} millibar, for example, when the input flow passing through inlet 102 is from an etching tool. Turbomolecular stage 100 may also or alternatively include blades 104 configured to rotate together to transition substance flow at lower input pressures, for example, a pressure as low as about 10^{-8} millibar when the input flow passing through inlet 102 is from a tool or other structure associated with an application other than etching, for example, physical vapor deposition ("PVD"). Turbomolecular stage 100 may be configured to transition substance flow to a second pressure of about 1 millibar to about 10 millibar. In some embodiments, the second pressure may be about 100 millibar to about 1 bar.

[035] Blades 104 may be disposed in turbomolecular stage 100 using bearings. The bearings may be mechanical bearings, such as ball bearings or a central shaft, or may be magnetic bearings configured to magnetically levitate blades 104 within turbomolecular stage 100. In some embodiments, turbomolecular stage 100 may have multiple types of bearings. For example, blades 104 closer to inlet 102 may be suspended by magnetic bearings (e.g., when the flow rate of substance flow through the inlet ranges from about 2000 liters per second to about 300 liters per second), while blades 104 closer to outlet 103 may be suspended by mechanical bearings. Magnetic bearings may be desirable at higher speeds of substance flow because they may actively reduce vibrations.

[036] In alternate examples shown in Figs. 7 and 9, blades 104 may be disposed on a shaft 106. A top portion of shaft 106 closer to inlet 102 may

be suspended by magnetic bearings, and a bottom portion of shaft 106 closer to outlet 103 may be suspended by mechanical bearings. In various embodiments, however, shaft 106 may be suspended by any number of bearings of any type and in any combination (e.g., two mechanical bearings or two magnetic bearings).

[037] Adjacent blades 104 may be spaced from one another by an intervening stator 105. Stators 105 may remain substantially stationary during a substance pumping process and may be fixed to the inner wall 101 that surrounds the blades 104.

[038] The molecules entering the turbomolecular stage 100 may have a substantially random motion. These molecules may collide with a rotating blade 104 and pick up the blade's 104 velocity such that upon leaving each blade 104, the molecule has a velocity substantially the same as that of blade 104 as well as having an intrinsic thermal velocity substantially similar to that of the blade 104. Thus, compression may be generated by a combination of blades 104 providing a higher transmission probability downwards rather than upwards due to the angle of blades 104 and the relative blade velocity. Stationary stator 105 also may be configured such that it generates compression through a combination of the relative gas velocity and the stator 105 providing a higher transmission probability downwards as compared to upwards due to the angle of the stator blade. Upward and downwards may refer to movement of gas relative to the outlet 103 (e.g., exhaust) of the pump. For example, downwards may refer to movement of gas towards the exhaust of the pump (e.g., moving toward a higher pressure area and/or being

compressed), while upwards may refer to movement of gas away from the exhaust of the pump (e.g., moving toward a lower pressure area and/or being expanded). Stator 105 may have a relative velocity from the reference of the molecule such that equal pumping may be provided by stator 105 and blade 104.

[039] One or more of blades 104, intervening stators 105, and/or other portions of the turbomolecular stage 100 may be configured to efficiently move substances at low pressures. The turbomolecular stage 100 may typically operate with inlet pressures ranging from about 10^{-1} millibar to about 10^{-8} millibar (10^{-7} millibar) and corresponding outlet pressures from about 0.1 millibar to about 1 millibar or less, depending, for example, on flow and the size of the pump downstream.

[040] Additional details concerning exemplary configurations of a turbomolecular stage 100 with blades 104 and stators 105, and its various components, are set forth in U.S. Patents 6,109,864 and 6,778,969, which are both incorporated herein by reference in their entirety.

[041] Pump 1 may include a drag stage 200, an example of which is shown in Fig. 2. Drag stage 200 may have an inlet 204 configured to receive a flow of the substance at a first pressure (e.g., from a semiconductor processing chamber or an outlet 103 of turbomolecular stage 100) and an outlet 205 to expel the substance flow at a second pressure, for example, to one or more of turbomolecular stage 100, dry stage 300, or the atmosphere. The second pressure may depend on the pressure to which pump 1 may ultimately exhaust.

For example, in some embodiments, pump 1 may not exhaust to atmospheric pressure, thus only turbomolecular stage 100 and drag stage 200 may be used.

[042] Drag stage 200 may include two or more co-axial hollow cylinders 201, 202. Each of cylinders 201, 202 may be composed of multiple cylindrical portions, for example, two or more cylindrical portions adjacent to each other (e.g., one cylindrical portion may be closer to inlet 204, while another cylindrical portion may be closer to outlet 205, with both cylindrical portions having substantially the same dimensions and/or configurations). Such cylindrical portions may be desirable, for example, so as to operate different parts of drag stage 200 at different efficiencies depending on pressure.

[043] One or more of the cylinders 201, 202 may have a helical thread 203 provided on its surface facing the other cylinder 201, 202. For example, Fig. 2 schematically shows a thread 203 on an inner surface of outer cylinder 201. In operation, one or more of the cylinders 201, 202 may rotate at relatively high speeds, for example, up to about twenty-thousand revolutions-per-minute or more. At low pressures, molecules may strike the surface of the rotating helical thread 203, giving the molecules a velocity component and tending to cause the molecules to have the same direction of motion as the surface against which they strike. The molecules may be urged through drag stage 200 in this manner and exit drag stage 200 at a higher pressure than that at which they entered. Helical thread 203 may have a relatively close clearance with cylinder 202, for example, between about 0.1 mm and about 0.5 mm depending on the pressure. Such a close clearance may provide a greater

probability of molecules moving towards the outlet of the pump than towards the inlet.

[044] Drag stage 200 may typically operate with inlet pressures ranging from about 10^{-1} millibar to about 10^{-7} millibar (e.g., about 10^{-6} millibar) and corresponding outlet pressures of from about 10 millibar to about 1 millibar or less, for example, depending on flow and the size of the pump downstream. At least some of the cylinders 201, 202, helical thread 203, and/or other parts of the drag stage 200 (e.g., those disposed closer to outlet 205) may be configured to efficiently move substances at higher pressure. Further details regarding exemplary drag stages and their various components can be found in U.S. Patent 5,772,395, which is incorporated herein by reference in its entirety.

[045] Drag stage 200 may have an alternate configuration, for example, as shown in Fig. 9. Drag stage 200 may have several stationary cylinders 201 having a helical thread 203 and several rotating cylinders 202. Rotating cylinders 202 may be connected, may rotate at substantially the same rotational speed, and/or may be disposed on the same shaft 106 as blades 104. Each stationary cylinder 201 and surface of rotating cylinder 202 facing its respective stationary cylinder may comprise a separate drag stage 200. Some drag stages 200 may include a surface of a stationary cylinder 201 having a helical thread 203 facing radially outward and also facing a substantially flat radially inward surface of a rotating cylinder 202. Some drag stages 200 may have the opposite configuration. Each stationary cylinder 201 may have helical threads 203 on its radially outward surface and/or its radially inward surface. Each rotating cylinder 202 may face a surface of a stationary cylinder 201

having helical threads 203 on its radially outward surface and/or its radially inward surface.

[046] Each drag stage 200 may be in flow communication with other drag stages 200. Each drag stage 200 may be disposed radially inward or outward from other drag stages 200. Each drag stage 200 may have a different configuration. For example, the helical threads 203 in each drag stage 200 may have a different length than helical threads 203 in other drag stages 200. Drag stages 200 may be disposed radially outward from turbomolecular stage 100. Each drag stage 200 may be configured to increase a pressure of the substance while the substance flows through the drag stage 200, and then exhaust the substance to a more radially outer drag stage 200 until the substance is exhausted by the final drag stage 200 to the dry stage 300, for example, at about atmospheric pressure or atmospheric flow.

[047] Pump 1 may include a dry stage 300 as show in Fig. 3. Dry stage 300 may be a pump configured to provide transition flow and/or viscous flow of the substance such that molecules of the substance are more likely to collide with each other rather than at least one interior wall 305 of the pump. Dry stage 300 may have an inlet 301 that receives a substance flow at a first pressure (e.g., from an outlet of turbomolecular stage 100 or drag stage 200) and an outlet 302 that expels the substance flow at a second pressure (e.g., about atmospheric pressure). One exemplary type of dry pump 300, an example of which is shown in Fig. 3, may include rotating blades 303, typically having a different geometry than those of a turbomolecular pump, such that they are suitable for operating at higher pressures with intervening stators 304.

The blades 303 and stators 304 may be configured to transition substance flow from an input pressure of about 1 millibar to about 10 millibar or less (e.g., a pressure as low as about 0.1 millibar) to about 100 millibar to about 1 bar (e.g., atmospheric pressure). Blades 303 may be disposed in dry stage 300 using bearings (e.g., one or more of a ball bearing, a cylinder shaft, and a magnetic bearing). Stators 304 may be fixed to a cylindrical housing that surrounds the blades 303. Blades 303 and stators 304 may operate substantially similar to the blades 103 and stators 104 described above with respect to turbomolecular stage 100, in that dry stage 300 may cause an increase in the pressure of the substance passing into dry stage 300 via the inlet 301 before the substance exits dry stage 300 via outlet 302. Examples of dry stages and their various components are disclosed in U.S. Patents 6,244,841, 6,705,830, 6,709,226, 6,755,611 B1, which are all incorporated herein by reference in their entirety. Other suitable examples of dry stages are disclosed in U.S. Patents 6,129,534, 6,200,116, 6,379,135, and 6,672,855, which are incorporated herein by reference in their entirety.

[048] Dry stage 300 may have an alternate configuration, for example, as shown in Figs. 8A, 8B, 8C, 8D, and 9. In the alternate configuration, dry stage 300 may include a regenerative rotor 350 and a regenerative stator 370.

[049] As shown in Figs. 8A, regenerative rotor 350 may include a plurality of substantially circular protrusions 351 extending from a surface of regenerative rotor 350. Protrusions 351 may have a plurality of blades 352 extending therefrom. A cross-section of protrusion 351 and blade 352 is shown in Fig. 8D.

[050] As shown in Fig. 8B, regenerative stator 370 may include a plurality of protrusions 371 defining a plurality of channels 372 therebetween. Adjacent channels 372 may be connected via intervening channels 373. A cross-section of protrusion 371 and channel 372 is shown in Fig. 8D. Each channel 372 may include a first portion 372a and a second portion 372b. First portion 372a may be slightly wider than a width of protrusion 351, for example, to prevent the flow of a substance therebetween. Thus, in operation, any substance may be substantially contained in second portion 372b. Second portion 372b may have any suitable cross-sectional shape to accommodate substance flow, for example, a curved or oval-like shape.

[051] As shown in Figs. 8C and 9, each blade 352 may be placed in one of channels 372 such that protrusion 351 is disposed in first portion 372a, and that blade 352 extends into second portion 372. Each set of blades 352 and channels 372 may include a corresponding inlet 391 and outlet 392 which may or may not be the same as intervening channels 373.

[052] In operation, blade 352 may rotate relative to channel 372. A substance may enter second portion 372b of channel 372 via inlet 391. Blade 352 may then cause the substance to flow in the same direction as the rotation of blade 352, for example, in a substantially oval-like and/or spiral-like pattern as a consequence of the gas gaining momentum and moving in a tangential direction to the rotating blade 352 but being constrained by the channel 372. The substance may then exit second portion 372b of channel 372 via outlet 392. The substance may then be sent to another blade 352 and channel 372 combination, or may be exhausted from pump 1.

[053] As shown in Fig. 9, dry stage 300 may have a plurality of blade 352 and channel 372 combinations. Each combination of blades 352 and channels 372 may be disposed radially inward and/or outward from other combinations of blades 352 and channels 372. Rotor 350 may be disposed on the same shaft 106 as blades 104 and cylinders 202. Each combination of blades 352 and channels 372 may exhaust the substance from an outer combination to a combination disposed radially inward. The inner-most combination may exhaust the substance out of the pump 1, for example, to the atmosphere.

[054] As shown in Figs. 4A and 4B, one or more of turbomolecular stage 100, drag stage 200, and dry stage 300 are disposed in a single housing 10. If pump 1 includes more than one of turbomolecular stage 100, drag stage 200, and dry stage 300, the boundary between the stages may not be externally discernable (i.e., a person viewing the exterior of the apparatus with only their naked eye would not be able to visualize the boundary between turbomolecular stage 100, drag stage 200, and dry stage 300). The pump may have a single driving motor to rotate the sets of blades, cylinders, or other components of turbomolecular stage 100, drag stage 200, and dry stage 300. In some embodiments, pump 1 may have one or more motors configured to drive one or more components of one or more of turbomolecular stage 100, drag stage 200, and/or dry stage 300.

[055] One or more of turbomolecular stage 100, drag stage 200, and dry stage 300 may be connected to each other without substantially having transition portions. For example, outlet 103 of turbomolecular stage 100 may

be substantially the same as inlet 204 of drag stage 200. In another example, outlet 205 of draft stage 200 may be substantially the same as inlet 301 of dry stage 300. In a further example, outlet 103 of turbomolecular stage 100 may be substantially the same as inlet 301 of dry stage 300.

[056] One or more of turbomolecular stage 100, drag stage 200, and dry stage 300 of pump 1 may be disposed in a single room 3 of a semiconductor processing facility, for example, as shown in Fig. 5. One advantage of pump 1 may be that it is possibly more compact than conventional pumps, providing savings with regards to space, and also reducing the number of pumps and/or components for a particular process, for example, a semiconductor manufacturing process.

[057] As shown in the example of Fig. 6, one or more of turbomolecular stage 100, drag stage 200, and dry stage 300 of pump 1 may have a common controller 90 that controls each of one or more of turbomolecular stage 100, drag stage 200, and dry stage 300. Common controller 90 may be connected to one or more of turbomolecular stage 100, drag stage 200, and dry stage 300 by a controller connection 91. One or more of turbomolecular stage 100, drag stage 200, and dry stage 300 may be associated with a semiconductor processing tool 2.

[058] In some examples, rather than having a wired connection, a wireless link may provide communication between common controller 90 and one or more of turbomolecular stage 100, drag stage 200, and dry stage 300.

[059] One or more of turbomolecular stage 100, drag stage 200, and dry stage 300 of pump 1 may share common connections. For example, one

or more of turbomolecular stage 100, drag stage 200, and dry stage 300 may share a common power connection. Power connection may provide electrical power to one or more of turbomolecular stage 100, drag stage 200, and dry stage 300 so as to power one or more motors associated with turbomolecular stage 100, drag stage 200, and/or dry stage 300. This connection may also be fed through the remote controller 90 to condition power before directing it to one or more of turbomolecular stage 100, drag stage 200, and dry stage 300 of pump 1. In various embodiments, pump 1 may include any suitable connections, for example, a nitrogen connection, a water connection, and/or a dry air connection.

[060] The invention may have several advantages. For example, the invention may operate at a greater efficiency than multiple pumps configured to transition the substance flow at the specified ranges. In another example, conductance losses present during the use of multiple pumps may be minimized and/or substantially eliminated, for example, due to a reduction in the length of the substance flow paths. In another example, the invention may take up less space than multiple pumps and require less energy, important advantages in an industry where space and power consumption is at a premium. In a further example, because the exhaust from the apparatus may be greater than or equal to about 100 millibar, double containment of the apparatus may not be necessary as any sub-atmospheric leaks may be inwards.

[061] The invention may overcome several problems. For example, each pump for each stage in a conventional machine may be delivered

separately. When delivered, the pressure in the chambers of each of these pumps may be at atmospheric pressure. To operate the chamber, the pressure in each chamber may be lowered to the proper operating pressure. While one option is to initially run the rotor in each chamber using a large motor, such an option is undesirable as it may overheat the rotor. Another option is to at least initially use another pump (e.g., a lock load pump) to reduce the pressure of the chamber. Once the inlet pressure in the chamber of each pump is below about 100 millibars (e.g., below about 10 millibars), the pump may operate unassisted. By integrating the various stages of the pump into a single pump, it may eliminate the need for the additional pump, for example, if the pump already exhausts to atmospheric pressure, allowing the pump to start and operate completely unassisted. In the alternative, if the pump exhausts to a pressure less than atmospheric pressure, only one additional pump may be necessary, as opposed to one pump for each stage of a conventional machine.

[062] In another example, discrepancies in size between a conventional turbomolecular pump, a conventional drag pump, and a conventional dry pump prevented their combination into a single pump. For example, there were large differences in the dimensions of shafts in the conventional turbomolecular pump, conventional drag pump, and conventional dry pump. Advances made in the dry pump, for example, in the dry stage shown in Figs. 8A, 8B, 8C, and 8D, have resulted in a more compact dry stage that may be configured to be more readily combined with a turbomolecular stage and/or drag stage.

[063] It will be apparent to those skilled in the art that various modifications and variations can be made to the structure described herein.

This, it should be understood that the invention is not limited to the subject matter discussed in the specification and shown in the drawings. Rather, the present invention is intended to include modifications and variations.

WHAT IS CLAIMED IS:

1 1. An apparatus for use in semiconductor processing, comprising:
2 a single pump configured to transition a substance flow having an input
3 pressure less than or equal to about 10^{-1} millibar to an output pressure greater
4 than or equal to about 100 millibar.

1 2. The apparatus of claim 1, wherein the single pump is configured
2 to transition a substance flow having an input pressure less than or equal to
3 about 10^{-3} millibar to an output pressure greater than or equal to about 100
4 millibar.

1 3. The apparatus of claim 1, wherein the single pump is configured
2 to transition the substance flow to an output pressure greater than or equal to
3 about 1 bar.

1 4. The apparatus of claim 1, wherein the single pump includes no
2 more than a single rotatable shaft.

1 5. The apparatus of claim 4, wherein the single shaft consists
2 essentially of a single vertical axis.

1 6. The apparatus of claim 4, wherein the single shaft is continuous.

1 7. The apparatus of claim 1, further comprising a semiconductor
2 processing tool associated with the single pump.

1 8. The apparatus of claim 1, wherein a flow rate of the substance
2 flow ranges from about 1,000 liters per second to about 10,000 liters per
3 second.

1 9. The apparatus of claim 8, wherein the flow rate of the substance
2 flow ranges from about 1,600 liters per second to about 3,000 liters per second.

1 10. The apparatus of claim 1, wherein the single pump includes at
2 least one ball bearing.

1 11. The apparatus of claim 10, wherein at least one ball bearing is
2 associated with a portion of the single pump that exhausts substance flow
3 having an output pressure greater than or equal to about 100 millibar.

1 12. The apparatus of claim 1, wherein the single pump includes at
2 least one magnetic bearing.

1 13. The apparatus of claim 12, wherein the at least one magnetic
2 bearing is associated with a portion of the single pump that receives substance
3 flow having an input pressure less than or equal to about 10^{-2} millibar.

1 14. The apparatus of claim 1, wherein the single pump includes no
2 more than one motor.

1 15. The apparatus of claim 1, wherein the single pump includes no
2 more than one bearing suspension unit.

1 16. The apparatus of claim 10, wherein the single pump includes at
2 least one magnetic bearing.

1 17. The apparatus of claim 16, wherein the at least one ball bearing is
2 associated with a portion of the single pump that exhausts the substance flow
3 having an output pressure greater than or equal to about 100 millibar.

1 18. The apparatus of claim 16, wherein the at least one magnetic
2 bearing is associated with a portion of the single pump that receives substance
3 flow having an input pressure less than or equal to about 10^{-2} millibar.

1 19. An apparatus for use in semiconductor processing, comprising:
2 a single pump configured to transition a substance flow from about
3 molecular pressure to about atmospheric pressure.

1 20. An apparatus for use in semiconductor processing, comprising:
2 a single pump configured to transition a substance from turbomolecular
3 flow to atmospheric flow.