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(54) PUMP APPARATUS FOR SEMICONDUCTOR PROCESSING

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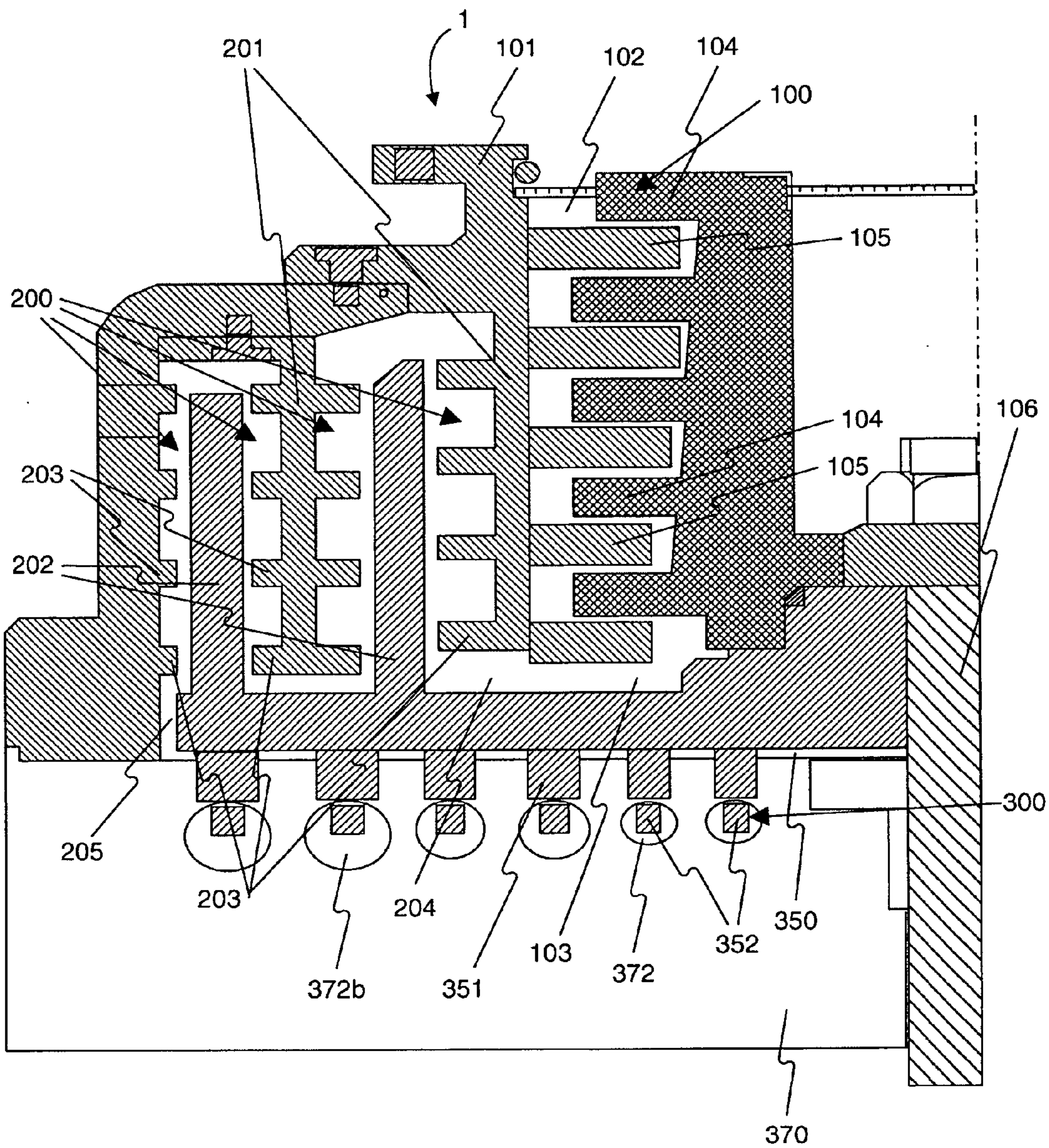
(57) ABSTRACT

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.



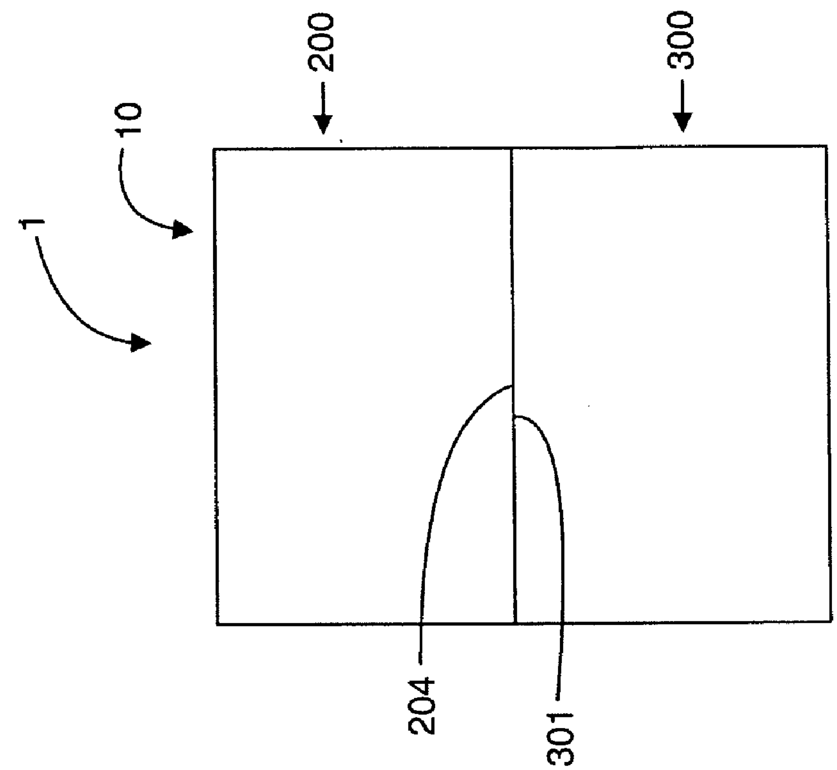


FIG. 1B

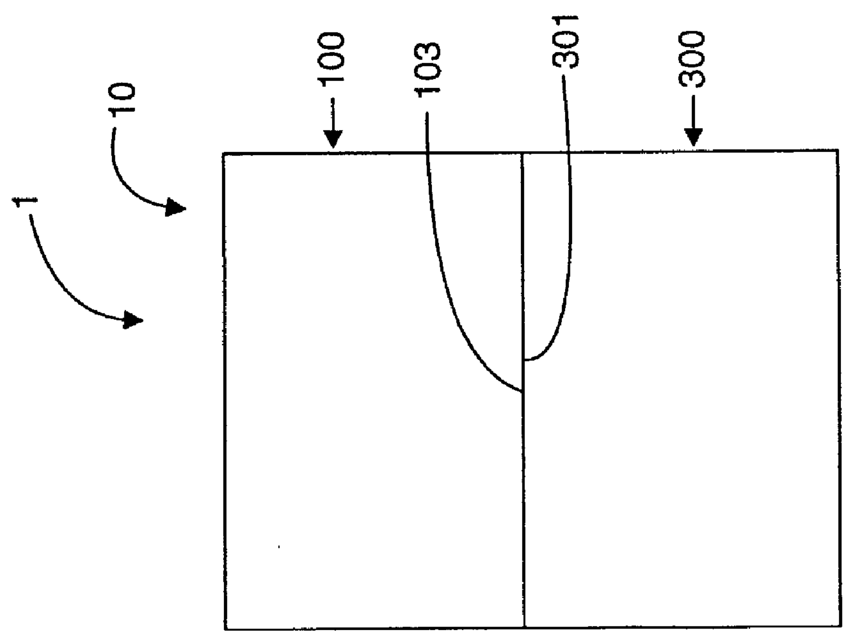


FIG. 1A

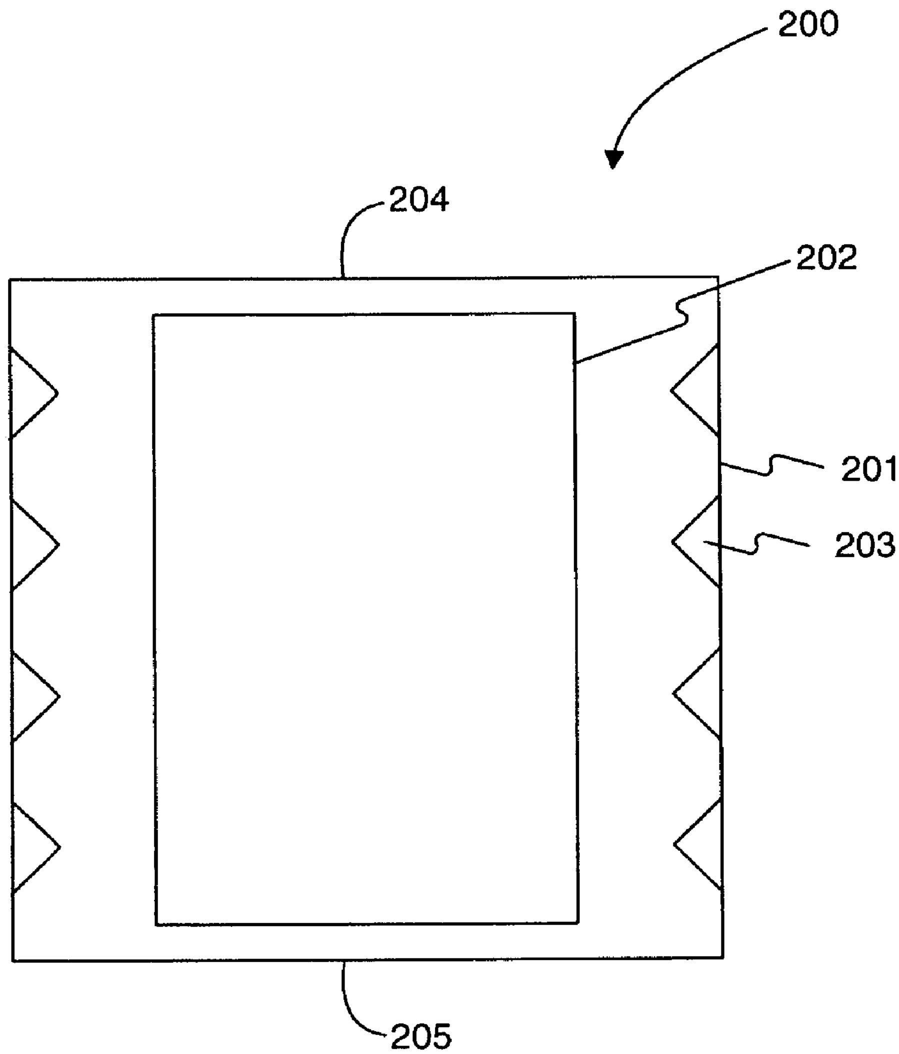


FIG. 2

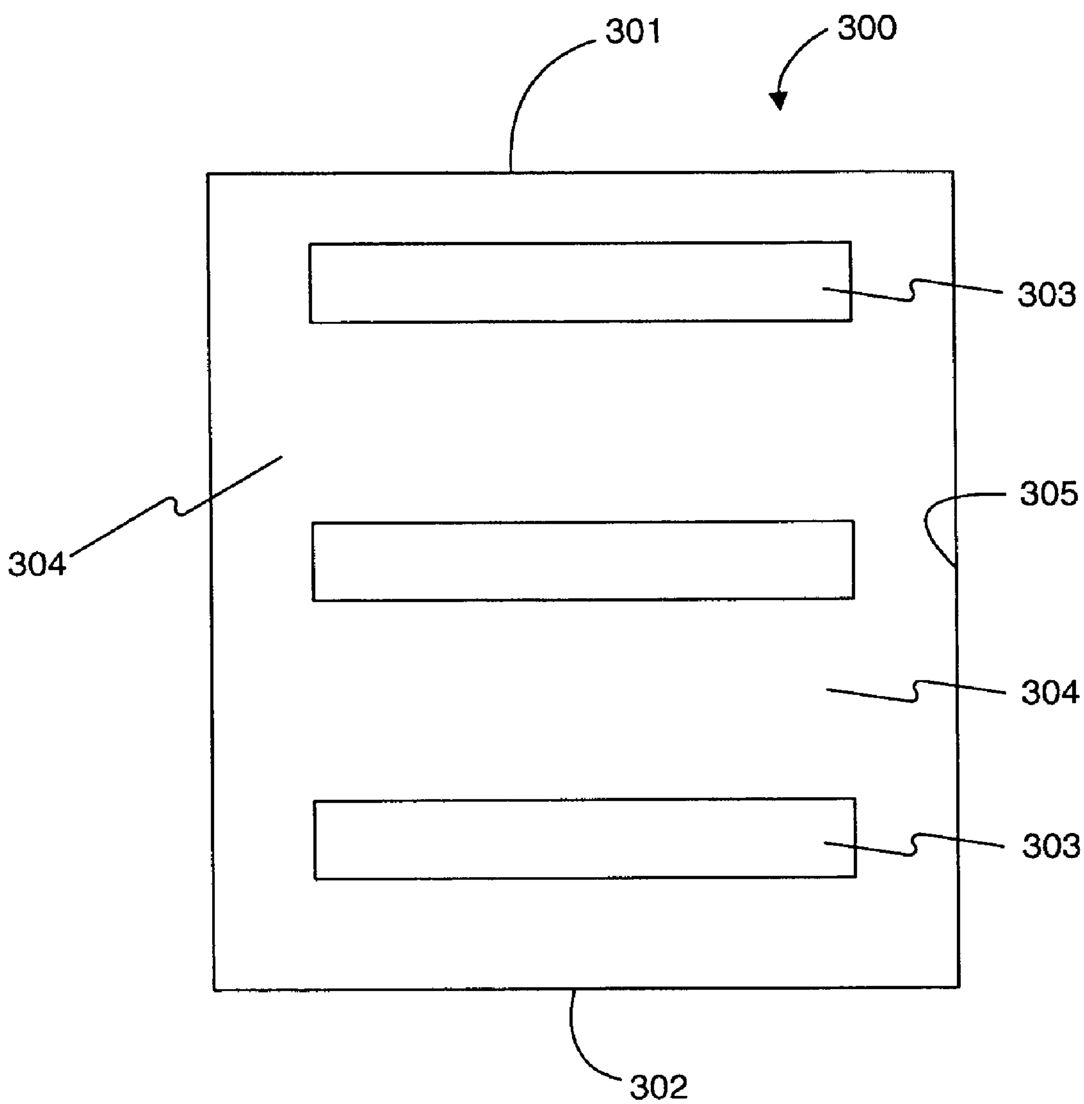


FIG. 3

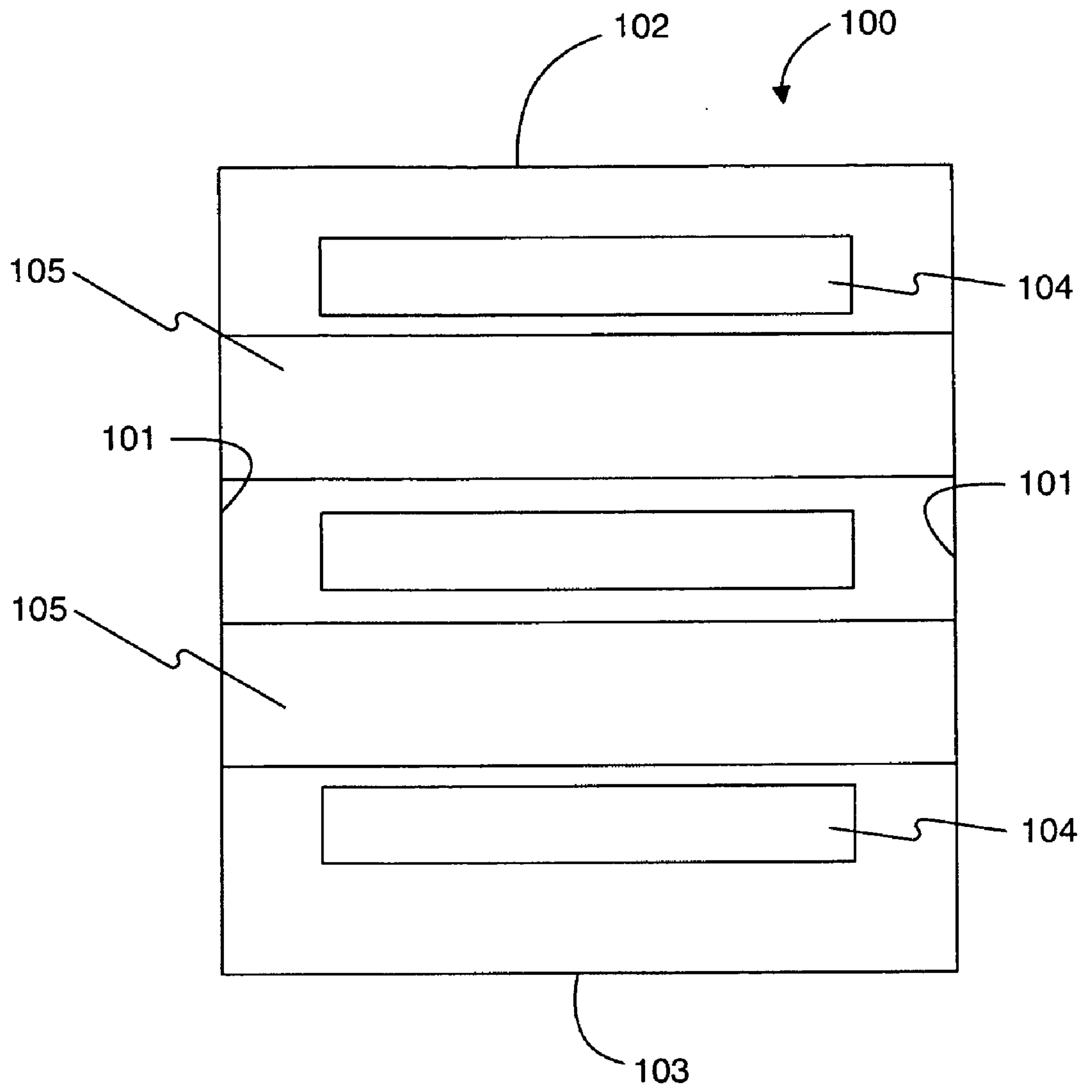


FIG. 4

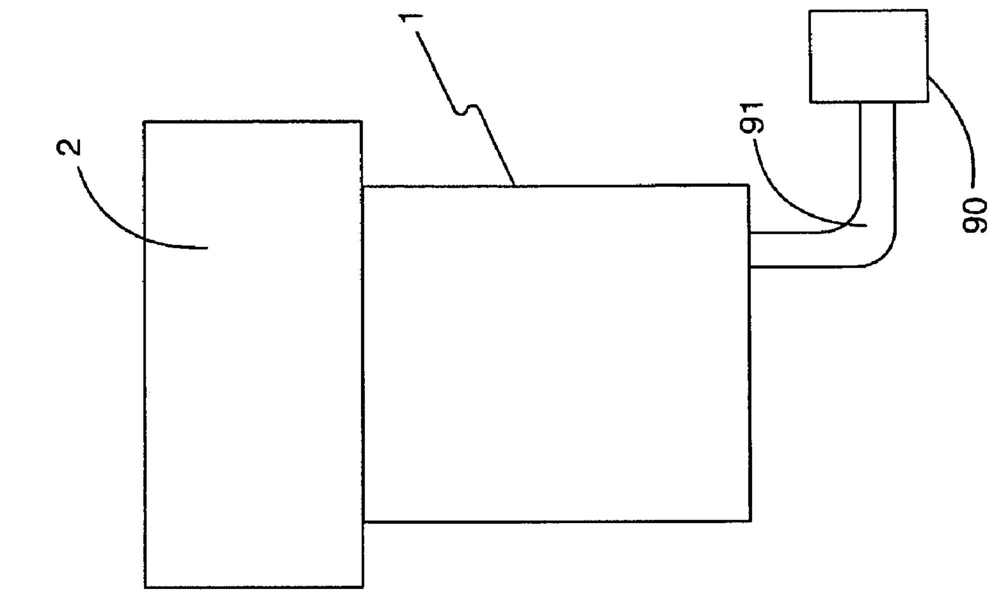


FIG. 6

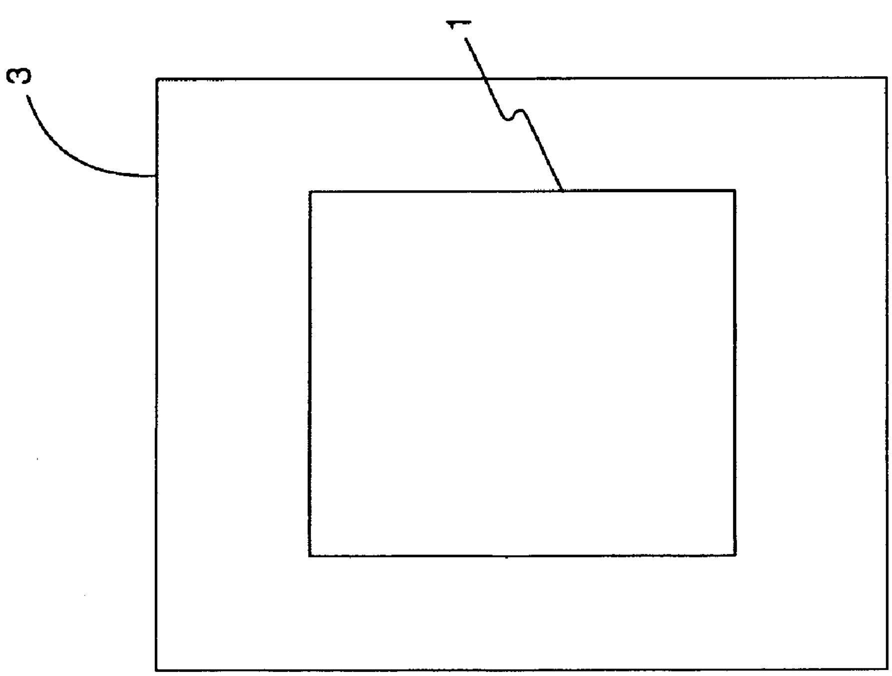


FIG. 5

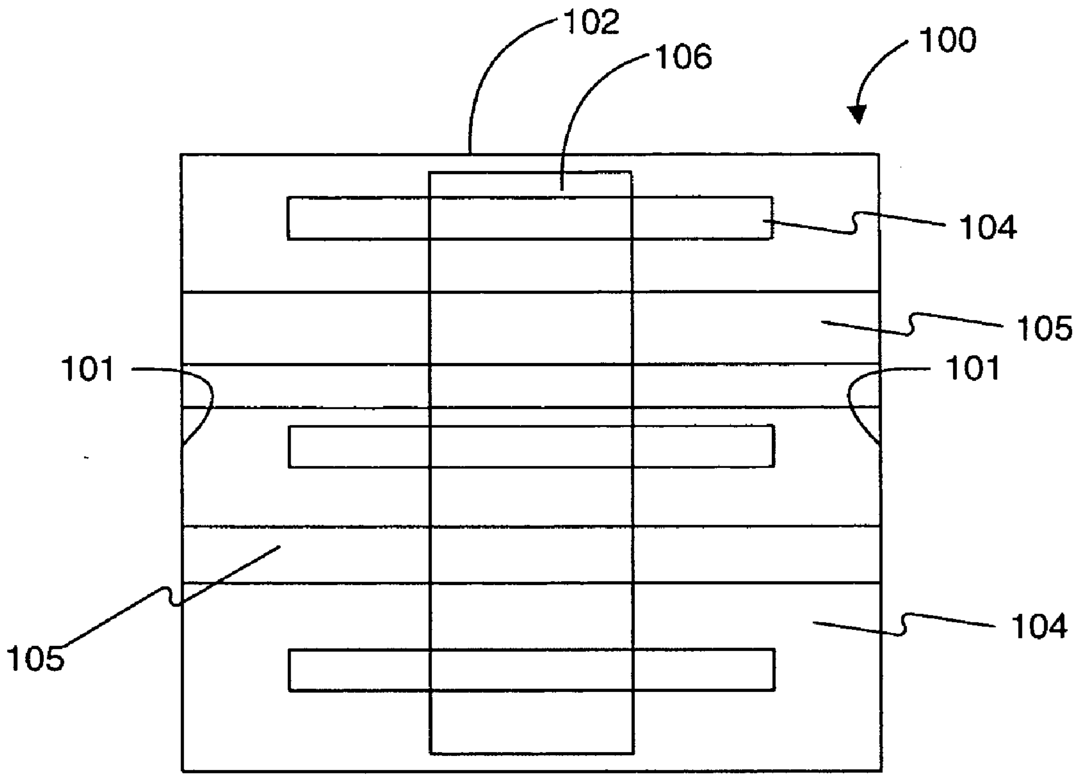


FIG. 7

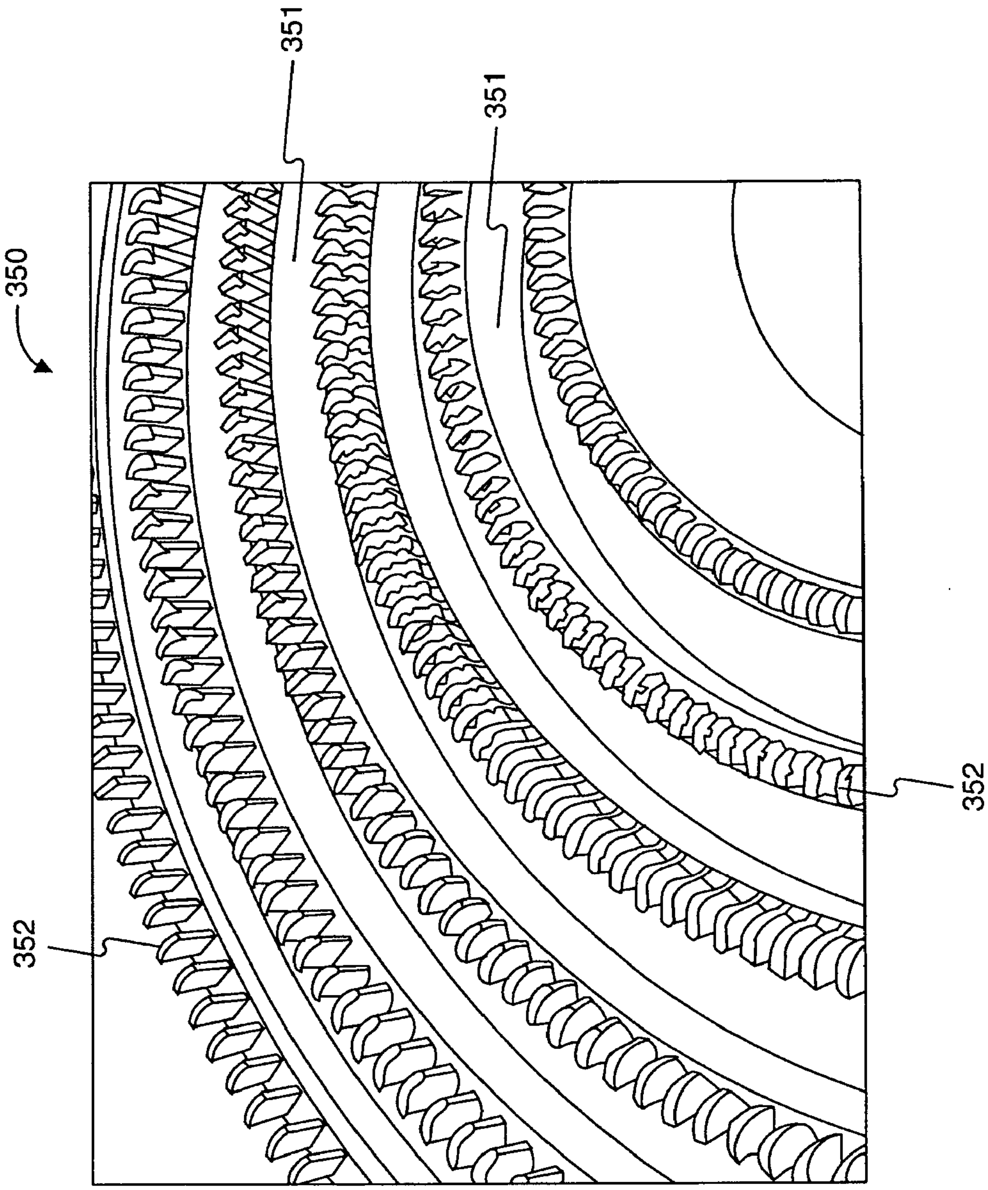


FIG. 8A

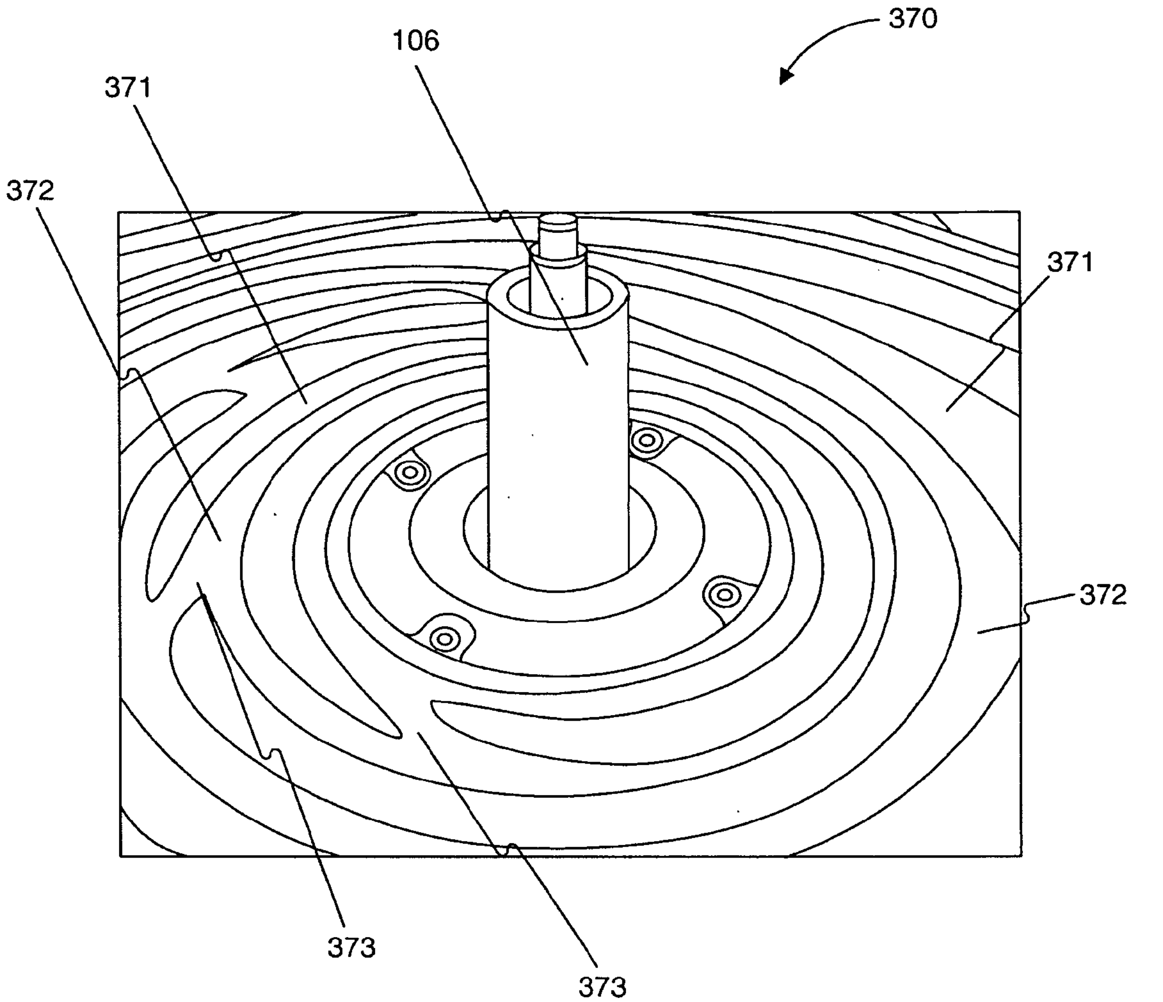


FIG. 8B

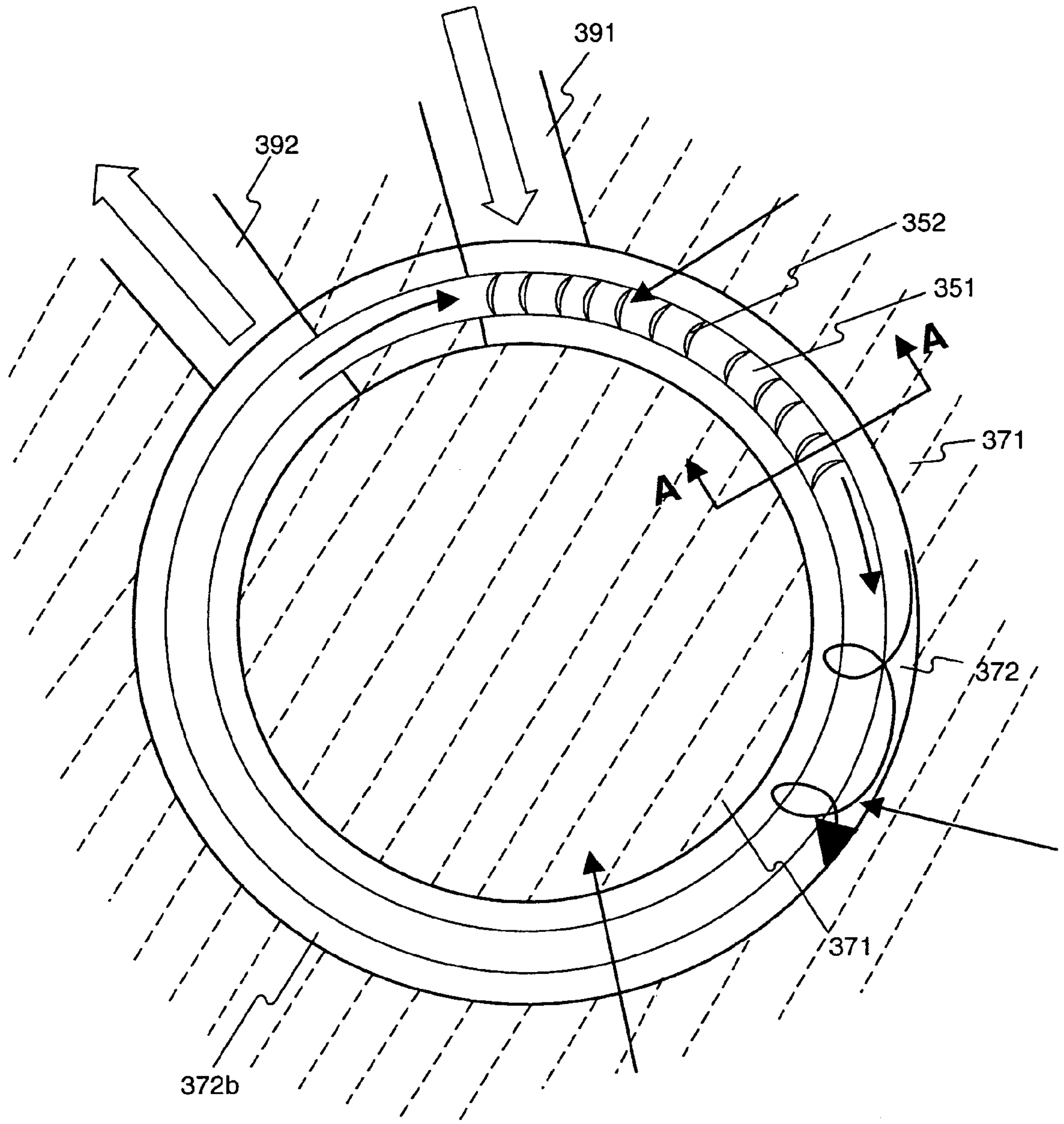


FIG. 8C

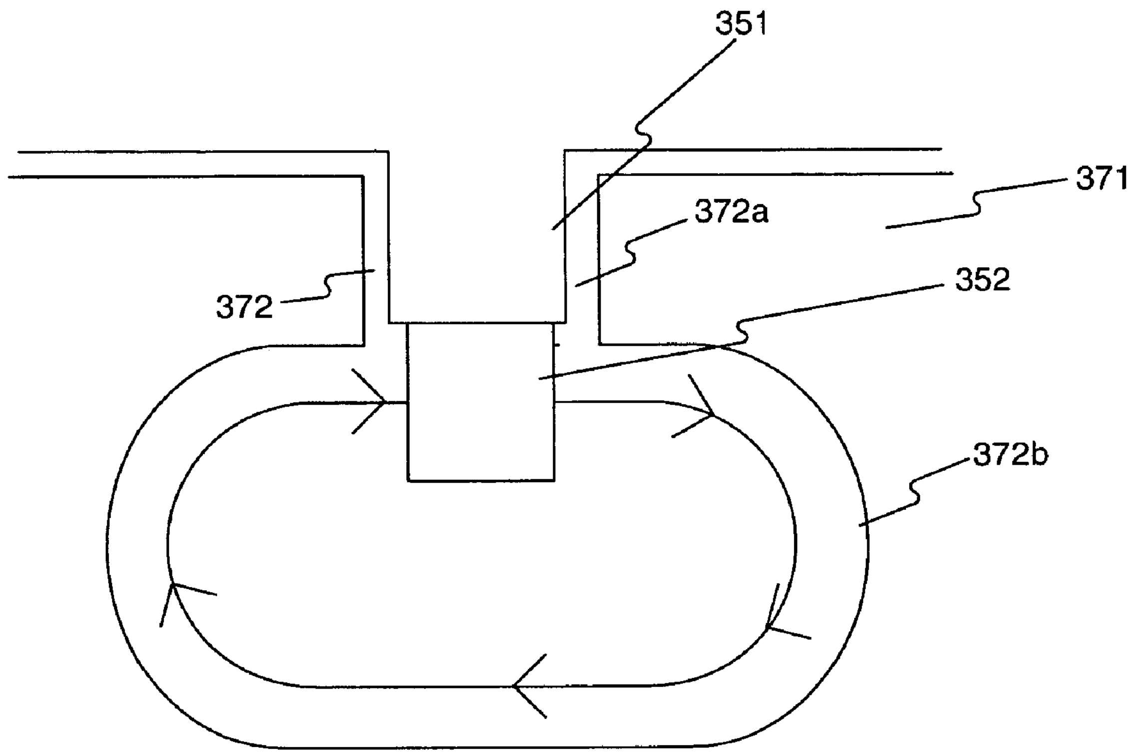


FIG. 8D

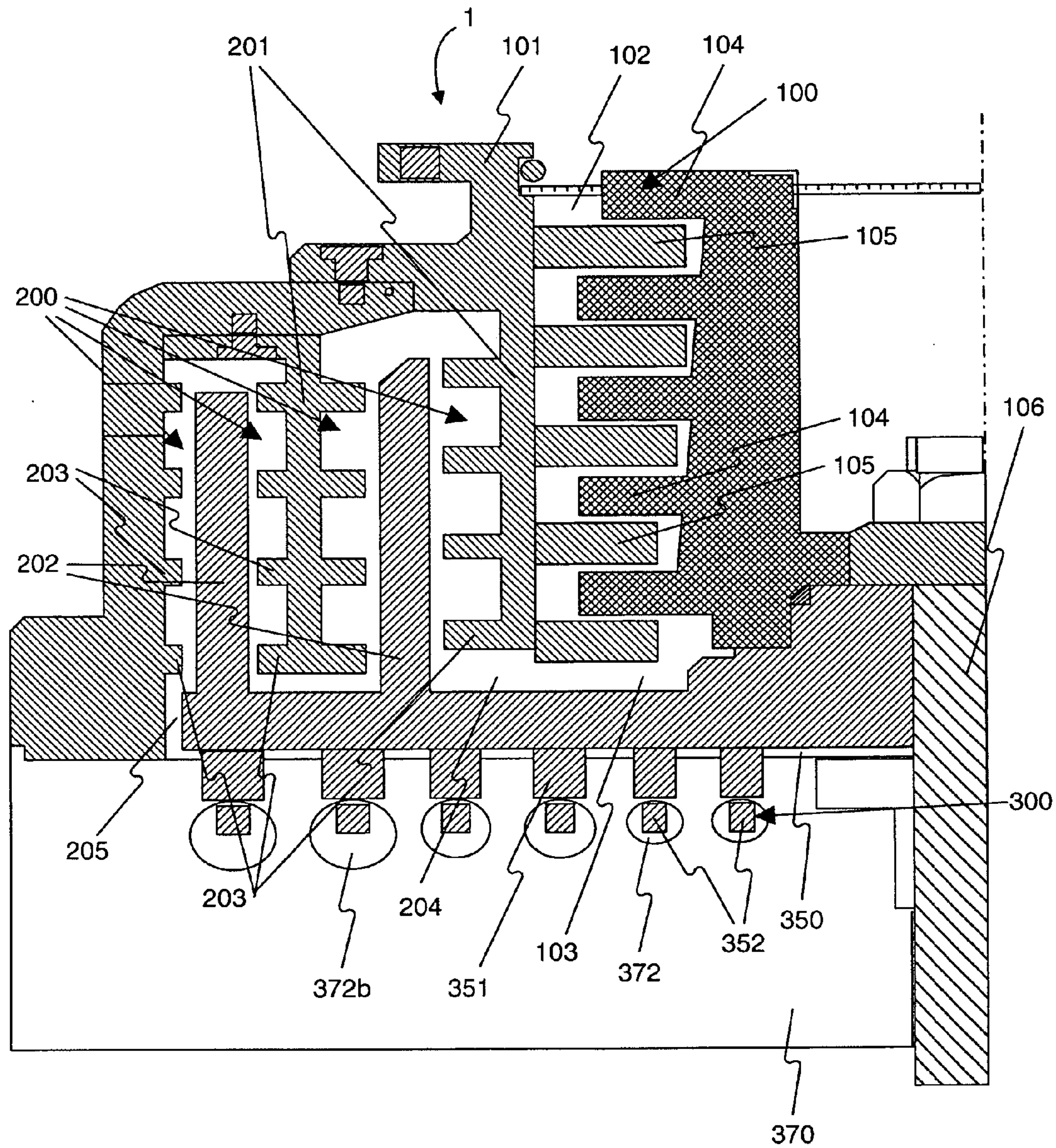

1
201
101
102
104
100
105
200
104
105
106
203
202
300
205
203
204
350
352
103
372
372b
351
370

FIG. 9

PUMP APPARATUS FOR SEMICONDUCTOR PROCESSING

FIELD OF THE INVENTION

[0001] 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

[0002] 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.

[0003] 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 finals step of extracting individual devices from the wafer and installing them in personal computers, telephones, mobile phones, or other electronic equipment.

[0004] 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.

[0005] 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.

[0006] 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.

[0007] 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 perflourocarbons, 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.

[0008] 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.

[0009] 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.

[0010] 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.

[0011] 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

[0012] 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.

[0013] One aspect, as embodied and broadly described herein, may relate to an apparatus for use in semiconductor processing.

[0014] 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.

[0015] 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.

[0016] 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.

[0017] 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.

[0018] 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

[0019] 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:

[0020] FIG. **1**A is a schematic view of an embodiment of an apparatus in accordance with the present invention;

[0021] FIG. **1**B is a schematic view of another embodiment of the apparatus;

[0022] FIG. **2** is a schematic view of a portion of the apparatus of FIG. **1**B;

[0023] FIG. **3** is a schematic view of a portion of the apparatus of FIG. **1**A;

[0024] FIG. **4** is a schematic view of a portion of the apparatus of FIG. **1**A;

[0025] FIG. **5** is a schematic view of a further embodiment of the apparatus disposed in a single room of a semiconductor processing facility;

[0026] FIG. **6** is a schematic view of still another embodiment of the apparatus associated with a semiconductor processing tool;

[0027] FIG. **7** is a schematic view of a portion of a still further embodiment of the apparatus;

[0028] FIGS. **8**A and **8**B are perspective views of portions of yet another embodiment of the apparatus;

[0029] FIGS. **8**C and **8**D are schematic views of the portions of FIGS. **8**A and **8**B; and

[0030] FIG. **9** is a schematic view of a yet further embodiment of the apparatus.

DESCRIPTION OF THE EMBODIMENTS

[0031] 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.

[0032] 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.

[0033] 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).

[0034] 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.

[0035] 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.

[0036] 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).

[0037] 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**.

[0038] 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**.

[0039] 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.

[0040] 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. Pat. Nos. 6,109,864 and 6,778,969, which are both incorporated herein by reference in their entirety.

[0041] 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.

[0042] 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.

[**0043**] 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.

[**0044**] 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. Pat. No. 5,772,395, which is incorporated herein by reference in its entirety.

[**0045**] 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.

[**0046**] 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.

[**0047**] 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. Pat. Nos. 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. Pat. Nos. 6,129,534, 6,200,116, 6,379,135, and 6,672,855, which are incorporated herein by reference in their entirety.

[**0048**] Dry stage **300** may have an alternate configuration, for example, as shown in FIGS. **8**A, **8**B, **8**C, **8**D, and **9**. In the alternate configuration, dry stage **300** may include a regenerative rotor **350** and a regenerative stator **370**.

[**0049**] As shown in FIGS. **8**A, 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. **8**D.

[**0050**] As shown in FIG. **8**B, 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. **8**D. Each channel **372** may include a first portion **372*a*** and a second portion **372*b***. First portion **372*a*** 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

372*b*. Second portion 372*b* may have any suitable cross-sectional shape to accommodate substance flow, for example, a curved or oval-like shape.

[0051] 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 372*a*, 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.

[0052] In operation, blade 352 may rotate relative to channel 372. A substance may enter second portion 372*b* 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 372*b* 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.

[0053] 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.

[0054] 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.

[0055] 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.

[0056] 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.

[0057] 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.

[0058] 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.

[0059] 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.

[0060] 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.

[0061] 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.

[0062] 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. **8**A, **8**B, **8**C, and **8**D, 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.

[0063] 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. An apparatus for use in semiconductor processing, comprising:

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.

2. The apparatus of claim 1, wherein the single pump is 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.

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

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

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

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

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

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

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

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

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

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

13. The apparatus of claim 12, wherein the at least one magnetic bearing is 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.

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

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

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

17. The apparatus of claim 16, wherein the at least one ball bearing is 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.

18. The apparatus of claim 16, wherein the at least one magnetic bearing is 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.

19. An apparatus for use in semiconductor processing, comprising:

a single pump configured to transition a substance flow from about molecular pressure to about atmospheric pressure.

20. An apparatus for use in semiconductor processing, comprising:

a single pump configured to transition a substance from turbomolecular flow to atmospheric flow.

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