SYSTEM FOR PROCESSING A WORKPIECE

DESCRIPTION

TECHNICAL FIELD

[0001] The invention relates to surface preparation, cleaning, rinsing and drying of workpieces, such as semiconductor wafers, flat panel displays, rigid disk or optical media, thin film heads or other workpieces formed from a substrate on which microelectronic circuits, data storage elements or layers, or micro-mechanical elements may be formed. These and similar articles are collectively referred to herein as a "wafer" or "workpiece." Specifically, the present invention relates to a workpiece processor and system for treating semiconductor workpieces.

BACKGROUND OF THE INVENTION

[0002] The semiconductor manufacturing industry is constantly seeking to improve the processes and machines used to manufacture microelectronic circuits and components, such as the manufacture of integrated circuits from wafers. The objectives of many of these improved processes and machines include: decreasing the amount of time required to process a wafer to form the desired integrated circuits; increasing the yield of usable integrated circuits per wafer by, for example, decreasing contamination of the wafer during processing; reducing the number of steps required to create the desired integrated circuits; improving the uniformity and efficiency of processes used to create the desired integrated circuits; and reducing the costs of manufacture.

[0003] As the semiconductor industry advances particle "adder" specifications, the number and size of the permitted particulate contamination in the manufacture of semiconductor wafers is continuously being reduced. Existing machines are not sufficient for future particle specifications.

[0004] Further, in the processing of wafers, it is often necessary to subject one or more sides of the wafer to a fluid in liquid, vapor or gaseous form. Such fluids are used to, for example, etch the wafer surface, clean the wafer surface, dry the wafer surface, passivate the wafer surface, deposit films on the wafer surface, remove films or masking materials from the wafer surface, etc. Controlling how the processing fluids are applied to the wafer surfaces,

reducing the potential for cross contamination of the processing fluids, and effectively cleaning or rinsing process fluids from process chamber surfaces are often important to the success of the processing operations.

SUMMARY OF THE INVENTION

[0005] A new wafer processing system has been invented that provides significant improvements in manufacturing microelectronic and similar devices. The new system reduces particle contamination. As a result there are fewer defects in the end products. This reduces the total amount of raw materials, process fluids, time, labor and effort required to manufacture microelectronic devices. Accordingly, the new wafer processing system of the present invention significantly increases manufacturing yields.

[0006] A unique workpiece processor design has been invented that significantly reduces cross contamination of process fluids. The unique design also greatly increases the ability to exhaust vapor or fumes and drain process fluids from the process chamber during processing of a semiconductor wafer. Further, the processor of the present invention utilizes a relatively simple, magnetic rotor engagement mechanism that reduces variability of vibration affects caused by variations in manufacturing techniques from one processor to another. As a result of these design improvements, the effects of wafer processing is more consistent from one workpiece processor to the next, and high manufacturing quality standards and increased efficiencies are achieved.

[0007] In one embodiment, the wafer processing system of the present invention provides a plurality of workpiece stations for plating, etching, cleaning, passivating, depositing and/or removing films and masking materials from a workpiece surface. The system includes a robot, which is moveable between the workpiece stations and moves the workpiece from one station to another. At least one of the workpiece stations includes a workpiece processor having an upper rotor and a lower rotor engageable to form a workpiece process chamber. A magnetic force between repulsing magnets is utilized to maintain contact between the rotors during operation of the processor. This unique process chamber design reduces vibrations, which have been found to be a major contributor to particulate contamination, and also reduces the chances of process fluids leaking onto the surface of processed wafers, which can result in defects or failure of the microelectronic end products. In one embodiment, the upper rotor is magnetically driven into contact with the lower rotor. In another embodiment, the

lower rotor is magnetically driven into contact with the upper rotor. In either embodiment preferably a face seal is provided between the upper and lower rotors.

[0008] The wafer processing system of the present invention has also been designed to increase air flow through the workpiece processor during processing. Better air flow management reduces particle contamination and increases overall processing efficiency. As a result, less time, materials and energy is consumed. Particularly, the processor of the present invention has air flow passageways in the process head, which draws ambient air from the mini-environment surrounding the processor, into the process head, and out through the bottom of the processor. Further, annular channels formed in the base and the upper rim of the base relieve pressure build up in the process chamber. During operation, openings in the upper rim of the base receive "blow-by" fluids. The annular channels bleed the "blow-by" fluids off to an exhaust port, relieving pressure build up. Moreover, an air aspirator is connected to an annulus positioned below the motor in the process head. The aspirator sucks any gaseous fluids that may come from the air flow passageways in the process head or the annular channels in the base. Additionally, a central opening in the process head and upper rotor, and a process fluid nozzle in the base which extends upwardly through an opening in the lower rotor and is connected to a snorkel permits air to be drawn directly into the workpiece processor during operation. As a result of these design improvements, air flow in the process chamber is greatly enhanced, and more uniform processing and increased efficiencies are achieved.

[0009] In another embodiment, the new processing system of the present invention includes a first rotor having a plurality of alignment pins, and a second rotor having one or more openings for receiving the alignment pins to form a workpiece processing chamber with the first rotor. This rotor design keeps the first rotor centered on the lower rotor, and also keeps a workpiece centered within the processing chamber. This improves the manufacturing yield or efficiency of the system, by reducing defects in the microelectronic or other end products, and by increasing the number of device chips produced per wafer.

[0010] Another separate feature of one embodiment of the new system is that it includes a workpiece processor having a substantially annular opening around an outer periphery of a fluid applicator in the first rotor. The fluid applicator is positioned to deliver a processing fluid to a central region of a workpiece in the processing chamber. A purge gas line is positioned for delivering a purge gas into the annular opening toward the workpiece. This

provides for more uniform delivery of purge gas into, and dispersion throughout, the processing chamber. As a result, processing fluids are more efficiently removed from the processing chamber. Consequently, manufacturing is more consistent, and workpiece defects are reduced.

[0011] In another separate feature of the invention, a new system includes a fluid applicator in the second rotor for delivering a processing fluid to an edge of a workpiece located in the processing chamber. One or more drain openings are preferably located in the first rotor for removing the processing fluid from the processing chamber. Purge gas is advantageously delivered across the upper surface of the workpiece. In one embodiment, a shield plate is located above the fluid applicator for directing the processing fluid to the edge of the workpiece. In a separate embodiment, a fluid delivery path extends from the fluid applicator and terminates at the edge of the workpiece for delivering the processing fluid directly to the edge of the workpiece. These designs provide for improved edge processing of the workpiece, as well as for improved particle removal from the processing chamber. Accordingly, edge particle deposition on the workpiece is substantially reduced or eliminated.

[0012] One feature of the invention is a new system that includes an upper rotor that is engageable with a lower rotor to form a workpiece processing chamber. The upper rotor has a central air inlet opening. This rotor design provides an air flow path through the processing chamber which tends to avoid having contaminant particles contact the workpiece. This improves the manufacturing yield or efficiency of the system, by reducing defects in the microelectronic or other end products.

[0013] Another separate feature of the invention is a fluid applicator or nozzle moveable within the central air inlet opening for distributing a processing fluid to different portions of the workpiece in the processing chamber. A fluid delivery line leading into the nozzle preferably includes a collection section for collecting processing fluid when fluid delivery to the nozzle is discontinued. This prevents excess processing fluid from dripping onto the workpiece. Consequently, manufacturing is more consistent, and defects are reduced. The nozzle is preferably moveable away from the upper rotor member so that the upper rotor member may be raised to facilitate loading of a workpiece into the processing chamber.

[0014] Another separate feature of the invention is a moveable drain assembly having multiple drain paths. Each drain path is separately alignable with the processing chamber by

moving the drain assembly to align a single drain path with the processing chamber. As a result, used liquid process chemical can be separately removed, collected, and either recycled or processed for disposal. Mixing of used liquid process chemicals is avoided. Processing is therefore less complex and less costly.

[0015] Other features and advantages of the invention will appear hereinafter. The features of the invention described above can be used separately or together, or in various combinations of one or more of them, with no single feature essential to the invention. The invention resides as well in sub-combinations of the features described. The process chamber can be used alone, or in a system with robotic automation and various other process chambers.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] FIG. 1 is a perspective view of a workpiece processing system according to the present invention.

[0017] FIG. 2 is a top plan view of the workpiece processing system shown in FIG. 1, with components removed for purpose of illustration.

[0018] FIG. 3 is a perspective view of a workpiece processor according to one embodiment of the present invention.

[0019] FIG. 4 is a top view of the workpiece process chamber shown in FIG. 3.

[0020] FIG. 5 is a cross-sectional view of the workpiece processor shown in FIG. 4 taken along dashed line A-A.

[0021] FIG. 6 is a cross-sectional view of the workpiece processor shown in FIG. 4 taken along dashed line B-B.

[0022] FIG. 7 is a cross-sectional view of the workpiece processor shown in FIG. 4 taken along dashed line C-C.

[0023] FIG 7A is an enlarged partial view of the area of the processor designated A in FIG 7.

[0024] FIG. 8 is a perspective view of a process head assembly according to the present invention.

[0025] FIG. 9 is a top view of the process head assembly shown in FIG. 8

[0026] FIG. 10 is a cross-sectional view of the process head assembly shown in FIG. 9 taken along dashed line A-A.

[0027] FIG. 11 is a perspective view of a bottom portion of a process head assembly according to the present invention.

[0028] FIG. 12 is a perspective view of a top portion of a base assembly according to the present invention.

[0029] FIG. 13 is a top view of the base assembly shown in FIG. 12.

[0030] FIG. 14 is a cross-sectional view of the base assembly shown in FIG. 13 taken along dashed line A-A.

[0031] FIG. 15 is a cross-sectional view of the base assembly shown in FIG. 13 taken along dashed line B-B.

[0032] FIG. 16 is a cross-sectional view of the base assembly shown in FIG. 13 taken along dashed line C-C.

[0033] FIG. 17A is a top perspective view of an upper rotor according to one embodiment of the present invention.

[0034] FIG. 17B is a cross-sectional view of the upper rotor illustrated in FIG. 17A.

[0035] FIG. 17C is a bottom perspective view of the upper rotor illustrated in FIGS. 17A and 17B.

[0036] FIG. 18A is a top perspective view of a lower rotor according to one embodiment of the present invention.

[0037] FIG. 18B is a cross-sectional view of the lower rotor illustrated in FIG. 18A.

[0038] FIG. 18C is a bottom perspective view of the lower rotor illustrated in FIGS. 18A and 18B.

[0039] FIG. 19A is a top perspective view of an upper rotor according to another embodiment of the present invention.

[0040] FIG. 19B is a cross-sectional view of the upper rotor illustrated in FIG. 19A.

[0041] FIG. 19C is a bottom perspective view of the upper rotor illustrated in FIGS. 19A and 19B.

[0042] FIG. 20A is a top perspective view of a lower rotor according to another embodiment of the present invention.

[0043] FIG. 20B is a cross-sectional view of the lower rotor illustrated in FIG. 20A.

[0044] FIG. 20C is a bottom perspective view of the lower rotor illustrated in FIGS. 20A and 20B.

[0045] FIG. 21A is a top perspective view of a head ring of a process head assembly according to the present invention.

[0046] FIG. 21B is a cross-sectional view of the head ring illustrated in FIG. 21A.

[0047] FIG. 21C is an enlarged partial view of the area of the head ring designated A in FIG. 21B.

[0048] FIG. 22 is a perspective cutaway view of one of the processors shown in FIG. 2 according to one embodiment of the present invention.

[0049] FIG. 23 is a section view of the processor of FIG. 22.

[0050] FIG. 24 is an enlarged partial section view of the processor of FIG. 22.

[0051] FIG. 25 is an exploded perspective view of the processor of FIG. 22.

[0052] FIG. 26 is a section view taken along line a-a of FIG. 25.

[0053] FIG. 27 is a section view taken along line b-b of FIG. 25.

[0054] FIG. 28 is a section view taken along line a-a of FIG. 25, and showing only the upper rotor, for purpose of illustration.

[0055] FIG. 29 is a section view taken along line b-b of FIG. 25 and showing only the upper rotor, for purpose of illustration.

[0056] FIG. 30 is top perspective view of the lower rotor of the processor of FIG. 22.

[0057] FIG. 31 is bottom perspective view of the lower rotor of FIG. 30.

[0058] FIG. 32 is a section view of the lower rotor of FIGS 30 and 31.

[0059] FIG. 33 is an enlarged partial section view of the upper rotor engaged with lower rotor, in the processor of FIG. 22, and showing a workpiece alignment pin.

[0060] FIG. 34 is an enlarged partial section view of the upper rotor engaged with the lower rotor of the processor of FIG. 22, and showing an upper workpiece support pin.

[0061] FIG. 35 is a section view of the head of the processor shown in FIG. 22, with the upper rotor removed for purpose of illustration.

[0062] FIG. 36 is an enlarged section view of the purge gas manifold in the head shown in FIG. 35.

[0063] FIG. 37 is a partial section view of an alternative embodiment processor having a shield plate for directing a processing fluid to the edge of a workpiece in the processing chamber.

[0064] FIG. 38 is a partial section view of a processor having a fluid delivery path for delivering a processing fluid directly to the edge of a workpiece in the processing chamber.

[0065] FIG. 39 is a section view of a base of an alternative processor having a lower rotor air inlet.

[0066] FIG. 40 is a perspective view of the inside of the upper rotor shown in FIG. 25.

[0067] FIG. 41 is a perspective view of a processor shown in FIG. 2 according to one embodiment of the present invention in a load/unload position.

[0068] FIG. 42 is a section view of the processor of FIG. 41.

[0069] FIG. 43 is a section view of the processor of FIG. 41 with a moveable fluid delivery tube directed into the processing chamber.

[0070] FIG. 44 is a perspective view of the processor of FIG. 41 shown in a processing position.

[0071] FIG. 45 is a section view of the processor of FIG. 44.

[0072] FIG. 46 is a cross-section view of the processor of FIG. 44 with a moveable fluid delivery tube directed into the processing chamber.

[0073] FIG. 47 is a cross-sectional view of a fluid delivery line having a fluid collection area.

[0074] FIG. 48 is a perspective view of a nozzle or liquid supply outlet having a fluid collection area.

DETAILED DESCRIPTION

Description With Reference To FIGS. 1-3

[0075] As shown in FIGS. 1-3, a processing system 10 has an enclosure 15, a control/display 17, and an input/output station 19 and a plurality of processing stations 14. Workpieces 24 are removed from carriers 21 at the input/output station 19 and processed within the system 10.

[0076] The processing system 10 includes a support structure for a plurality of processing stations 14 within the enclosure 15. At least one processing station 14 includes a workpiece processor 16 and an actuator 13 for opening and closing processor 16. The processor 16 of the present invention is designed to be utilized in a processing system 10, for example, as disclosed in pending U.S Patent Application Serial Nos. 60/476,786, filed June 6, 2003, 10/691,688, filed October 22, 2003 and 10/690,864, filed October 21, 2003. These U.S. patent applications are incorporated herein by reference. System 10 may include only a plurality of processors 16 or it may include other processing modules, in addition to one or

more processors 16, such as could be configured to perform a variety of functions including but not limited to electrochemical processing, etching, rinsing, and/or drying.

[0077] The system 10 in FIG. 2 is shown having ten process stations 14, but any desired number of processing stations 14 may be included in the enclosure 15. The processing station support preferably includes a centrally located, longitudinally oriented platform 18 between the processing stations 14. One or more robots 26 having one or more end-effectors 31 move within the enclosure 15 for delivering workpieces 24 to and from various processing stations 14, and to load and unload workpieces 24 into and out of the process stations 14. In a preferred embodiment, the robot 26 moves linearly along a track 23 in the space 18. A process fluid source and associated fluid supply conduits may be provided within enclosure 15 below the platform 18 in fluid communication with a workpiece processor 16 (shown in FIG. 3) and other processing stations 14.

Description With Reference To FIGS. 3-21

[0078] FIGS. 3-11 illustrate a workpiece processor 16 according to the present invention. The processor 16 comprises a process head assembly 28 and a base assembly 30. The head assembly 28 is comprised of a process head 29, a head ring 33, an upper rotor 34, a fluid applicator 32 and a motor 38. The base assembly 30 is comprised of a mounting base 40, a lower rotor 36 and a bowl mount 43. The head assembly 28 can be moved vertically to engage with and separate from the base assembly 30. The head assembly 28 and the base assembly 30 form a process chamber 37 within which the upper 34 and lower 36 rotors are positioned.

[0079] Turning specifically to FIGS. 5-11, a process fluid applicator 32 extends upwardly from a central portion of the head assembly 28 and extends downwardly through a sleeve 96 into the head assembly. Air inlet 140 and process fluid inlets 92, 94 are positioned within the sleeve 96. The air inlet 140 and the process fluid applicator 32 run downwardly through central openings in the process head 29, the head ring 33 and the upper rotor 34. Process fluid supply lines (not shown) are connected to the upwardly extending portion of the process fluid applicator 32 for delivering process fluids into the workpiece process chamber. The motor 38 is positioned in the head 29 and is coupled to the upper rotor 34. During operation, the motor 38 spins the upper rotor 34. The head ring 33 mounts the upper rotor 34 and the motor 38 within the head 29. An automated actuator 13 is attached to the head assembly 28 and moves the process head assembly 28 from an open position, where a workpiece may be

loaded into and removed from the process chamber 37 by robot 26, to a closed position where the workpiece will be processed. As will be explained more fully below, the head assembly 28 has a plurality of air inlets and passageways that contribute to the improved air flow management of the present invention.

[0080] The base assembly 30 lower rotor 36 has an engagement ring 110 with three tabs 114 which cooperate with a slotted mounting member 144 positioned at the bottom of the base 40 to attach the lower rotor 36 to the base 40. The tabs 114 of the engagement ring 110 cooperate with the slots of the mounting member 144 to create a bayonet connection. Positioned within the base 40 is at least a first annular magnet 42. The lower rotor 36 also includes at least one second magnet 44. It should be understood, that instead of using single annular magnets in the base 40 and lower rotor 36 a plurality of non-annular magnets may also be used. The first 42 and second 44 magnets are adjacent to one another and have a like polarity. By utilizing magnets having a like magnetic field or polarity, the first 42 and second 44 magnets repel one another, causing the lower rotor 36 to be forced upwards from the base 40 by a magnetic force. When the head and base assemblies 28 and 30 are separated, the magnetic force of the magnets 42, 44 pushes the lower rotor 36 away from base 40 causing the tabs 114 of the engagement ring 110 to firmly engage the mounting member 144 of the base, thus providing the desired bayonet connection.

[0081] When the head and base assemblies are to be engaged, the actuator 13 lowers the head assembly 28 until the upper rotor 34 contacts the lower rotor 36. Upon further force from the actuator 13, the upper rotor 34 pushes down on the lower rotor 36 and against the repulsion force created by the magnets 42, 44 until the head ring 33 seats on the base as shown in FIG 7A at 33A. When the head ring 33 seats on the base, the contact between the tabs 114 of the engagement ring 110 and the mounting member 144 is broken, and the lower rotor 36 is free to spin with the upper rotor 34. With the head ring 33 and base 40 in the positions shown in FIGS 5-7A, with the lower rotor free to spin with the upper rotor, the repulsion force created by the magnets 42,44 maintains the contact between the upper and lower rotors until the head assembly is raised for loading/unloading the processor.

[0082] Turning to FIGS. 5-7 and 12-16, the base 40 includes an annular plenum 80 which has several (e.g., four) drains 82. The drains 82 are pneumatically actuated via a poppet valve 84 and actuator 86. Each drain 82 is provided with a fitting connector 88 to provide separate paths for conducting processing liquids of different types to appropriate systems (not

shown) for storage, disposal, or recirculation. Accordingly, cross contamination of process fluids is minimized. As best shown in FIGS. 5-7, 18A-C and 20A-C, the lower rotor 36 has a skirt 48, which extends downwardly into annular plenum 80 and encourages process fluids to flow into annular plenum 80 and through the drains 82.

[0083] Still referring to FIGS. 5-7, 18A-C and 20A-C, the lower rotor 36 has a plurality of pins extending upwardly from its surface. First, the lower rotor 36 includes a plurality of stand-off pins 50. When the workpiece 24 is loaded into the process chamber 37, the workpiece 24 initially sits on the stand-off pins 50. The lower rotor 36 also includes a plurality of alignment pins 52, which align and center the workpiece 24 in the x-y plane when the workpiece 24 is loaded into the process chamber 37. The alignment pins 52 extend farther away from the surface 150 of the lower rotor 36 than the stand-off pins 50 do, preventing the workpiece 24 from being misaligned in the process chamber 16. Finally, the lower rotor 36 includes at least one, and preferably a plurality of engagement pins 54. The engagement pins 54 preferably having a beveled end to enhance coupling with the upper rotor 34 (as explained below) and an annular gasket or O-ring 56 formed from a compressible material to create a flexible contact with the upper rotor 34.

[0084] Turning to FIGS. 5-7, 17A-C and 19A-C, the upper rotor 34 includes a plurality of stand-off pins 120 and countersunk bores 46. During operation, and best shown in FIGS. 5-7, the workpiece 24 (not shown) is contained between the stand-off pins 120 of the upper rotor 34 and the stand-off pins 50 of the lower rotor 36. Workpiece process chamber 37 is formed between the inner surface 148 of the upper rotor 34 and an inner surface 150 of the lower rotor 36. The stand-off pins 50, 120 do not clamp the workpiece 24 between them, but instead contain the workpiece within a desired clearance, allowing the workpiece 24 to slightly "clock," i.e., float within the desired clearance, during processing. This prevents the workpiece 24 from being pinched and accidentally damaged and allows a greater surface area of the workpiece 24 to be treated. In a preferred embodiment, there is a 0.02 inch clearance between stand-off pins 50, 120, which permits the workpiece 24 to be "clocked" during processing. This arrangement allows substantially the entire surface of the workpiece 24 to be treated, even the surface area which would otherwise be covered by the stand-off pins 50, 120.

[0085] Referring specifically to FIG. 5, as the upper rotor 34 engages the lower rotor 36, the beveled end of the engagement pins 54 are inserted into a corresponding one of the

plurality of bores 46 (shown in FIG. 17C) in the upper rotor 34. The annular, compressible gasket or O-ring 56 enhances contact between the upper rotor 34 and the lower rotor 36 and acts as a vibration dampener when the process chamber 16 is in use.

[0086] While the general configuration of the upper 34 and lower 36 rotors is as described above, the specific configuration may vary depending on the desired process to be carried out in the process chamber 16. For example, FIGS. 17A-C and 18A-C show the upper 34 and lower 36 rotors utilized in a process for removing polymer or a masking material from a wafer surface. In this preferred embodiment, the rotor configurations conform to the general description provided above. As shown in FIGS. 17A-C, however, the upper rotor 34 is segmented or provided with notches 160 to allow process fluids to more freely exit the process chamber 37.

[0087] However, it may be preferred to employ slight variations to the rotor configurations described above for a different process. For example, the rotor configurations for a process commonly known as "backside bevel etch" are disclosed in FIGS. 19A-C and 20A-C. Generally, in a "backside bevel etch" process, a chemical solution (e.g., hydrofluoric acid) is provided to etch, or selectively remove, metal or oxide layers from the backside and/or peripheral edge, i.e., the bevel edge, of the wafer. During this process, while the backside and bevel are being supplied with the chemical solution, the top side of the wafer is being supplied with an inert gas or deionized water rinse, or an alternate processing solution. After etching, the etched side and preferably both sides of the wafer are supplied with deionized water rinse, spun to remove fluids, and dried with heated nitrogen. A detailed explanation of semiconductor etching processes, including the "backside bevel etch" process is disclosed in U.S. Patent No. 6,632,292, assigned to the assignee of the present invention, and incorporated herein by reference.

[0088] In a preferred embodiment, the upper rotor 34 utilized for a "backside bevel etch" process is disclosed in FIGS. 19A-C. The upper rotor 34 includes a process fluid passageway 108 that communicates with an annulus 146 formed in the inner surface 148 of the upper rotor 34. Turning to FIGS. 20A-C, the lower rotor 36 preferred for use in the "backside bevel etch" process includes a sealing member 118 that runs circumferentially around the outer perimeter of the lower rotor 36. Preferably, the sealing member 118 is formed from a compressible material. When the upper 34 and lower 36 rotors are engaged, the sealing member 118 deforms and creates a contact face seal between the rotors. The contact face

seal is not a complete seal. That is, even with the contact face seal, "leaks" are provided to allow draining of the process chamber 37. The magnetic force from magnets 42, 44 keep the lower rotor 36 and upper rotor 34 engaged and the contact seal in place during processing. During the "backside bevel etch" process, the acidic process fluid applied to the backside of the wafer wraps around the periphery or bevel edge of the wafer onto a portion of the top side of the wafer. As a result, the acidic process fluid is forced into the annulus 146 formed in the inner surface 148 of the upper rotor 34 by the inert gas being applied to the top side of the wafer, and is vented out through the process fluid passageway 108 in the upper rotor 34.

[0089] Turning to FIGS. 21A-C, and as shown in FIG. 7A, the head ring 33 includes a rim 162 and a vertical cylindrical alignment surface 164. When the head assembly 28 and base assembly 30 are closed, the vertical cylindrical alignment surface 164 aligns the head ring 33 with the base 40 and rim 162 rests on the rim of the base 40 to ensure proper alignment between the upper 34 and lower 36 rotors.

[0090] The improved air flow and process fluid drainage aspects of the new wafer processing system illustrated in FIGS. 1-21 will now be discussed.

[0091] First, the head assembly 28 has a multitude of air flow passageways which draw ambient air from the fab environment into the head assembly 28 and out through the base 40 of the process chamber 16. As shown in FIG. 6, an annulus 136 is positioned in the head 29 just below the motor 38. The annulus 136 is connected to an air aspirator (not shown), which sucks gaseous vapors or particles from the motor 38 out of the head 29. An aspirator tube (not shown) exits the head 29 via a service conduit attached to support 130. The negative pressure created by the aspirator 132 also acts to remove any gaseous vapors or fumes that may come from other air passageways in the head assembly 28 or the base 40.

[0092] Second, turning to FIGS. 5-7 and 21A-C, a plurality of vents holes 60 are formed in the head ring 33. As specifically shown in FIGS. 21A-C, the vent holes 60 draw air from the mini-environment within enclosure 15 through air channels 124 into an inner volume or air gap 134 formed by the slanting outer surface of the upper rotor 34 and the head ring 33. The inner air gap 134 communicates with a channel 137 that wraps around the periphery of both the upper rotor 34 and the lower rotor 36, and continues down into the annular drain cavity 80 formed in the recess of the base 40. Eventually, process fluid vapors are vented out through the exhaust ports 82 formed in the annular drain cavity 80.

[0093] Third, the process chamber 16 of the present invention is also designed to relieve inherent pressure build up experienced by carrying out operations in a closed process chamber 16. Referring to FIGS. 12-14, a plurality of openings 71 are formed in the upper rim 73 of the base 40. The openings 71 are connected to exhaust channels 142 formed in a lower portion of base 40. A pump or the like (not shown) is connected to the exhaust channels 142 via at least one, and preferably two, exhaust ports 72, creating a negative pressure and a path for exhausting process fluids through the channels 142 (represented by the dashed lines in FIG. 14). Turning now to FIG. 5, when the head assembly 28 is lowered and engages the base 40, an annular plenum 70 formed in the head ring 33 covers the upper rim 73 of the base 40. The annular plenum 70 in the head ring 33 permits the openings 71 in the upper rim 73 to receive "blow-by" of process fluids during operation. These "blow-by" process fluids are bled off by the negative pressure in the exhaust channels 142. Again, this process path is represented by dashed lines in FIG. 5. Accordingly, unwanted pressure build up in the process chamber 37 is minimized during operation.

[0094] Fourth, air is introduced directly into the workpiece process chamber through openings in the head assembly 28 and the base assembly 30. Turning to FIGS. 12-16, the base assembly 30 includes a centrally positioned process fluid applicator 62 that extends upwardly from the base 40. Generally, the processing fluids may be a liquid, vapor or gas or a combination of liquid/vapor/gas. The process fluid applicator 62 in the base assembly 30 includes a back-side vent aperture 64. In a preferred embodiment, process fluid applicator 62 includes a plurality of back-side vent apertures 64. The back-side vent apertures 64 communicate via air channel 66 with snorkel 68. The snorkel 68 is open to the mini-environment inside the enclosure 15, allowing air to be delivered directly to the backside of the workpiece. Turning to the head assembly 28 and FIGS. 3-7, an air inlet 140 is formed in a central portion of the assembly 28. One end of the air inlet 140 is open to the mini-environment and one end opens into the workpiece process chamber through opening 106 in the upper rotor 34. Accordingly, air is drawn from the mini-environment into the workpiece process chamber to provide air directly to the top and backsides of the workpiece.

[0095] During operation, process fluids are applied to the top and backsides of the workpiece. The process fluid applicators of the present invention will now be discussed in more detail. Both the head assembly 28 and the base assembly 30 include process fluid applicators. Referring to FIG. 13, the base assembly 30 has a process fluid applicator 62 in

the base 40. The applicator 62 includes a connector 74 for connecting the process fluid applicator to a various process fluid supplies. Accordingly, the applicator 62 includes additional ports; e.g., lateral slotted port 76 and apertures 78. The ports and apertures in the process fluid applicator 62 direct process fluid upward through opening 112 in the lower rotor 36 towards the backside workpiece surface. For example, in a preferred embodiment, air is supplied through vent apertures 64, an etchant (e.g., hydrofluoric acid, sulfuric acid, or a mixed acid/oxidizer) is supplied through lateral slotted port 76, deionized water is supplied through a first aperture 78 and nitrogen and isopropylalcohol are supplied through second aperture 78. The applicator 62 may also include a purging nozzle for directing a stream of purging gas, such as nitrogen across the workpiece surface.

[0096] With reference now to FIGS. 5-11, and as mentioned above, the head assembly 28 also includes a process fluid applicator 32. The applicator 32 has a nozzle 35 for directing streams of processing fluids through inlets 92, 94 and out into the workpiece process chamber through openings 100 in the head 29 and 106 in the upper rotor 34, respectively. The processing fluids provided through nozzle 35 and inlets 92, 94 may be the same or different fluids. Examples of such processing fluids include air nitrogen, isopropylalcohol, deionized water, hydrogen peroxide, ST-250 (a post-ash residue remover solution), an etchant (e.g., hydrofluoric acid, sulfuric acid), or any combination thereof. The nozzle 35 and inlets 92, 94 extend axially downwardly through a sleeve 96 (that includes air inlet 140) in the head 29 so as not to interfere with rotation of the upper rotor 34, which is coupled to motor 38.

[0097] Operation of the new wafer processing system illustrated in FIGS. 1-21 will now be explained. With the process head assembly in an open position, robot 26 loads a workpiece 24 into the process chamber 37 where it sits on stand-off pins 50 extending from the lower rotor 36. Actuator 13 begins to lower the head assembly 28 until it engages base assembly 30. Axial centering extension 122 of the head ring 33 contacts the chamber assembly first, ensuring that head assembly 28 and the base assembly 30 are axially aligned. The head assembly 28 continues to move downward, until the upper rotor 34 makes contact with the lower rotor 36. Eventually, the force applied to the lower rotor 36 (from the actuator 13 via upper rotor 34) will overcome the magnetic repulsion force between the magnets 42 in the base bowl 40 and the magnets 44 in the lower rotor 36, relieving engagement ring 110 (of the lower rotor 36) from the slotted mounting member 144 (of the base 40). Engagement pins 54 of the lower rotor 36 are inserted into the corresponding bores 46 in the upper rotor

34. It may be necessary to rotate the rotors 34, 36 slightly in order to align the engagement pins 54 with the bores 46.

[0098] At this point in the operation of processor 16, the process chamber 37 is in a fully-closed, process position. In this position, the device or top side of the workpiece 24 and the inner surface 148 of upper rotor 34 form a first process chamber 102. The bottom side or backside of the workpiece 24 and the inner surface 150 of lower rotor 46 form a second process chamber 104. As discussed above, fluid applicator 32 introduces process fluid to the first process chamber 102, while fluid applicator 62 introduces process fluid to the second process chamber 104. In a preferred embodiment, the motor 38 rotates one of either the upper rotor 34 or the lower rotor 36. Because the rotors 34, 36 are engaged, the workpiece 24 is spun while process fluids are applied to the top and backsides of the workpiece 24. Liquids flow outwardly over the workpiece 24 via centrifugal force. This coats the workpiece 24 with a relatively thin liquid layer. The tight tolerance between the upper and lower rotors 34, 36 and the workpiece 24 helps to provide a controlled and uniform liquid flow. Gases, if used, can purge or confine vapors of the liquids, or provide chemical treatment of the workpiece 24 as well. The spinning movement of the rotors 34, 36 drives the fluids radially outward over the workpiece 24, and into the annular plenum 80 formed in the base 40. From here, the process fluids exit the base 40 via drains 82. The valves 84 control release of the process fluids through fittings 88.

[0099] After processing is complete, the actuator 13 lifts the head assembly 28 away from the base assembly 30 by actuating a motor. In the system 10 shown in FIG. 2, the robot 26 moves along the track 23 and uses end-effector 31 to remove the workpiece 24 from the open process chamber 16. The robot 26 then travels along the linear track 23 for further processing of the workpiece 24, or to perform a transport operation at the input/output station 19.

[0100] While the present invention has been described in terms of concurrently providing different process fluids to the device and bottom sides of the workpiece, multiple sequential processes of a single workpiece can also be performed using two or more processing fluids sequentially provided through a single inlet. For example, a processing fluid, such as a process acid, may be supplied by the lower process fluid applicator 62 to the lower process chamber 104 for processing the lower surface of the workpiece 24, while an inert fluid, such as nitrogen gas, may be provided to the upper process chamber 102. As such, the process

acid is allowed to react with the lower surface of the workpiece 24 while the upper surface of the workpiece is effectively isolated from hydrofluoric acid reactions.

Description With Reference To FIGS. 22-36

[0101] Turning to FIGS. 22-24, there is illustrated another embodiment of the wafer processing system according to the present invention. The system comprises a processor 150 with a head 153 and a base 163. The base 163 is preferably attached to frame 142 and does not move. The head 153 is supported on an actuator arm 151 which lifts and lowers the entire head 153, to engage and separate the head 153 and the base 163. The head 153 includes an upper frame ring 166 that is engageable with a lower frame ring 168 on the base. A cover 152 over the upper frame ring 166 isolates the interior components of the head 153 from the outside environment. An upper rotor 156 in the head 153 is engageable with a lower rotor 158 in the base 163 to form a processing chamber 165 around a workpiece 160. When the head 153 is moved into engagement or contact with the base 163, the upper rotor 156 moves into engagement with the lower rotor 158. A seal or o-ring 170 is preferably included between a flange 178 of the upper rotor 156 and the lower rotor 158, to control fluid flow in the processor 150.

[0102] Referring still to FIGS. 22-24, a first or upper fluid applicator 157 delivers a processing fluid through an opening in the upper rotor 156, preferably to a central region of the upper surface of the workpiece 160. A second or lower fluid applicator 159 in the lower frame ring 168 delivers a processing fluid through an opening 190 in the lower rotor 158, preferably to a central region of the lower surface of the workpiece 160 and/or to an edge region of the workpiece 160, as described below. The first and second fluid applicators 157, 159 may include nozzles, orifices, brushes, pads or other equivalents for applying or delivering processing fluid to the workpiece.

[0103] One or more drain outlets 180 are preferably located at or near the perimeter or outer edge of the upper rotor 156 for removing processing fluids from the processing chamber 165. Additionally, one or more horizontal weep holes 181 extend through the flange 178. In a preferred embodiment, for example FIGS. 28-29, three spaced apart horizontally oriented weep holes are provided (each having a diameter of about 0.018 to 0.024 inches or 0.4572 mm to 0.6096 mm) for draining processing fluid trapped between the flange 178 and the lower rotor 158, above the seal 170.

[0104] As shown in FIGS. 22 and 23, a motor 154 in the head 153 preferably includes a motor plate 164 attached to the upper rotor 156. A skirt 176 projects downwardly from the motor plate 164 and isolates the processing chamber from the upper and lower frame rings 166, 168. The motor 154 rotates the motor plate 164, and in turn, the upper rotor 156, via an axle 184 positioned around the first fluid applicator 157. When the upper rotor 156 is engaged with the lower rotor 158, the two rotors 156, 158 rotate together. The first fluid applicator 157 is supported on the motor housing 155 and does not rotate with the upper rotor 156. The axle 184 is supported on bearings 262 to allow rotation of the axle 184, the motor plate 164, and the upper and lower rotors 156, 158 about a vertical spin axis 175.

[0105] Turning to FIGS. 25-29, the upper rotor 156 includes a plurality of downwardly projecting alignment pins 200. Each alignment pin 200 preferably includes a tapered leading end. The alignment pins 200 are preferably located at least partially around a periphery of the upper rotor 156 and are positioned so that each alignment pin 200 contacts the edge of a workpiece 160 when the workpiece 160 is positioned in the processing chamber. The alignment pins are located with tight dimensional tolerances on a circle concentric with the spin axis 175 or the axle 184. As a result, the alignment pins 200 center the workpiece 160 in the processing chamber so that the workpiece 160 is accurately concentric with the spin axis 175.

[0106] Turning to FIGS. 30-34, a pair of spaced apart shoulders 192 are positioned at the outer edges of the lower rotor 158. The shoulder 192 includes pin receiving surfaces, such as a groove or slot 194, or in the form of individual holes, for receiving the tapered leading end of an alignment pin 200. The slot 194 is preferably tapered to correspond to the tapered leading end of the alignment pin 200.

[0107] Each shoulder 192 on the lower rotor 158 preferably includes upwardly projecting lower workpiece support pins 196 for supporting the workpiece 160 and for spacing the workpiece 160 from the interior face or surface 195 of the lower rotor 158. The shoulders 192 are preferably spaced apart to provide a loading/unloading slot 198 between them, for receiving an end effector or other workpiece loading device. Accordingly, an end effector supporting a workpiece 160 may enter the lower rotor 158 through the slot 198 between the shoulders 192, and then set the workpiece 160 onto the lower support pins 196, when the processor 150 is in the open position. As shown in FIGS. 22, 30 and 32, the pins 196 on the shoulders 192 support the workpiece or wafer 160 in a plane P (shown in dotted line in FIG.

32) above the upper surface 197 of the lower rotor. The lower surface of the workpiece or wafer 160 is therefore spaced vertically apart from the surface 197 by e.g., from 2-10 or 4-6 mm. This allows the end effector of the robot to move in under the workpiece, for loading or unloading the workpiece into the processor. In contrast, as shown in FIG. 24, the spacing between the lower interior surface 201 (FIG. 28) of the upper rotor is much less, typically 1, 2, 3 or 4 mm (when the processor is closed or in the process position). As also shown in FIG. 28, the surface 201 of the upper rotor has a slightly conically tapered section 203, running at an angle of 2-8 or 4-6 degrees.

[0108] Referring to FIG. 34, the upper rotor 156 preferably includes downwardly projecting upper workpiece support pins 210 for holding the workpiece 160 against the lower support pins 196. The upper support pins 210 are preferably positioned to contact the upper surface of the workpiece 160 at locations at least 2, 3, 4, 5 or 6 mm radially inwardly from the outer perimeter or edge of the workpiece 160. By positioning the upper support pins 210 at least 4 mm in from an outer perimeter of the workpiece 160, the upper support pins 210 are located outside of the primary fluid flow path during edge processing of the workpiece 160, as described below. Thus, spots of residual metal (e.g., copper plating) that may result from upper support pins positioned closer to the perimeter of the workpiece, and therefore in the primary fluid path, are avoided.

[0109] In addition, as shown in FIGS. 24-27, the shaft or axle 184 of the motor 154 connects directly to the motor plate 164 on the upper rotor assembly, via a shaft plate 173. Consequently, as there is a more direct connection between the shaft 184, which defines the spin axis, and the pins 200, which position the workpiece. In contrast to earlier designs, spin concentricity is improved (to about ± 0.5 mm). In other designs where the workpiece is positioned by pins or other features on the lower rotor, the accumulation of dimensional tolerances can result in significant eccentricity (e.g. ± .9 mm) between the spin axis and the workpiece.

[0110] As shown in FIG. 24, the upper rotor 156 has a liner or chamber plate 177 preferably made of a corrosion resistant material, such as Teflon® (fluorine resins). The chamber plate is attached to the motor plate 164. The motor plate 164 and other components in the head 153 are typically metal, such as stainless steel. The lower rotor, as shown in FIGS. 30-32, will also typically be made of a corrosion resistant material or plastic, such as Teflon®. This allows the processor 150 to better resist corrosion caused by highly reactive

gases or liquids, such as acids, used in processing. The pins 200 are secured into the motor plate 164 and pass through the chamber plate 177. Typically eight pins 200 are evenly spaced apart on the upper rotor, although more or less pins may be used.

[0111] Referring to FIGS. 22-25, on or in the head 153, the cover 152; motor housing 155; motor 154, fluid applicator 157 and upper frame ring 166, are fixed in place and do not rotate (although they can lift up vertically). The shaft or axle 184 (which is connected to or forms part of the motor shaft); shaft plate 173; motor plate 164 including the flange 178, the skirt 176 and the liner plate 177, all rotate together when the motor 154 is turned on.

[0112] In or on the base 163, the lower frame ring 168; drain 208; valve 206; cam actuator 204; fluid applicator or nozzle 159, are preferably fixed in place, and do not rotate. The lower rotor 158 including the seal 170, cams 172, latch ring 174 and other attached components shown in FIGS. 30-32, rotate with the lower rotor, when the lower rotor is engaged with and driven by the upper rotor.

[0113] Turning to FIGS. 35 and 36, an annular opening 220 is provided around the manifold forming the first fluid applicator 157, as well as around a liquid delivery path 161 leading to the first fluid applicator 157. Purge gas, such as N_2 gas, is supplied from an inlet 221 into the annular opening 220. The annular opening 220 extends from the inlet into the processing chamber. By delivering a purge gas into the processing chamber via the annular opening 220, extremely uniform delivery of the purge gas into the processing chamber is achieved, providing more uniform and consistent processing.

[0114] With reference to FIGS. 1-2 and 22-36, in use, a pod, cassette, carrier or container 21 is moved onto the input/output station 19. If the container is sealed, such as a FOUP or FOSBY container, the container door is removed, via robotic actuators in the system 10. A robot 26 then removes a workpiece 160 from the container 21, places the workpiece 160 into a processor 150, and sets the workpiece 160 onto the lower support pins 196 of the lower rotor 158. To place the workpiece 160 onto the lower support pins 196, the robot 26 moves an end effector 31, or similar device supporting the workpiece 160, through the loading/unloading slot 198 in the lower rotor 158, and lowers the workpiece 160 onto the lower support pins 196. The robot 26 then withdraws the end effector 31 from the processor 150. While the processor 150 could alternatively be provided as a stand alone manually loaded system (without the input/output station 19, the robots 26, or the enclosure 15), the automated system shown in FIGS. 1 and 2 is preferred.

[0115] The upper and lower rotors 156, 158 are then brought together into engagement with each other, preferably by lowering the head 153 down into contact with the base 163. As this occurs, the upper rotor 156 is lowered down toward the lower rotor 158. The tapered leading ends of the alignment pins 200 on the upper rotor 156 move into the tapered openings or slot 194 in the lower rotor 158 to center the upper rotor 156 on the lower rotor 158 and to form the processing chamber 165 around the workpiece 160. The inner edge of the tapered portion of each alignment pin 200 preferably contacts the edge of the workpiece 160 to center the workpiece 160 within the processing chamber. As a result, the workpiece 160 is positioned concentrically with the vertical spin axis 175 of the processing chamber. This helps to provide uniform and efficient processing, particularly edge processing, of the workpiece 160.

[0116] When the upper rotor 156 is lowered into engagement with the lower rotor 158, the upper support pins 210 on the upper rotor 156 closely approach or contact the upper surface of the workpiece 160 to secure or confine the workpiece 160 within the processing chamber. After the rotors are brought together, cam actuators 204 in the base 163 move down, causing cams 172 to pivot and release sections of a latch ring 174. The latch ring sections then move radially outwardly and into grooves 182 in the flange 178 of the upper rotor. This operation is described in U.S. Patent No. 6,423,642, incorporated herein by reference. The lower rotor 158 is thus secured to the upper rotor 156 to form a combined rotor unit or assembly 185 (FIGS. 26 and 27).

[0117] Once the processor 150 is in the closed or processing position, a processing fluid is supplied via one or both of the first and second fluid applicators 157, 159 to the upper and/or lower surfaces of the workpiece 160. The rotor unit 185 is rotated by the motor 154. Centrifugal force creates a continuous flow of fluid across the surfaces of the workpiece 160. Processing fluid moves across the workpiece surfaces in a direction radially outward from the center of the workpiece 160 to the edges of the workpiece 160.

[0118] At the perimeter of the processing chamber 165, used processing fluid moves out of the processing chamber through the drain outlets 180 and/or other weep holes 181 or drain paths in the upper and/or lower rotors 156, 158, due to the centrifugal force. The used fluid collects in a drain area 208 and may be delivered to a recycling system for reuse, or to a disposal area for proper disposal, by opening a valve 206.

[0119] When the step of processing with the first processing fluid is completed, a purge gas, such as N_2 gas, is preferably delivered into the processing chamber 165 to help remove any remaining processing fluid from the chamber. The purge gas is preferably delivered from the purge gas inlet 222 into the annular opening 220 around the first fluid applicator 157. The purge gas continues through the annular opening 220 into the processing chamber 165. Accordingly, the purge gas is delivered into the processing chamber in the form of an annular ring of gas, which facilitates uniform dispersion of the purge gas throughout the processing chamber. As a result, processing fluids are more effectively and efficiently removed from the processing chamber.

[0120] Once the first processing fluid is removed from the processing chamber, similar processing and purging steps may be performed for one or more additional processing fluids. A rinsing step, preferably using a deionized (DI) rinse water, may be performed after each processing step, or may be performed after all of the processing steps are completed. A drying step, performed with isopropyl alcohol (IPA) vapor or another drying fluid, may be performed after the final processing or rinsing step.

[0121] Once processing has been completed, head 153 is lifted or separated from the base 163 to allow access to the workpiece 160. In this open position, the workpiece 160 may be removed from the processing chamber by the robot 26, and another workpiece 160 may be placed into the processing chamber by the same robot 26, or by another robot.

Description With Reference To FIGS. 37 and 38

[0122] Turning to FIGS. 37 and 38, two alternative embodiments of the processor 150 that may be used for edge processing of a workpiece 160 are illustrated. In these embodiments, a fluid delivery path is provided for directing processing fluid to an edge of the workpiece 160 so that edge processing may be performed. In these embodiments, processing fluid may be supplied via the second fluid applicator 159, or via a separate fluid delivery device.

[0123] Referring to FIG. 37, a lower fluid delivery path 230 is formed between a shield plate 232 and the interior face of the lower rotor 158. The shield plate 232 is co-axial with the round workpiece 160 and has a diameter preferably about 2-12, 4-10, or 5-8 mm less than the workpiece. Processing fluid is provided toward the center of the lower surface of the shield plate and directed radially outwardly along the shield plate 232 via centrifugal force.

The fluid flows off of the circumferential edges of the shield plate, and onto the outer edges of the workpiece 160. As a result, only the edge of the workpiece 160 is processed.

[0124] In the embodiment illustrated in FIG. 38, a fluid delivery path 240 is provided from the second fluid applicator 159 (or other fluid source) directly to the edge of the workpiece 160. Thus, processing fluid enters the processing chamber directly at the edge of the workpiece 160, as opposed to entering toward the center of the workpiece 160 and being guided toward the edge of the workpiece with a shield plate 232. The fluid delivery path 240 may include a fluid delivery line 242, or may simply be one or more paths or bores in the lower rotor 158.

[0125] If processing of the lower surface of the workpiece 160 is also desired in the embodiment shown in FIG. 38, a valve or a similar device may be located in the second fluid applicator 159 to selectively direct fluid to the fluid delivery path 240, and to the center of the workpiece 160. In one embodiment, the fluid delivery path 240 may be connected to the second fluid applicator 159 by a rotary union, or a similar device, so that the fluid delivery path 240 may rotate while the second fluid applicator 159 remains stationary.

[0126] In the embodiments illustrated in FIGS. 37 and 38, drain holes 236 in the upper rotor 156, and a drain path 238 in the lower rotor 158, allow the processing fluid to escape from the processing chamber. A purge gas, such as N_2 gas, is preferably directed radially outwardly above the workpiece 160 during processing to aid in directing the processing fluid out through the drain holes 236, so that the processing fluid does not contact the inner or central surfaces of the workpiece 160. As shown in FIG. 38, a fluid delivery tube 186, typically for DI water, extends down through the opening or path 161 in the manifold 167. The tube 186 ends flush with the lower end of the manifold 167. With the tube 186 flush, dripping is reduced, as compared to having the tube 186 recessed or protruding, even slightly, from the manifold 167.

[0127] As shown in FIGS. 37 and 38, the seal 170 is positioned in a groove or channel 171 around the outside of the lower rotor 158. A chamfer 169 at the edge of the groove 171 helps to reduce or prevent droplets of fluid from clinging too the upper rotor during separation, and subsequently falling onto the workpiece and causing potential damage or contamination. As shown in FIG. 32, the edges of the groove 171 may alternatively be rounded or radiused.

[0128] Referring still to FIGS. 37 and 38, the processor 150 uses improved air and gas flow designs, which dramatically speed up workpiece drying. This reduces required processing times and increases manufacturing efficiency or throughput. During drying, clean dry air (which may be filtered and/or heated) flows down through the opening 167, due to the low pressure zone created around the center of the processor via the spinning movement. This air, shown by arrow A in FIG. 36, impinges on the top surface of the workpiece and then flows outwardly. If (nitrogen) gas is also used during drying, then the air mixes with the gas flowing from the annular opening 220. The air and gas then flows out through the drain holes. In comparison to earlier designs requiring e.g., 60 seconds for drying, the processor shown in FIGS. 35 and 36 dries a workpiece in about 20 seconds.

[0129] The processor components in the processing system 10 may be made of any suitable material, such as Teflon® (synthetic fluorine-containing resins) or stainless steel. Any processing fluids typically used to process workpieces, such as semiconductor wafers, may be used in the processing system 10. For example, aqueous or gaseous ozone, aqueous or gaseous HF or HCL, ammonia, nitrogen gas, IPA vapor, DI rinse water, H_2SO_4, etc. may be used to perform the various processing steps. In applications where harsh acids or solvents are used, such as HF or H_2SO_4, it is preferable to use Teflon® components so that the rotor components are not damaged by the processing chemistries. Preferably, the first and second fluid applicators 157, 159 are connected with, and have separate outlets for, DI water, clean dry air, nitrogen, and one or more of the liquid process chemicals listed above. One or more valves may be used to control the flow of liquids and gases through the first and second fluid applicators 157, 159.

[0130] Additional system components, such as an IPA vaporizer, a DI water supply, heating elements, flowmeters, flow regulators/temperature sensors, valve mechanisms, etc. may also be included in the processing system 10, as is common in existing systems. All of the various components of the processing system 10 may be under the control of a controller unit having appropriate software programming.

Description With Reference To FIGS. 41-46

[0131] FIG. 41 illustrates the workpiece processor 316 in an up, open or workpiece load/unload position. While in the open position, a workpiece 324 may be loaded and unloaded to and from the processor 316. The robot arm 320, includes an end effector 322 for loading and unloading a workpiece 324 into and out of the processor 316. In a preferred

embodiment, the robot arm 320 is supported on a robot base that moves linearly along a track 23 in the space 18 (as shown in FIG. 2). The robot moves within the enclosure for delivering workpieces to and from the various processing stations 14. Preferably the processors 316 (or 16 as designated in FIG. 2) are arranged in first and second columns as shown in FIG. 2, with first and second robots 26 loading and unloading workpieces only into processors in the first and second columns, respectively. However, other designs may also be used. For example, a single robot may be used to load and unload all processors 16 or 316. Alternatively, two robots may be used, with crossover operation, so that either robot can load and unload any processor 16 or 316.

[0132] Turing to FIG. 42, the processor 316 includes an upper rotor 326 that is engageable to a lower rotor 328 to form a processing chamber 351. In the illustrated embodiment, the workpiece 324 is a round wafer having flat upper and lower surfaces.

[0133] The upper rotor 326 is preferably annular with a relatively large central opening or bore 332. The bore 332 preferably has a diameter that is 20-80%, 30-70%, or 40-60% greater than the diameter of a workpiece 324. For example, if the processor is configured to process 200 mm diameter wafers, the diameter of the bore 332 is preferably between 100 and 150mm in diameter, more preferably approximately 125mm in diameter.

[0134] One or more pneumatic air cylinders 338 or other actuators are attached to the support plate 334 for raising and lowering the upper rotor 326 between the open position illustrated in FIGS. 41-43, and the closed position illustrated in FIGS. 44-46.

[0135] The lower rotor 328 is preferably fixed in position on a base 340 such that the upper rotor 326 is lowerable to engage or contact the lower rotor 328 to form the processing chamber 351. In an alternative embodiment, the lower rotor 328 may be lifted to engage a fixed upper rotor 326, or the two rotors 326, 328 may be moveable toward one another to form the process chamber 351.

[0136] The workpiece 324 is preferably supported in the processing chamber on a plurality of lower supports 327 extending upwardly from the lower rotor 328. Upper support pins 329 on the upper rotor 326 generally tend to limit upward movement of the workpiece off of the lower supports 327, as illustrated in FIG. 43. The workpiece 324 may alternatively be secured, as described in U.S. Patent No. 6,423,642, the disclosure of which is incorporated herein by reference.

[0137] Referring to FIG. 42, an annular housing 355 is attached to the plate 334. An annular flange 343 on the upper rotor 326 extends into an annular slot 353 in the housing 355. A lower magnet ring 357 is attached on top of the flange 343. The upper rotor 326, the flange 343 and magnet ring 357 form an upper rotor assembly 359 which spins as a unit within the housing 355. The upper rotor 326 preferably has an inner PVDF or Teflon® (Flourine resins) liner 361 attached to a metal, e.g., stainless steel ring 363, which supports the flange 351. The lower rotor is also preferably PVDF or Teflon®. Three pins 352 extend up at the perimeter of the lower rotor 328 for engagement or insertion into openings or receptacles 354 in the upper rotor. The pins 352 have tapered conical tips to align the upper rotor with the lower rotor, as they are brought together. The pins 352 also transmit torque from the lower rotor to the upper rotor, as the rotors spin together as a rotor unit 335 during processing.

[0138] A ring plate 367 is attached to the housing 355. The top end of the upper rotor 326 extends up through the ring plate 367. An upper magnet ring 369 is attached to the ring plate 367. The upper magnet ring 369 repels the lower magnet ring 357. The ring plate 367 has a conical section 371 which overlies and is attached to the plate 334. The plate 334, housing 355, ring plate 367 and conical section 371, and the upper magnet ring 369, form a housing assembly 373, which moves vertically via the actuators 338, but does not rotate. Rather, the upper rotor assembly 359 rotates within the stationary housing assembly 373. As shown in FIG. 42, with the processor 316 in the open or up position, the flange 343 of the upper rotor assembly 359 rests on the annular lip or ledge 377 of the housing 355, with no other contact between the rotor assembly 359 and the housing assembly 373. Anti-clocking pins 358 (FIG. 45) extend up from the lip 377 into the flange 343 when the processor is in the open or up position, to keep the upper rotor in angular alignment with the lower rotor.

[0139] As shown in FIG. 45, with the processor 316 in the down or closed position, the upper rotor assembly 359 is floating or suspended within the housing 355, i.e., there is no physical contact between the upper rotor assembly 359 and any part of the housing 355 or housing assembly 373. The repelling force of the magnet rings 357 and 369 drives the upper rotor assembly 359 down into contact with lower rotor 328, without physical contact. The magnet rings 357 and 369 may be replaced by individual magnets, electro-magnets or other magnetic elements.

[0140] Since the upper rotor 326 is suspended and there is no physical or mechanical connection between the upper rotor 326 or upper rotor assembly 359, and the surrounding structure, such as the housing 355, plate 367 or plate 334, the upper rotor 326 can automatically align itself with the lower rotor 328, when they are brought together. The need for precise alignment of the upper rotor to the lower rotor is therefore avoided. In addition, as there is no physical contact between the fixed housing assembly 373 and the rotating rotor assembly 359 during processing, the potential for generating contaminant particles is greatly reduced.

[0141] A face seal or other sealing element 331 may be used to form a seal between the upper and lower rotors 326, 328 when they are brought together. For some applications, no seal is needed. The upper and lower rotors 326, 328 preferably contact one another only at the seal 331. The seal 331 may be located on an interior face of one or both of the rotors 326, 328, and is preferably located around the perimeter of the rotors.

[0142] When the rotors 326, 328 are brought together, they form a combined rotor unit 335 rotatable via a motor 339 supported on a base 340. The motor 339 is contained in a motor housing 337 attached to a base plate 340 or the frame 312. A motor rotor 375 is joined to a backing plate 341 which is attached to and supports the lower rotor 328. As shown in FIGS. 42-43, the motor rotor 375 has a diameter which is at least 50, 60, 70, 80, 90 or 100% of the diameter of the workpiece. This allows for improved dynamic balancing of the system, and less vibration. A barrier ring 378 forms a tortuous path with the bottom of the backing plate 341. This helps to reduce migration of any particles from the motor outwardly and up towards the workpiece. A conical depression at the center of the lower rotor forms a sump 381 which collects and drains away stray liquid. Drain outlets 330 extend through the upper rotor, as shown in FIG. 42.

[0143] When the rotor unit 335 rotates, air is drawn into the processing chamber 351 through the opening or bore 332 in the upper rotor 326. The bore 332 is relatively large, and the chamber outlets are restricted to a much smaller cross section area. This creates a low pressure differential within the processing chamber. This low pressure differential results in air flowing into the processing chamber at a low velocity. As a result, significantly fewer contaminant particles are likely to be drawn into the processing chamber by the incoming airflow, in comparison to existing designs. This reduces the chances of the workpiece becoming contaminated.

[0144] As illustrated in FIGS. 44-46, an upper nozzle 342 or fluid applying device extends into the bore 332 in the upper rotor 326. The nozzle 342 supplies one or more processing fluids to an upper surface of the workpiece 324. The upper nozzle 342 is attached to an end of a relatively inflexible upper fluid delivery tube or line 344. The upper fluid delivery line 344 is attached to a motorized lifting and rotating mechanism 346, which can raise and lower, as well as pivot, the upper fluid delivery line 344 and the upper nozzle or outlet 342 in a back and forth alternating movement. Accordingly, the upper nozzle 342 is moveable above the upper workpiece surface for distributing processing fluid to different portions of the upper workpiece surface. Additionally, the upper nozzle 342 may be lifted out of the bore 332 and pivoted away from the processing chamber, so that the upper rotor 326 may be raised into the open or workpiece-receiving position.

Description With Reference To FIGS. 47-48

[0145] As illustrated in FIG. 47, the upper fluid delivery line 344 of the upper nozzle 342 may include a fluid collection area 345, or "Z-trap," for collecting processing fluid after fluid delivery to the processing chamber is discontinued. In existing systems, there is a potential for excess fluid to drip from the upper nozzle or tube onto the workpiece after fluid delivery has been stopped. This can lead to workpiece contamination or other defects. Suck-back and gas purging techniques have been used in an attempt to completely empty the fluid delivery tube, but residual drops often still occur. Thus, the collection area 345 may be employed, in conjunction with suck-back or purging, to collect the residual fluid so that it does not drip into the processing chamber.

[0146] The fluid collection area 345 is preferably formed by a first tube section 347 extending upwardly at an angle, connecting into a second section 349 is included in the upper fluid delivery line 344 or upper nozzle 342 so that processing fluid is directed toward the processing chamber. The fluid collection area 345 is preferably large enough to contain several drops of fluid that are purged or sucked back into the collection area 345. As illustrated in FIG. 48, a nozzle 342 incorporating a collection area 345 or Z-trap may be manufactured as a separate component that may be attached to the end of the upper fluid delivery tube or line 344.

[0147] As illustrated in FIGS. 42 and 45, a lower nozzle 348 or other fluid delivery outlet is preferably centrally positioned beneath the workpiece 324 for delivering one or more processing fluids to a lower surface of the workpiece 324. A lower fluid delivery tube or line

350 is attached to the lower nozzle 348 for supplying fluid to the lower nozzle 348. The lower fluid delivery line 350 may be supplied with processing fluid from the same or from different fluid reservoir(s) from which the upper fluid delivery line 344 is supplied. Thus, the upper and lower surfaces of the workpiece 324 may be processed simultaneously, or sequentially, with the same or with different processing fluids. The nozzles 342 and 348 may be spray nozzles or applicators of any shape or pattern, or they may be simple outlets or openings, to supply a process liquid or gas or vapor to the workpiece, in any format or condition.

[0148] The drain outlets 330 are spaced apart around the perimeter of the upper rotor 326, as shown in FIG. 42. The drain outlets 330 allow fluid to exit from the processing chamber 351 via centrifugal force when the rotor unit 335 spins during processing. The drain outlets 330 alternatively can be in the lower rotor or on both the upper and lower rotors. The drain outlets 330 can also be provided in other forms, such as a slot or an opening between the rotors. As illustrated in FIGS. 41-46, an annular drain assembly 370 is positioned around the rotor unit 335. The drain assembly 370 is preferably vertically moveable via a lifting mechanism or elevator 372. The elevator 372 includes an armature 374 attached to the drain assembly 370. A motor 379 turns a jack screw 376 to raise and lower the armature 374 and the drain assembly 370.

[0149] The drain assembly 370 includes a plurality of drain paths that are separately alignable with the outlets 330 in the processing chamber. Three drain paths 380, 382, 384 are shown in FIGS. 42 and 43, but any desired number of drain paths may be included in the drain assembly 370. Multiple drain paths are provided so that different processing chemistries, as well as deionized (DI) water, may be removed from the processing chamber along separate paths, which eliminates cross-contamination between the processing chemistries and the DI water. The drain paths 380, 382, 384 lead to a system drain tube 386, which preferably extends out of the processor 316 from below the drain paths 380, 382, 384.

[0150] When the upper rotor member 326 is in the open or workpiece-receiving position, the drain assembly 370 is preferably at its lowest position, adjacent to the base 340, as illustrated in FIGS. 41-43. This allows for loading and unloading of a workpiece 324 into and out of the processor 316, as shown in FIG. 41. When the upper rotor 326 is lowered into the closed or processing position, the drain assembly 370 is raised by the elevator 372 to

align one of the drain path 380, 382, or 384 with the outlets 330 in the processing chamber, as illustrated in FIGS. 44-46.

[0151] Processing fluid is removed from the processing chamber through the outlets 330 via centrifugal force generated by rotation of the rotor unit. The fluid then flows along the drain path that is aligned with the processing chamber outlets, and continues into the tube 376, which removes the fluid from the workpiece processor 316. The processing fluid may then be recycled or sent to a disposal area.

[0152] With reference to FIG. 2 in use, a pod, cassette, carrier or container 21 is moved onto the input/output station 19. If the container is sealed, such as a FOUP or FOSBY containers, the door is removed, via robotic actuators in the system 10. The robot(s) 26 (referred to as reference number 320 in FIG. 41) then remove a workpiece 24 (also referred to as 224, 324, in FIGS. 22-40 and 41-46, respectively) from the container 21 and place the workpiece 24 in a processor 316, as shown in FIG. 41. The processor 316 is in the up or open position, and the drain assembly 70 is in the down position, as shown in FIG. 41. While the processor 316 could also be provided as a stand alone manually loaded system (without the input/output station 19, the robots 26 or the enclosure 15), the automated system shown in FIGS. 1 and 2 is preferred.

[0153] Turning back to FIGS. 41-46, the workpiece 324 is positioned on the workpiece supports 327 on the lower rotor 328. The upper rotor 326 is then lowered down via the actuators 338 and engages with the lower rotor member 328 to form a processing chamber 351 around the workpiece 324. The repulsion of the magnets or magnet rings 357 and 369 forces the upper rotor against the lower rotor, with the face seal forming a seal at the perimeter. The spacing members or support pins 329 on the upper rotor member 326 closely approach or contact the upper surface of the workpiece 324 to secure or confine the workpiece in place.

[0154] Once the rotor unit 335 is in the closed or processing position, the drain assembly 370 is raised by the elevator 372 so that it is positioned around the rotor unit. A drain path 380, for removing the first processing fluid used to process the workpiece 324, is aligned with the outlets 330. The spacing between the entrance to the drain paths 380, 382, 384 and the outlets 330 is minimized, so that liquid exiting the outlets 330 moves into the drain paths, rather than running down the sides of the lower rotor. Alternatively, annular ring seals may

be used to help move liquid from the outlets 330 into the drain paths, without dripping or leaking.

[0155] After the drain path 380 is properly aligned, a processing fluid is supplied via one or both of the upper and lower fluid supply tubes 344, 350 to one or both of the upper and lower nozzles or outlets 342, 328, which deliver the processing fluid to the upper and/or lower surfaces of the workpiece 324. The rotor unit is generally rotated by the motor 339 to generate a continuous flow of fluid across the surfaces of the workpiece 324 via centrifugal force. Processing fluid is thus driven across the workpiece surfaces in a direction radially outward from the center of the workpiece 324 to the edges of the workpiece 324. The upper nozzle 342 may be moved back and forth within the bore 332 by the motorized lifting and rotating mechanism 346, to more evenly distribute processing fluid to the upper workpiece surface.

[0156] As the rotor unit rotates, air is drawn into the processing chamber through the bore 332 in the upper rotor assembly 359 and housing assembly 373. As the bore 332 is relatively large, and the processing chamber 351 is substantially closed, except at the outlets 330, the air flows through the processing chamber at a relatively low velocity, thus reducing the likelihood of entraining particles that could contaminate the workpiece.

[0157] At the perimeter of the chamber 351, used processing fluid moves out of the processing chamber through the outlets 330, due to the centrifugal force. The processing fluid then flows down the drain path 380 and out through the drain tube 386. The spent fluid may be delivered to a recycling system for reuse, or to a disposal area for proper disposal. The drain tube 386 can telescopically extend to move up and down with the drain assembly 370.

[0158] When the step of processing with the first processing fluid is completed, a purge gas, such as N_2 gas, is preferably sprayed from the nozzles 324 and/or 342 toward the outlets 330 to help remove any remaining processing fluid from the chamber. Depending on whether a second processing fluid or a DI rinse water is to be used next, the drain assembly 370 is raised further by the lift mechanism 372 to align the appropriate drain path 382 or 384 with the outlets 330.

[0159] For example, if a rinsing step performed with DI rinse water is to be performed next, the elevator 372 raises the drain assembly 370 until drain path 384 is aligned with the outlets in the processing chamber. DI rinse water is then sprayed onto the workpiece surfaces

and moves across the workpiece surfaces to the exterior perimeter of the workpiece 324 via centrifugal force. The DI rinse water flows through the outlets 330 into the drain path 384. The DI rinse water then flows along the drain path 384 into the tube 386 for removal from the workpiece processor 316. As separate drain paths are used for the first processing fluid and the DI rinse water, these liquids are not mixed when they exit the processing chamber, and cross-contamination does not occur.

[0160] Similar steps may be performed for one or more additional processing fluids. A rinsing step may be performed after each processing step, or may be performed after all processing steps are completed. A drying step performed with isopropyl alcohol (IPA) vapor or another drying fluid may be performed after the final processing or rinsing step. In a preferred embodiment, one drain path is assigned to each type of processing fluid used, including the DI rinse water. Thus, cross-contamination between the different processing chemistries, as well as the DI rinse water, is avoided.

[0161] Once processing has been completed, the drain assembly 370 is lowered and the upper rotor member 326 is raised to allow access to the workpiece 324, as shown in Figs. 41-42. In this open position, the workpiece 324 may be removed from the processing chamber and another workpiece may be placed into the processing chamber.

[0162] The rotor and drain components in the processing system 10 may be made of any suitable material, such as Teflon® (synthetic fluorine-containing resins) or stainless steel. Any processing fluids typically used to process workpieces, such as semiconductor wafers, may be used in the processing system 10. For example, aqueous or gaseous ozone, aqueous or gaseous HF or HCL, ammonia, nitrogen gas, IPA vapor, DI rinse water, H_2SO_4, etc. may be used to perform the various processing steps. In applications where harsh acids or solvents are used, such as HF or H_2SO_4, it is preferable to use Teflon® processing components so that the rotor components and drain are not damaged by the processing chemistries. Preferably the upper nozzle or outlet 342 and lower nozzle 348 are connected with, and have separate outlets for DI water, clean dry air, nitrogen, and one of the liquid process chemicals listed above. One or more valves 390 near the lower end of the tube 350 control flow of liquids and gases through the lower nozzle 348. The lower nozzle 348 may include e.g., four separate sub-nozzles, each dedicated to a single liquid or gas.

[0163] Additional system components, such as an IPA vaporizer, a DI water supply, optional heating elements, optional flowmeters, optional flow regulators/temperature sensors,

valve mechanisms, etc. may also be included in the processing system, as in existing systems. All of the various components of the processing system 10 may be under the control of a controller unit 17 having appropriate software programming.

[0164] While the process head, process head assembly, chamber assembly, rotors, workpieces and other components are described as having diameters, they can also have non-round shapes. Further, the present invention has been illustrated with respect to a wafer or workpiece. However, it will be recognized that the present invention has a wider range of applicability. By way of example, the present invention is applicable in the processing of flat panel displays, microelectronic masks, and other devices requiring effective and controlled wet chemical processing.

WHAT IS CLAIMED IS

1. A system for processing a workpiece, comprising:

a plurality of workpiece processors, with at least one of the workpiece processors comprising:

an upper rotor; a lower rotor engageable with the upper rotor to form a workpiece processing chamber; a robot moveable between the processors for loading and unloading workpieces into and out of the processors;

and a moveable drain assembly including a plurality of separate drain paths, with each drain path separately alignable with the processing chamber by moving the drain mechanism to align a single drain path with the processing chamber.

2. The system of claim 1 wherein the lower rotor is at a fixed vertical position, and the upper rotor and the drain assembly are moveable vertically, relative to the lower rotor.

3. The system of claim 1 further comprising a nozzle extending into the upper rotor for introducing a processing fluid to an upper surface of a workpiece.

4. The system of claim 1 further comprising a loading station, with the robot moveable from the loading station to one or more of the workpiece processors.

5. The system of claim 1 wherein the workpiece processors are arranged in a first row and a second row, with the robot moveable between the two rows.

6. A system for processing a workpiece, comprising: a plurality of workpiece processors, with at least one of the workpiece processors comprising: an upper rotor having a first magnetic element; a lower rotor having a second magnetic

element, with the upper rotor engageable to the lower rotor via interaction of the magnetic elements, to form a workpiece processing chamber; and a robot moveable between the workpiece processors for loading and unloading a workpiece into and out of one or more processors.

7. The system of claim 6 with the upper rotor having a through opening with a diameter which is 20-80% of the diameter of the workpiece.

8. The system of claim 6 further comprising an upper fluid applicator extending into the through opening in the upper rotor, to provide a processing fluid to an upper surface of the workpiece.

9. The system of claim 6 further comprising an actuator for moving the upper fluid applicator within the through opening for distributing a processing fluid to different portions of the workpiece, and for moving the upper fluid applicator vertically and radially out of the processing chamber.

10. The system of claim 6 further comprising a lower fluid applicator extending through the lower rotor for introducing a processing fluid to a lower surface of a workpiece.

11. The system of claim 6 further comprising a moveable drain assembly including a plurality of drain paths, with each drain path separately alignable with the processing chamber by vertically moving the drain assembly.

12. A system for processing a workpiece, comprising: a plurality of workpiece processors, with at least one of the workpiece processors comprising: a first rotor; a second rotor engagement means for engaging the first rotor to the second rotor, without the need for physical contact with the first rotor; and loading means for loading a workpiece into and out of one or more of the processors.

13. The system of claim 12 wherein the engagement means comprises elements for creating magnetic repulsion or attraction between the first and second rotors.

14. The system of claim 12 further comprising drain means for separately draining fluids from the processing chamber.

15. A method of processing a workpiece, comprising the steps of: placing the workpiece into a first rotor; engaging a second rotor to the first rotor via a non-contact force, to form a processing chamber around the workpiece; spinning the first and second rotors; and applying a first processing fluid to a first side of the workpiece, with the first processing fluid flowing radially outwardly over the first side of the workpiece via centrifugal force.

16. The method of claim 15 further comprising the step of removing the first processing fluid from the processing chamber via a first drain path located in a moveable drain mechanism in communication with the processing chamber.

17. The method of claim 15 wherein the non-contact force comprises magnetic force.

18. A system for processing a workpiece, comprising: a plurality of workpiece processors, with at least one of the workpiece processors comprising: an upper rotor; a lower rotor engageable to the upper rotor to form a workpiece processing chamber; a moveable drain assembly alignable with the processing chamber, the drain assembly separated from the processing chamber by a gap in which a downward airflow is created when the drain assembly is lowered and/or the upper rotor is raised; and a robot moveable between the workpiece processors for loading and unloading a workpiece into and out of one or more processors.

19. The system of claim 18 wherein the gap is 0.125 to 0.250 inches wide.

20. A workpiece processor, comprising: an upper rotor having a through air flow opening; a lower rotor engageable to the upper rotor to form a workpiece processing chamber; wherein the through air flow opening in the upper rotor has a diameter which is 20-80% of the diameter of the workpiece.

21. The processor of claim 20 further comprising an upper fluid applicator extending into the through opening in the upper rotor, to provide a processing fluid to an upper surface of the workpiece.

22. The processor of claim 21 further comprising an actuator for moving the upper fluid applicator within the through opening.

23. The processor of claim 21 wherein the upper fluid applicator comprises a nozzle having a collection section for collecting processing fluid when fluid delivery to the upper nozzle is discontinued so that excess processing fluid does not drip from the upper nozzle into the processing chamber.

24. The processor of claim 20 further comprising a lower fluid applicator extending through the lower rotor for introducing a processing fluid to a lower surface of a workpiece.

25. The processor of claim 20 further comprising one or more magnets for engaging the upper and lower rotors.

26. The processor of claim 20 further comprising a moveable drain assembly including a plurality of drain paths, with each drain path separately alignable with the processing chamber by vertically moving the drain assembly.

27. A system for processing a workpiece, comprising: a plurality of workpiece processors, with at least one of the workpiece processors comprising: an upper rotor having a through air flow opening; a lower rotor engageable to the upper rotor to form a workpiece processing chamber; an air supply line in communication with the processing chamber and having an inlet located vertically above the processing chamber for delivering clean air into the processing chamber; and a robot moveable between the workpiece processors for loading and unloading a workpiece into and out of one or more processors.

28. A system for processing a workpiece, comprising: a plurality of workpiece processors, with at least one of the workpiece processors comprising: a first rotor; a second rotor engagement means for engaging the first rotor to the second rotor, without the need for physical contact with the first rotor, with the engagement means including elements for creating magnetic repulsion or attraction force on a rotor; and loading means for loading a workpiece into and out of one or more of the processors.

29. A system for processing a workpiece, comprising: a plurality of workpiece processors, with at least one of the workpiece processors comprising: a first rotor; a second rotor engagement means for engaging the first rotor to the second rotor, without the need for physical contact with the first rotor; drain means for separately draining fluids from the processing chamber; and loading means for loading a workpiece into and out of one or more of the processors.

30. The system of claim 29 wherein the engagement means comprises elements for creating magnetic repulsion or attraction on the first or second rotor.

31. A workpiece processor, comprising: a base housing; a base magnet on the base housing; a first rotor rotatable within the base housing; a second rotor adapted to engage and form a processing chamber with the first rotor; a rotor

magnet on the first rotor, with the rotor magnet repelled by the base magnet.

32. The system of claim 31 further comprising means for spinning the first rotor, with the first rotor making no physical contact with the housing while spinning.

33. The system of claim 31 where the base magnet, or the rotor magnet, or both, comprise a magnet ring.

34. A workpiece processor, comprising: a fixed, non-rotating housing; at least one housing magnet on the housing; a first rotor rotatable within the housing; at least one rotor magnet on the first rotor; a second rotor engageable with the first rotor; and with first rotor biased away from the housing via the rotor magnet repelling the housing magnet.

35. The workpiece processor of claim 34 further comprising a drain assembly vertically moveable relative the first rotor.

36. A workpiece processor, comprising: an upper rotor; a lower rotor engageable with the upper rotor to form a workpiece processing chamber; and a moveable drain assembly including a plurality of separate drain paths, with each drain path separately alignable with the processing chamber by moving the drain mechanism to align a single drain path with the processing chamber.

37. The processor of claim 36 wherein the lower rotor is at a fixed vertical position, and the drain assembly is moveable vertically, relative to the lower rotor.

38. The system of claim 36 wherein the upper rotor has a central through opening for air flow having a diameter of 20-80% of the diameter of the workpiece.

39. A workpiece processor, comprising: a first rotor; a second rotor; and engagement means for engaging the first rotor to the second rotor, without the need for physical contact with the first rotor.

40. The processor of claim 39 wherein the engagement means comprises elements for creating magnetic repulsion or attraction between the first and second rotors.

41. The processor of claim 39 further comprising drain means for separately draining fluids from the processing chamber.

42. A workpiece processor, comprising: an upper rotor; a lower rotor engageable with the upper rotor to form a processing chamber; an opening in the lower rotor; and a snorkel having a first end vertically above the upper rotor, and having a second end leading to the opening in the lower rotor.

43. The processor of claim 42 further comprising a nozzle arranged to spray a process liquid through the opening in the lower rotor and onto a lower surface of a workpiece in the processing chamber, a tube connecting to the nozzle and to the second end of the snorkel, and a valve associated with the snorkel or the tube.

44. A workpiece processor, comprising: an upper rotor; a lower rotor engageable with the upper rotor; a sump section on the lower rotor; and a nozzle extending up at least partially through the sump section.

45. The processor of claim 44 wherein the sump section comprises a conical depression around the center of the lower rotor.