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TITLE OF THE INVENTION

LIFT AND ROTATE ASSEMBLY FOR USE IN A WORKPIECE
PROCESSING STATION AND A METHOD OF ATTACHING
THE SAME

CROSS-REFERENCE TO RELATED APPLICATIONS

Not Applicable

STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH
OR DEVELOPMENT

Not Applicable

BACKGROUND OF THE INVENTION

The present invention is directed to an apparatus for processing of semiconductor wafers, and in particular, a lift and rotate assembly for use in a workpiece processing station.

During the manufacture of semiconductor integrated circuits and other semiconductor articles from semiconductor wafers, it is often necessary to perform several processing steps in one or more processing stations. In order to more fully automate the process and minimize operator handling, tool architectures have been developed incorporating multiple processing stations and automated means for moving semiconductor wafers from one processing station to the next.

When developing a tool architecture one consideration is the overall size of a

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tool. One reason for this is because the manufacture of semiconductor integrated circuits typically take place in a clean room environment, where the creation and maintenance of clean room space has a relatively higher cost, which is related to the size of the space. As a result efforts and developments which reduce the overall tool size can have a significant cost benefit.

Tool size can often be an important consideration when adding to and/or updating a particular tool in a line. If the size and shape of the new tool is equal to or smaller than the available space or the space created by the removal of the old tool being replaced, the impact on nearby tools is minimized. In contrast, when a new or replacement tool is larger than the available space or the space required by the previous tool, it can potentially require the adjustment and/or relocation of the placement of nearby tools.

One reason to update one or more tools in a semiconductor manufacturing line is to make a transition from a smaller to a larger wafer size. The use of larger wafer sizes is desirable because it enables a greater number of devices to be manufactured on each wafer. By producing more devices on each wafer the cost of manufacturing each device can often be reduced.

Whereas the present standard wafer size for a majority of semiconductor manufacturing lines is 200 millimeters, there is an increasing trend toward the use of 300 millimeter wafers. Therefore efforts at minimizing or maintaining tool size, while enabling the tool to handle larger wafer sizes would similarly be beneficial.

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Another consideration when developing a tool architecture is ease of maintenance. Occasionally individual processing stations or portions thereof, need to be removed for regular cleaning and/or maintenance, or replacement. The easier it is to service the assembly or subassembly requiring maintenance, the less time a tool will be down or out of service.

Ease of maintenance becomes especially important when one considers that, as previously noted, semiconductor manufacturing tools are often located in a clean room environment. In clean room environments, personnel are typically required to wear protective clothing including gloves, coats, masks, etc., which can make even routine tasks more cumbersome. Therefore improvements in accessibility of installed assemblies and/or subassemblies and the ease of installation and/or removal of the same would similarly be beneficial.

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BRIEF SUMMARY OF THE INVENTION

A lift and rotate assembly for use in a workpiece processing station is provided. The lift and rotate assembly comprises a body and a process head for receiving a workpiece. The process head is coupled to the body by an assembly, which enables the process head to be lifted and/or rotated with respect to the body.

In at least one embodiment the assembly coupling the body to the process head is coupled to a workpiece processing tool frame which includes a tool platform, without encroaching upon the tool platform. The assembly coupling the body to the process head can be used to couple various types of processing heads to various types of processing chambers. In one example the assembly is used in connection with a processing head having a plurality of contacts in the form of discrete flexures or a Belville ring contact. In another example the assembly is used in connection with a processing head having a workpiece housing, which is rotated by a motor and distributes processing fluid across at least one face of a workpiece by centrifugal force.

In at least another embodiment the lift and rotate assembly has a rotating portion which includes a motor, wherein the motor is located within the process head. The shaft of the motor is coupled to and rotationally fixed with respect to the body.

In at least yet another embodiment the lift and rotate assembly further includes a lift mechanism for lifting the portion of the body coupled to the process

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head with respect to the other portion of the body, in addition to the rotating mechanism.

The lift and rotate assembly further provides for a cable assembly providing at least one of signals, gases, and fluids to the processing head. The cable assembly includes a common cable loop for feeding additional length of cable along both the lift direction of movement by the lift mechanism and the rotational direction of movement by the rotating mechanism.

In a further embodiment the lift and rotate assembly provides for pins adapted for mounting the assembly to an exposed surface of a tool frame.

BRIEF DESCRIPTION OF THE SEVERAL
VIEWS OF THE DRAWINGS

FIG. 1 illustrates a top plan view of a prior art processing tool.

FIG. 2 illustrates an isometric view of a partial processing tool in accordance with the present invention shown with several panels removed.

FIG. 3 illustrates an isometric front view of the lift and rotate assembly in accordance with the present invention, showing the process head lifted vertically into a raised position with the process head rotated up into a load position.

FIG. 4 illustrates an isometric back view of the lift and rotate assembly illustrated in FIG. 3.

FIG. 5 illustrates an isometric front view of the lift and rotate assembly in accordance with the present invention, showing the process head lowered vertically into a lowered position with the process head rotated down into a processing position.

FIG. 6 illustrates an isometric back view of the lift and rotate assembly illustrated in FIG. 5.

FIG. 7 illustrates an isometric view of the lift and rotate assembly mounted to an exposed surface of a processing tool with the side panel removed.

FIG. 8 illustrates an isometric view of the socket, saddle, and adjustable surfaces, coupled to an exposed surface of the processing tool, within and against which the pins of the lift and rotate assembly rest.

FIG. 9 illustrates the lift and rotate assembly of FIG. 4 with the back covers

removed.

FIG. 10 illustrates the lift and rotate assembly of FIG. 6 with the back covers removed.

FIG. 11 illustrates a side cross sectional view of the lift and rotate assembly rotated down in the processing position.

FIG. 12 illustrates a cross-sectional view of a microelectronic workpiece housing and a rotor assembly corresponding to part of a processing station, which can incorporate the lift and rotate assembly of FIGS. 3-11.

FIG. 13 illustrates an exploded view of a further embodiment of a microelectronic workpiece housing.

FIG. 14 illustrates a top plan view of the workpiece housing of FIG. 13 when the housing is in an assembled state.

FIG. 15 illustrates a cross-sectional view of the workpiece housing taken along line 15 - 15 of FIG. 14.

FIG. 16 illustrates a cross-sectional view of the workpiece housing taken along line 16 - 16 of FIG. 14.

FIG. 17 illustrates a cross-sectional view of the workpiece housing taken along line 17 - 17 of FIG. 14.

FIGS. 18A and 18B illustrate cross-sectional views showing the workpiece housing in a closed state and connected to a rotary drive assembly.

FIGS. 19A and 19B illustrate cross-sectional views showing the workpiece

housing in an open state and connected to a rotary drive assembly.

FIG. 20 illustrates a cut-away, perspective view of a reactor of a similar type, as shown in FIGS. 12-19, seen from a different vantage.

FIG. 21 illustrates a cross-sectional view of the reactor, as taken through its central, vertical axis.

FIG. 22 illustrates an enlarged detail of certain elements of the reactor, as taken within a circle drawn in FIG. 14.

FIGS. 23 and 24 illustrate further enlarged details of a portion of what is illustrated in FIG. 22, as taken at different places around the reactor.

FIG. 25 illustrates a cross-sectional view through an electroplating reactor, which can also incorporate the lift and rotate assembly of FIGS. 3-11.

FIG. 26 illustrates a specific construction of one embodiment of a reactor bowl suitable for use in the assembly illustrated in FIG. 25.

FIG. 27 illustrates one embodiment of a process head, comprised of a stationary assembly and a rotor assembly that is suitable for use in the reactor illustrated in FIG. 25.

FIG. 28 illustrates one embodiment of a contact assembly using flexure contacts that is suitable for use in the reactor assembly illustrated in FIG. 25.

FIGS. 29 - 33 illustrate various aspects of one embodiment of a quick-attach mechanism.

FIG. 34 is a cross-sectional view of the reactor head illustrating the

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disposition of the process head in a condition in which it may accept a workpiece.

FIG. 35 is a cross-sectional view of the process head illustrating the disposition of the process head in a condition in which it is ready to present the workpiece to the reactor bowl.

FIG. 36 illustrates an exploded view one embodiment of the rotor assembly.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 illustrates a top plan view of one example of a prior art processing tool 10. Specifically, FIG. 1 illustrates a top plan view of the top deck 15 of an LT-210™ processing tool manufactured by Semitool, Inc. The LT-210™ processing tool is a tool architecture designed for processing semiconductor wafers up to 200 millimeters in size. The deck 15 includes openings 20 and 25 within which individual processing stations or components thereof can be received. Openings 20 correspond to openings within which processing chambers/bowls are typically received. Openings 25 correspond to openings within which corresponding lift and rotate mechanisms are typically received. To install a corresponding lift and rotate assembly, the assembly is raised above the opening and a portion of the assembly is inserted into the opening 25.

FIG. 2 illustrates an isometric view of a partial processing tool 100, in accordance with the present invention. Several of the panels are shown removed, however, a pair of side panels 105 are shown still in place. FIG. 2 further shows several lift and rotate assemblies 200, which are installed in the partial processing tool 100. Some of the lift and rotate assemblies 200 are shown without their corresponding process heads 205. Similar to the processing tool 10 in FIG. 1, the processing tool 100 includes a deck 110 having openings 115 within which processing chambers/bowls 400 (FIG. 7) are typically received.

Whereas the lift and tilt assemblies of the prior art processing tool 10 (FIG. 1) have openings 25 in the deck 10 within which the lift and tilt assemblies are received,

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the preferred embodiment of the present invention includes lift and tilt assemblies 200, which attach at the back edge 120 of the deck 110. This enables more room on the deck for accommodating a larger processing chamber/bowl which is capable of handling larger wafer sizes.

The lift and rotate assemblies 200 can be used in conjunction with the processing chambers/bowls 400 to provide for processes including plating processes, rinse/dry processes, electroless plating processes, and/or immersion chamber processes.

FIGS. 3 and 4 illustrate an isometric view of each of the front and back view of the lift and rotate assembly 200. The lift and rotate assembly includes a process head 205 and a base 210. The process head 205 is rotatably coupled to the base by a rotating mechanism more clearly shown in connection with FIG. 11. The base 210 includes a first portion 215 and a second portion 220. The second portion 220 is adapted so as to be capable of being lifted with respect to the first portion 215. Specifically, the process head 205 is coupled to the second portion 220 of the base 210, so as to move with the second portion 220 as it moves with respect to the first portion 215.

In the preferred embodiment the process head 205 is shown with a single ring contact 225, against which a wafer to be processed after being received will be held in place. In at least one preferred embodiment the ring contact provides power to the wafer.

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At the side near the bottom of the base 210 is a connection box 230 through which signal, including both communication and power signals, gases, and fluids can be received. In the preferred embodiment, the connection box 230 includes three terminals 235, 240 and 245. Terminal 235 receives electronic signals. Terminal 240 receives plating power. Terminal 245 receives gases for actuating the pneumatics and for a backside nitrogen (N_2) purge.

The body 210 further includes a pair of pins 250 (one not shown) on each side of the body 210. The pins 250 are adapted for mounting the lift and rotate assembly to the workpiece processing tool frame 100, shown in FIG. 2.

FIGS. 5 and 6 illustrate an isometric view of each of the front and back view of the lift and rotate assembly 200 in accordance with the present invention, showing the process head 205 lowered vertically into a lowered position with the process head 205 rotated down into a processing position. Otherwise the features are very similar to the ones shown in FIGS. 3 and 4.

FIG. 7 illustrates an isometric view of the lift and rotate assembly 200 mounted to an exposed surface 125 of a processing tool 100 with the side panel 105, shown in FIG. 2, removed. On the exposed surface 125 of the processing tool 100 is a socket 130, a saddle 135, and a pair of adjustable surfaces 140. A pair of clips 145 captivates the two top pins 250 with respect to each of the adjustable surfaces 140. It is noted that the clips can take on a variety of forms. A couple of examples include a screw on clamp or a self retaining spring clip.

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Processing chambers/bowls 400 are shown extending from openings within the deck 110.

FIG. 8 illustrates an isometric view of the socket 130, saddle 135, and adjustable surfaces 140, coupled to an exposed surface 125 of the processing tool 100, within and against which the pins 250 of the lift and rotate assembly 200 are adapted to rest.

The socket 130 includes a spherical recess 150 for receiving a pin 250, and has a jack screw 160, which enables the socket 130 to be adjusted in a direction shown by the arrow labeled X. The saddle 135 includes a cylindrical groove 155 for receiving a pin 250, and similarly has a jack screw 165, which enables the saddle 135 to be adjusted in a direction shown by the arrow labeled Z. A pair of jack screws 170 enables the adjustable surfaces 140 to be adjusted in a direction shown by the arrows labeled Y.

Initially when the lift and rotate assembly 200 is being installed, the lower left pin 250 is placed in the spherical groove 150 of the socket 130. With the lower left pin in place, the lower right pin 250 is then lifted up and over the lip 175 of the saddle 135 and lowered into the cylindrical groove 155.

Aided by the weight of the process head 205, the center of gravity causes the remaining two upper pins 250 of the lift and rotate assembly 200 to fall in the direction of the process head 205 until it comes into contact with the adjustable surfaces 140. In order to provide greater stability, the upper pins 250 of the lift and

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rotate assembly 200 are captivated against the adjustable surfaces 140. A pair of clips 145 are attached to the adjustable surfaces 140 in holes 180 located at the top of the adjustable surface. When in place the clips 145 extend over and around the upper pins 250, as shown in FIG. 7.

The socket 130, the saddle 135, and the adjustable surfaces 140 can each be independently adjusted to provide proper alignment with the process chamber/bowl 400. Adjustment is provided by turning one or more of the jack screws.

By attaching the lift and rotate assembly 200 to the exposed surface 125 of processing tool 100 via the pins 250 and corresponding hardware 130, 135 and 140, the lift and rotate assembly 200 can be readily attached and detached from the processing tool 100. Furthermore the full surface of the deck 110 can then be used to provide an opening for the processing chamber/bowl 400 thereby maximizing bowl size.

Another factor which influences the available space on the deck 110 is the depth D of the body 210. The depth of the body 210 is affected by the arrangement of the mechanical and electrical components inside the body 210.

FIGS. 9 and 10 illustrate the lift and rotate assembly of FIGS. 4 and 6 with the back covers removed. With the back covers removed, the internal structure of the body 210 of the lift and rotate assembly 200 becomes visible.

The preferred embodiment of the lift and rotate assembly 200 includes a lift mechanism 255. The lift mechanism includes a lift axis motor 260 and a lift actuator

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265, which turns a ball screw 270. As the ball screw turns a guide block 275 travels up and down the ball screw. The guide block 275 is coupled to the second portion 220 of the body 210. Correspondingly, as the guide block 275 travels up and down in response to the turning of the ball screw 270, the second portion 220 of the body 210 is raised and lowered.

A compressed gas spring 280 is coupled between the first portion 215 and the second portion 220 of the body 210. The gas spring 280 ideally provides a counterbalance force approximately equivalent to the force of gravity being exerted on the process head 205 and related components being similarly raised and lowered. This minimizes the force required by the lift axis motor 260 for raising and lowering the process head 205.

The preferred embodiment further includes a linear encoder 282, which provides the lift mechanism 255 with absolute coordinates for locating itself.

Located within the second portion 220 of the body 210 is a rotate axis assembly 285. The rotate axis assembly includes a sensor 290 and a sensor flag 295 for monitoring the rotational movement of the process head 205. The rotate axis assembly is coupled to a rotating mechanism 300 (FIG. 11) including a motor 305 (FIG. 11) located in the process head 205.

The shaft 310 of the motor 305 is coupled to and rotationally fixed with respect to the body 210. By fixing the motor shaft 310, the motor 305 rotates when activated, correspondingly rotating the process head 205. This enables the

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processing head to be rotated, and the bulk of the motor 305 to be located in the processing head 205. As a result, a body 210 having a reduced depth D is possible.

The process head 205 receives at least one of signals, gases, and fluids from the signals, gases, and fluids supplied to the lift and rotate assembly 200 via the connection box 230 and a cable assembly 295. The cable assembly includes a cable loop 315 for feeding additional length of cable to account for movement by the lift mechanism 255 and the rotating mechanism 300. In positioning the rotating mechanism 300 and the lift mechanism 255, the rotating mechanism 300 has been aligned with the lift mechanism 255 so as to provide a common direction of movement.

By providing a common direction of movement a single cable loop 315 can provide additional cable length for both the lift direction of movement and the rotational direction of movement, thus eliminating the need for a second cable loop. By eliminating the need for a second cable loop further space is conserved within the body 210 of the lift and rotate assembly 200.

The base 210 further includes circuitry 320 for controlling the functioning of the lift and rotate assembly 200.

By locating the bulk of the rotating mechanism 300 in the process head 205 and eliminating the need for a second cable loop, space is conserved in the base 210 of the lift and rotate assembly 200. Correspondingly this allows for the depth D of the lift and rotate assembly 200 to be reduced and greater space on the deck 110 of

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the processing tool 100 to be available for the processing chamber/bowl 400.

FIG. 11 illustrates a side cross sectional view of the lift and rotate assembly rotated down in the processing position. In addition to illustrating the presence of the bulk of the motor for the rotating mechanism 300 in the processing head, FIG. 11 illustrates a second motor 325 adapted for spinning a received workpiece in a plane parallel to the face 330 of the process head 205.

The lift and rotate assembly 200 generally can be used in various types of processing stations for coupling various types of processing heads to various types of processing chambers. A couple of examples of one type of processing station are illustrated in FIGS. 12-24. The processing station illustrated in FIGS. 12-19 incorporates a capsule type processing environment or workpiece housing, which is rotated by a motor and distributes processing fluid across at least one face of a workpiece by centrifugal force.

As illustrated in FIG. 12, the processing station is generally comprised of a rotor portion 1015 and a microelectronic workpiece housing 1020. The rotor portion 1015 includes a plurality of support members 1025 that extend downwardly from the rotor portion 1015 to engage the workpiece housing 1020. Each of the support members 1025 includes a groove 1030 that is dimensioned to engage a radially extending flange 1035 that extends about a peripheral region of the workpiece housing 1020. Rotor portion 1015 further includes a rotor motor assembly 1040 that is disposed to rotate a hub portion 1045, including the support

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members 1025, about a central axis 1047. Workpiece housing 1020 is thus secured for co-rotation with hub portion 1045 when support members 1025 are engaged with flange 1035. Other constructions of the rotor portion 1015 and the engagement mechanism used for securement with the workpiece housing 1020 may also be used.

The workpiece housing 1020 of the embodiment of FIG. 12 defines a substantially closed processing chamber 1050. Preferably, the substantially closed processing chamber 1050 is formed in the general shape of the microelectronic workpiece 1055 and closely conforms with the surfaces of the workpiece. The specific construction of FIG. 12 includes an upper chamber member 1060 having an interior chamber face 1065. The upper chamber member 1060 includes a centrally disposed fluid inlet opening 1070 in the interior chamber face 1065. The specific construction also includes a lower chamber member 1075 having an interior chamber face 1080. The lower chamber member 1075 has a centrally disposed fluid inlet opening 1085 in the interior chamber face 1080. The upper chamber member 1060 and the lower chamber member 1075 engage one another to define the processing chamber 1050. The upper chamber member 1060 includes sidewalls 1090 that project downward from the interior chamber face 1065. One or more outlets 1100 are disposed at the peripheral regions of the processing chamber 1050 through the sidewalls 1090 to allow fluid within the chamber 1050 to exit therefrom through centripetal acceleration that is generated when the housing 1020

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is rotated about axis 1047.

In the illustrated embodiment, the microelectronic workpiece 1055 is a generally circular wafer having upper and lower planar surfaces. As such, the processing chamber 1050 is generally circular in plan view and the interior chamber faces 1065 and 1080 are generally planar and parallel to the upper and lower planar surfaces of the workpiece 1055. The spacing between the interior chamber faces 1065 and 1080 and the upper and lower planar surfaces of the workpiece 1055 is generally quite small. Such spacing is preferably minimized to provide substantial control of the physical properties of a processing fluid flowing through the interstitial regions.

The wafer 1055 is spaced from the interior chamber face 1080 by a plurality of spacing members 1105 extending from the interior chamber face 1080. Preferably, a further set of spacing members 1110 extend from the interior chamber face 1065 and are aligned with the spacing members 1105 to grip the wafer 1055 therebetween.

Fluid inlet openings 1070 and 1085 provide communication passageways through which one or more processing fluids may enter the chamber 1050 for processing the wafer surfaces. In the illustrated embodiment, processing fluids are delivered from above the wafer 1055 to inlet 1070 through a fluid supply tube 1115 having a fluid outlet nozzle 1120 disposed proximate inlet 1070. Fluid supply tube 1115 extends centrally through the rotor portion 1015 and is preferably concentric

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with the axis of rotation 1047. Similarly, processing fluids are delivered from below the wafer 1055 to inlet 1085 through a fluid supply tube 1125. Fluid supply tube 1125 terminates at a nozzle 1130 disposed proximate inlet 1085. Although nozzles 1120 and 1130 terminate at a position that is spaced from their respective inlets, it will be recognized that tubes 1115 and 1125 may be extended so that gaps 1135 are not present. Rather, nozzles 1120 and 1130 or tubes 1115 and 1125 may include rotating seal members that abut and seal with the respective upper and lower chamber members 1060 and 1075 in the regions of the inlets 1070 and 1085. In such instances, care should be exercised in the design of the rotating joint so as to minimize any contamination resulting from the wear of any moving component.

During processing, one or more processing fluids are individually or concurrently supplied through fluid supply tubes 1115 and 1125 and inlets 1070 and 1085 for contact with the surfaces of the workpiece 1055 in the chamber 1050. Preferably, the housing 1020 is rotated about axis 1047 by the rotor portion 1015 during processing to generate a continuous flow of any fluid within the chamber 1050 across the surfaces of the workpiece 1055 through the action of centripetal acceleration. Processing fluid entering the inlet openings 1070 and 1085 are thus driven across the workpiece surfaces in a direction radially outward from the center of the workpiece 1055 to the exterior perimeter of the workpiece 1055. At the exterior perimeter of the workpiece 1055, any spent processing fluid is directed to exit the chamber 1050 through outlets 1100 as a result of the centripetal

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acceleration. Spent processing fluids may be accumulated in a cup reservoir disposed below and/or about the workpiece housing 1020. As will be set forth below in an alternative embodiment, the peripheral regions of the workpiece housing 1020 may be constructed to effectively separate the processing fluids provided through inlet 1070 from the processing fluids supplied through inlet 85 so that opposite surfaces of wafer 1055 are processed using different processing fluids. In such an arrangement, the processing fluids may be separately accumulated at the peripheral regions of the housing 1020 for disposal or recirculation.

In the embodiment of FIG. 12, the workpiece housing 1020 may constitute a single wafer pod that may be used to transport the workpiece 1055 between various processing stations and/or tools. If transport of the housing 1020 between the processing stations and/or tools takes place in a clean room environment, the various openings of the housing 1020 need not be sealed. However, if such transport is to take place in an environment in which wafer contaminants are present, sealing of the various housing openings should be effected. For example, inlets 1070 and 1085 may each be provided with respective polymer diaphragms having slits disposed therethrough. The ends of fluid supply tubes 1115 and 1125 in such instances may each terminate in a tractor structure that may be used to extend through the slit of the respective diaphragm and introduce the processing fluid into the chamber 1050. Such

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tracor/slitted diaphragm constructions are used in the medical industry in intravenous supply devices. Selection of the polymer material used for the diaphragms should take into consideration the particular processing fluids that will be introduced therethrough. Similar sealing of the outlets 1100 may be undertaken in which the tracor structures are inserted into the diaphragms once the housing 1020 is in a clean room environment.

Alternatively, the outlets 1100 themselves may be constructed to allow fluids from the processing chamber to exit therethrough while inhibiting the ability of fluids to proceed from the exterior of housing 1020 into chamber 1050. This effect may be achieved, for example, by constructing the openings 1100 as nozzles in which the fluid flow opening has a larger diameter at the interior of chamber 1050 than the diameter of the opening at the exterior of the housing 1020. In a further construction, a rotational valve member may be used in conjunction with the plurality of outlets 1100. The valve member, such as a ring with openings corresponding to the position of outlets 1100, would be disposed proximate the opening 1100 and would be rotated to seal with the outlets 1100 during transport. The valve member would be rotated to a position in which outlets 1100 are open during processing. Inert gas, such as nitrogen, can be injected into the chamber 1050 through supply tubes 1115 and 1125 immediately prior to transport of the housing to a subsequent tool or processing

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station. Various other mechanisms for sealing the outlets 1100 and inlets 1070 and 1085 may also be employed.

FIG. 13 is a perspective view of a further reactor construction wherein the reactor is disposed at a fixed processing station and can open and close to facilitate insertion and extraction of the workpiece. The reactor, shown generally at 1200, is comprised of separable upper and lower chamber members, 1205 and 1210, respectively. As in the prior embodiment, the upper chamber member 1205 includes a generally planar chamber face 1215 having a centrally disposed inlet 1220. Although not shown in the view of FIG. 13, the lower chamber member 1210 likewise has a generally planar interior chamber face 1225 having a central inlet 1230 disposed therethrough. The upper chamber member 1205 includes a downwardly extending sidewall 1235 that, for example, may be formed from a sealing polymer material or may be formed integrally with other portions of member 1205.

The upper and lower chamber members, 1205 and 1210, are separable from one another to accept a workpiece therebetween. With a workpiece disposed between them, the upper and lower chamber members, 1205 and 1210, move toward one another to form a chamber in which the workpiece is supported in a position in which it is spaced from the planar interior chamber faces 1215 and 1225. In the embodiment of the reactor disclosed in FIGS. 13-19B, the workpiece, such as a semiconductor wafer, is clamped in place between a plurality of support

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members 1240 and corresponding spacing members 1255 when the upper and lower chamber members are joined to form the chamber (see FIG. 18B). Axial movement of the upper and lower chamber members toward and away from each other is facilitated by a plurality of fasteners 1307, the construction of which will be described in further detail below. Preferably, the plurality of fasteners 1307 bias the upper and lower chambers to a closed position such as illustrated at FIG. 18A.

In the disclosed embodiment, the plurality of wafer support members 1240 extend about a peripheral region of the upper chamber member 1205 at positions that are radially exterior of the sidewall 1235. The wafer support members 1240 are preferably disposed for linear movement along respective axes 1245 to allow the support members 1240 to clamp the wafer against the spacing members 1255 when the upper and lower chamber members are in a closed position (see FIG. 18A), and to allow the support members 1240 to release the wafer from such clamping action when the upper and lower chamber members are separated (see FIG. 19A). Each support member 1240 includes a support arm 1250 that extends radially toward the center of the upper chamber member 1205. An end portion of each arm 1250 overlies a corresponding spacing member 1255 that extends from the interior chamber face 1215. Preferably, the spacing members 1255 are each in the form of a cone having a vertex terminating proximate the end of the support arm 1250. Notches 1295 are disposed at peripheral portions of the lower chamber member 1210 and engage rounded lower portions 1300 of the wafer support

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members 1240. When the lower chamber member 1210 is urged upward to the closed position, notches 1295 engage end portions 1300 of the support members 1240 and drive them upward to secure the wafer 1055 between the arms 1250 of the supports 1240 and the corresponding spacing members 1255. This closed state is illustrated in FIG. 16. In the closed position, the notches 1295 and corresponding notches 1296 of the upper chamber member (see FIG. 13) provide a plurality of outlets at the peripheral regions of the reactor 1200. Radial alignment of the arm 1250 of each support member 1240 is maintained by a set pin 1308 that extends through lateral grooves 1309 disposed through an upper portion of each support member.

The construction of the fasteners 1307 that allow the upper and lower chamber members to be moved toward and away from one another is illustrated in FIGS. 13, 17 and 18B. As shown, the lower chamber member 1210 includes a plurality of hollow cylinders 1270 that are fixed thereto and extend upward through corresponding apertures 1275 at the peripheral region of the upper chamber member 1205 to form lower portions of each fastener 1307. Rods 1280 extend into the hollow of the cylinders 1270 and are secured to form an upper portion of each fastener 1307. Together, the rods 1280 and cylinders 1270 form the fasteners 1307 that allow relative linear movement between the upper and lower chamber members, 1205 and 1210, along axis 1283 between the open and closed position. Two flanges, 1285 and 1290, are disposed at an upper portion of each rod 1280.

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Flange 1285 functions as a stop member that limits the extent of separation between the upper and lower chamber members, 1205 and 1210, in the open position. Flanges 1290 provide a surface against which a biasing member, such as a spring (see FIG. 17) or the like, acts to bias the upper and lower chamber members, 1205 and 1210, to the closed position.

With reference to FIG. 17, the spring 1303 or the like, has a first end that is positioned within a circular groove 1305 that extends about each respective fastener 1307. A second end of each spring is disposed to engage flange 1290 of the respective fastener 1307 in a compressed state thereby causing the spring to generate a force that drives the fastener 1307 and the lower chamber member 1210 upward into engagement with the upper chamber member 1205.

The reactor 1200 is designed to be rotated about a central axis during processing of the workpiece. To this end, a centrally disposed shaft 1260 extends from an upper portion of the upper chamber member 1205. As will be illustrated in further detail below in FIGS 18A – 19B, the shaft 1260 is connected to engage a rotary drive motor for rotational drive of the reactor 1200. The shaft 1260 is constructed to have a centrally disposed fluid passageway (see FIG. 15) through which a processing fluid may be provided to inlet 1220. Alternatively, the central passageway may function as a conduit for a separate fluid inlet tube or the like.

As illustrated in FIGS. 14 and 15, a plurality of optional overflow passageways 1312 extend radially from a central portion of the upper chamber

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member 1205. Shaft 1260 terminates in a flared end portion 1315 having inlet notches 1320 that provide fluid communication between the upper portion of processing chamber 1310 and the overflow passageways 1312. The flared end 1315 of the shaft 1260 is secured with the upper chamber member 1205 with, for example, a mounting plate 1325. Mounting plate 1325, in turn, is secured to the upper chamber member 1205 with a plurality of fasteners 1330 (FIG. 16). Overflow passages 1312 allow processing fluid to exit the chamber 1310 when the flow of fluid to the chamber 1310 exceeds the fluid flow from the peripheral outlets of the chamber.

FIGS. 18A and 18B are cross-sectional views showing the reactor 1200 in a closed state and connected to a rotary drive assembly, shown generally at 1400, while FIGS. 19A and 19B are similar cross-sectional views showing the reactor 1200 in an opened state. As shown, shaft 1260 extends upward into the rotary drive assembly 1400. Shaft 1260 is provided with the components necessary to cooperate with a stator 1405 to form a rotary drive motor assembly 1410.

As in the embodiment of FIG. 12, the upper and lower chamber members 1205 and 1210 join to define the substantially closed processing chamber 1310 that, in the preferred embodiment, substantially conforms to the shape of the workpiece 1055. Preferably, the wafer 1055 is supported within the chamber 1310 in a position in which its upper and lower faces are spaced from the interior chamber faces 1215 and 1225. As described above, such support is facilitated by the support

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members 1240 and the spacing members 1255 that clamp the peripheral edges of the wafer 1055 therebetween when the reactor 1200 is in the closed position of FIGS. 18A and 18B.

It is in the closed state of FIGS. 18A and 18B that processing of the wafer 1055 takes place. With the wafer secured within the processing chamber 1310, processing fluid is provided through passageway 1415 of shaft 1260 and inlet 1220 into the interior of chamber 1310. Similarly, processing fluid is also provided to the chamber 1310 through a processing supply tube 1125 that directs fluid flow through inlet 1230. As the reactor 1200 is rotated by the rotary drive motor assembly 1410, any processing fluid supplied through inlets 1220 and 1230 is driven across the surfaces of the wafer 1055 by forces generated through centripetal acceleration. Spent processing fluid exits the processing chamber 1310 from the outlets at the peripheral regions of the reactor 1200 formed by notches 1295 and 1296. Such outlets exist since the support members 1240 are not constructed to significantly obstruct the resulting fluid flow. Alternatively, or in addition, further outlets may be provided at the peripheral regions.

Once processing has been completed, the reactor 1200 is opened to allow access to the wafer, such as shown in FIGS. 19A and 19B. After processing, actuator 1425 is used to drive an actuating ring 1430 downward into engagement with upper portions of the fasteners 1307. Fasteners 1307 are driven against the bias of spring 1303 causing the lower chamber member 1210 to descend and

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separate from the upper chamber member 1205. As the lower chamber member 1210 is lowered, the support members 1240 follow it under the influence of gravity, or against the influence of a biasing member, while concurrently lowering the wafer 1055. In the lower position, the reactor chamber 1310 is opened thereby exposing the wafer 1055 for removal and/or allowing a new wafer to be inserted into the reactor 1200. Such insertion and extraction can take place either manually, or by an automatic robot.

The foregoing arrangement makes the reactor 1200 particularly well-suited for automated workpiece loading and unloading by, for example, a robotic transfer mechanism or the like. As evident from a comparison of FIGS. 18A and 19A, the spacing between the upper surface of the workpiece and the interior chamber wall of the upper chamber member 1205 varies depending on whether the reactor 1200 is in an open or closed state. When in the open state, the upper surface of the workpiece is spaced from the interior chamber wall of the upper chamber member 1205 by a distance, x_1 , that provides sufficient clearance for operation of, for example, a workpiece transfer arm of a robotic transfer mechanism. When in the closed processing state, the upper surface of the workpiece is spaced from the interior chamber wall of the upper chamber member 1205 by a distance, x_2 , that is less than the distance, x_1 . The distance, x_2 , in the disclosed embodiment may be chosen to correspond to the spacing that is desired during workpiece processing operations.

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FIGS. 20-24, illustrate a further example of a processing station similar to the type shown in FIGS. 12-19. In FIGS. 20-24, there is shown a reactor 2100 for processing a microelectronic workpiece, such as a silicon wafer 2010 having an upper side 2012, a lower side 2014, and an outer, circular perimeter 2016, in a micro-environment. For certain applications, the upper side 2012 is the front side, which may be otherwise called the device side, and the lower side 2014 is the back side, which may be otherwise called the non-device side. However, for other applications, the silicon wafer 2010 is inverted.

Generally, except as disclosed herein, the reactor 2100 is similar to the reactors illustrated and described above. However, as illustrated in the drawings and described herein, the reactor 2100 is improved to be more versatile in executing selected microelectronic fabrication processes.

The reactor 2100 has an upper chamber member that includes an upper chamber wall 2120 and a lower chamber member that includes a lower chamber wall 2140. These walls 2120, 2140, are arranged to open so as to permit a wafer 2010 to be loaded into the reactor 2100 for processing, by a loading and unloading mechanism (not shown) that, for example, may be in the form of a robot having an end effector. These walls 2120, 2140, are arranged to close so as to define a capsule 2160 supporting a wafer 2010 in a processing position, between these walls 2120, 2140.

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The reactor 2100, which defines a rotation axis A, has a head 2200 containing a rotor 2210, which mounts the upper chamber wall 2120, and mounting a motor 2220 for rotating the rotor 2210 and the upper and lower chamber walls 2120, 2140, when closed, around the axis A, conjointly with a wafer 2010 supported in the processing position. The motor 2220 is arranged to drive a sleeve 2222, which is supported radially in the head 2200, by rolling-element bearings 2224. The head 2200 is arranged to be raised for opening these walls 2120, 2140, and to be lowered for closing these walls 2120, 2140.

The upper chamber wall 2120 has an inlet 2122 for processing fluids, which may be liquid, vaporous, or gaseous, and the lower chamber wall 2140 has an inlet 2142 for such fluids, which for a given application may be similar fluids or different fluids. The head 2200 mounts an upper nozzle 2210, which extends axially through the sleeve 2222 so as not to interfere with the rotation of the sleeve 2222. The upper nozzle 2210 directs streams of processing fluids downwardly through the inlet 2122 of the upper chamber wall 2120.

The upper chamber wall 2120 includes an array of similar outlets 2124, which are spaced similarly at uniform angular spacings around the vertical axis A. In the disclosed embodiment, thirty-six such outlets 2124 are employed. Each outlet 2124 is spaced outwardly from the vertical axis A by a comparatively larger radial distance and is spaced inwardly from the outer perimeter 2016 of a wafer 2010 supported in the processing position by a comparatively smaller radial distance, such as a distance of approximately 1.5 millimeters.

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When the upper and lower chamber walls 2120, 2140, are closed, they define a micro-environment reactor 2160 the having an upper processing chamber 2126 that is defined by the upper chamber wall 2120 and by a first generally planar surface of the supported wafer 2010, and a lower processing chamber 2146 that is defined by the lower chamber wall 2140 and a second generally planar surface of the supported wafer opposite the first side. The upper and lower processing chambers 2126, 2146, are in fluid communication with each other in an annular region 2130 beyond the outer perimeter 2016 of the supported wafer 2010 and are sealed by an annular, compressible seal (e.g. O-ring) 2132 bounding a lower portion 2134 of the annular region 2130. The seal 2132 allows processing fluids entering the lower inlet 2142 to remain under sufficient pressure to flow toward the outlets 2134.

As compared to reactors of the type disclosed in the previously described embodiments, the reactor 2100 is particularly suitable for executing a range of unique microfabrication processes. For example, reactor 2100 is particularly suited to execute a process that requires complete contact of a processing fluid at a first side of a workpiece and at only a peripheral margin portion of the second side thereof. Such processes may be realized because processing fluids entering the inlet 2142 of the lower chamber wall 2140 can act on the lower side 2014 of a supported wafer 2010, on the outer periphery 2016 of the supported wafer 2010, and on an outer margin 2018 of the upper side 2012 of the supported wafer 2010 before reaching the outlets 2124, and because processing fluids entering the inlet 2122 of the upper chamber wall 2120 can

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act on the upper side 2012 of the supported wafer 2010, except for the outer margin 2018 of the upper side 2012, before reaching the outlets 2124.

As a significant example of one such process, the reactor 2100 can be used with control of the respective pressures of processing fluids entering the respective inlets 2122, 2142, to carry out a process in which a processing fluid is allowed to contact a first side of the workpiece, the peripheral edge of the workpiece, and a peripheral region of the opposite side of the workpiece. Such fluid flow/contact can also be viewed as a manner of excluding a processing fluid that is applied to the opposite side from a peripheral region of that side. In accordance with one embodiment of such a process, a thin film of material is etched from the first side, peripheral edge of the workpiece, and peripheral region of the opposite side of the workpiece.

In a more specific embodiment of such a process, the process may employed in a metallization process that is used to form a microelectronic component and/or interconnect structures on a semiconductor wafer or the like. To this end, a thin film, such as the seed layer, is applied over a barrier layer on the front side and over at least a portion of the outer perimeter. After one or more intervening steps, such as electroplating of a copper layer or the like thereover, an etchant capable of etching the electroplating material, thin film material, and/or the barrier layer material is caused to flow selectively over only an outer margin of the first side while being concurrently prevented from flowing over other radial interior portions of the first side. Thus, one or more of the layers are removed from the outer margin of the first side while the layers remain intact at the portions of the first side that are disposed interior of the outer margin. If the

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etchant is driven over the opposite side and over the outer perimeter, as well as over the outer margin of the first side, the one or more layers are also removed from the outer perimeter of the wafer and, further, any contaminant that the etchant is capable of removing is stripped from the back side.

Based on the description of the foregoing process, it will be recognized that other layers and/or materials may be selectively etched, cleaned, deposited, protected, etc., based on selective contact of a processing fluid with the outer margin and/or opposing side of the workpiece. For example, oxide may be removed from the opposite side and outer margin of the first side of a workpiece through selective contact with an oxide etchant, such as hydrofluoric acid. Similarly, the oxide etchant may be controlled in the reactor so that it contacts all of the front side of the workpiece except for the outer margin thereby leaving the oxide at the outer margin intact. It will also be recognized that removal of the outlets 2124 allows the reactor 2100 to be used for processes in which selective outer margin inclusion or exclusion is unnecessary or otherwise undesirable.

A further example of a type of processing station suitable for use with the lift and rotate assembly 200 illustrated in FIGS. 3-11, is illustrated in FIGS. 25-36. The illustrated processing station incorporates a processing head having a plurality of contacts in the form of discrete flexures or a Belleville ring contact. More specifically, FIGS. 25-36 illustrate a reactor assembly 3020 for electroplating a microelectronic workpiece, such as a semiconductor wafer 3025. Generally stated, the reactor assembly 3020 is comprised of a processing head 3030 and a

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corresponding reactor bowl 3035. This type of reactor assembly is particularly suited for effecting electroplating of semiconductor wafers or like workpieces, in which an electrically conductive, thin-film layer of the wafer is electroplated with a blanket or patterned metallic layer.

The specific construction of one embodiment of a reactor bowl 3035 suitable for use in the reactor assembly 3020 is illustrated in FIG. 26. The electroplating reactor bowl 3035 is that portion of the reactor assembly 3020 that contains electroplating solution, and that directs the solution against a generally downwardly facing surface of an associated workpiece 3025 to be plated. To this end, electroplating solution is circulated through the reactor bowl 3035. Attendant to solution circulation, the solution flows from the reactor bowl 3035, over the weir-like periphery of the bowl, into a lower overflow chamber 3040 of the reactor assembly 3020. Solution is drawn from the overflow chamber typically for re-circulation through the reactor.

The reactor bowl 3035 includes a riser tube 3045, within which an inlet conduit 3050 is positioned for introduction of electroplating solution into the reactor bowl 3035. The inlet conduit 3050 is preferably conductive and makes electrical contact with and supports an electroplating anode 3055. The anode 3055 may be provided with an anode shield 3060. Electroplating solution flows from the inlet conduit 3050 through openings at the upper portion thereof, about the anode 3055, and through an optional diffusion plate 3065 positioned in operative association with the anode. The anode 3055 may be consumable whereby metal ions of the anode are transported by the electroplating solution to the electrically-conductive surface

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of the associated workpiece, which functions as a cathode. Alternatively, the anode 3055 may be inert, thereby removing the need for the anode shield 3060.

As shown in FIGS. 25 and 27, the illustrated embodiment of the processing head 3030 of the electroplating reactor 3020 comprises a stationary assembly 3070 and a rotor assembly 3075. Rotor assembly 3075 is configured to receive and carry an associated wafer 3025 or like workpiece, position the wafer in a process-side down orientation within reactor bowl 3035, and to rotate or spin the workpiece while joining its electrically-conductive surface in the plating circuit of the reactor assembly 3020. The lift and rotate assembly 3080 rotates the processing head 3030 from an upwardly-facing disposition, wherein it receives the wafer to be plated, to a downwardly facing disposition, wherein the surface of the wafer to be plated is positioned downwardly in reactor bowl 3035, generally in confronting relationship to diffusion plate 3065. A robotic arm 3415 (sometimes referred to as including an end effector) is typically employed for placing the wafer 3025 in position on the rotor assembly 3075, and for removing the plated wafer from within the rotor assembly.

In the illustrated embodiment, the reactor 3020 employs a ring contact assembly 3085 that provides either a continuous electrical contact or a high number of discrete electrical contacts with the wafer 3025. By providing a more continuous contact with the outer peripheral edges of the semiconductor wafer 3025, in this case around the outer circumference of the semiconductor wafer, a more uniform current is supplied to the semiconductor wafer 3025 that promotes more uniform current densities. The more uniform current densities enhance

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uniformity in the depth of the deposited material.

The contact assembly 3085, in accordance with the illustrated embodiment, includes contact members that provide minimal intrusion about the wafer periphery while concurrently providing consistent contact with the seed layer. Contact with the seed layer is enhanced by using a contact member structure that provides a wiping action against the seed layer as the wafer is brought into engagement with the contact assembly. This wiping action assists in removing any oxides at the seed layer surface thereby enhancing the electrical contact between the contact structure and the seed layer. As a result, uniformity of the current densities about the wafer periphery are increased and the resulting film is more uniform. Further, such consistency in the electrical contact facilitates greater consistency in the electroplating process from wafer-to-wafer thereby increasing wafer-to-wafer uniformity.

The contact assembly 3085, as will be set forth in further detail below, also includes one or more structures that provide a barrier, individually or in cooperation with other structures, that separates the contact/contacts, the peripheral edge portions and backside of the semiconductor wafer 3025 from the plating solution. This prevents the plating of metal onto the individual contacts and, further, assists in preventing any exposed portions of the barrier layer near the edge of the semiconductor wafer 3025 from being exposed to the electroplating environment. As a result, plating of the barrier layer and the appertaining potential for contamination due to flaking of any loosely adhered electroplated material is substantially limited.

In the illustrated embodiment, the contact assembly 3085 forms part of the rotor assembly

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3075 and provides electrical contact between the semiconductor wafer 3025 and a source of electroplating power.

FIGURE 28 illustrates a partial cross-section view of the contact assembly 3085. In the illustrated embodiment, the contact assembly includes an outer body member 3100, an annular wedge 3105, a plurality of flexure contacts 3090, a contact mount member 3110, and an interior wafer guide 3115. In one embodiment, annular wedge 3105, flexure contacts 3090, and contact mount member 3110 are formed from platinized titanium while wafer guide 3115 and outer body member 3100 are formed from a dielectric material that is compatible with the electroplating environment. Annular wedge 3105, flexure contacts 3090, mount member 3110, and wafer guide 3115 join together to form a single assembly that is secured together by outer body member 3100.

Contact mount member 3110 includes a first annular groove 3120 disposed about a peripheral portion thereof and a second annular groove 3125 disposed radially inward of the first annular groove 3120. The second annular groove 3125 opens to a plurality of flexure channels 3130 that are equal in number to the number of flexure contacts 3090.

Each flexure contact 3090 is comprised of an upstanding portion 3135, a transverse portion 3140, a vertical transition portion 3145, and a wafer contact portion 3150. Similarly, wedge 3105 includes an upstanding portion 3155 and a transverse portion 3160. Upstanding portion 3155 of wedge 3105 and upstanding portion 3135 of each flexure contact 3090 are secured within the first annular groove 3120 of the contact mount member 3110 at the site of

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each flexure channel 3130. Self-adjustment of the flexure contacts 3090 to their proper position within the overall contact assembly 3085 is facilitated by first placing each of the individual flexure contacts 3090 in its respective flexure channel 3130 so that the upstanding portion 3135 is disposed within the first annular groove 3120 of the contact mount member 3110 while the transition portion 3145 and contact portion 3150 proceed through the respective flexure channel 3130. The upstanding portion 3155 of wedge member 3105 is then urged into the first annular groove 3120. To assist in this engagement, the upper end of upstanding portion 3155 is tapered. The combined width of upstanding portion 3135 of the flexure contact 3090 and upstanding portion 3155 of wedge 3105 are such that these components are firmly secured with contact mount member 3110.

Transverse portion 3160 of wedge 3105 extends along a portion of the length of transverse portion 3140 of each flexure 3090. In the illustrated embodiment, transverse portion 3160 of wedge portion 3105 terminates at the edge of the second annular groove 3125 of contact mount member 3110. As will be more clear from the description of the flexure contact operation below, the length of transverse portion 3160 of wedge 3105 can be chosen to provide the desired degree of stiffness of the flexure contacts 3090.

Wafer guide 3115 is in the form of an annular ring having a plurality of slots 3165 through which contact portions 3150 of flexures 3090 extend. An annular extension 3170 proceeds from the exterior wall of wafer guide 3115 and engages a corresponding annular groove 3175 disposed in the interior wall of contact mount member 3110 to thereby secure the wafer

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guide 3115 with the contact mount member 3110. As illustrated, the wafer guide member 3115 has an interior diameter that decreases from the upper portion thereof to the lower portion thereof proximate contact portions 3150. A wafer inserted into contact assembly 3085 is thus guided into position with contact portions 3150 by a tapered guide wall formed at the interior of wafer guide 3115. The portion 3180 of wafer guide 3115 that extends below annular extension 3170 is formed as a thin, compliant wall that resiliently deforms to accommodate wafers having different diameters within the tolerance range of a given wafer size. Further, such resilient deformation accommodates a range of wafer insertion tolerances occurring in the components used to bring the wafer into engagement with the contact portions 3150 of the flexures 3090.

Outer body member 3100 includes an upstanding portion 3185, a transverse portion 3190, a vertical transition portion 3195 and a further transverse portion 3200 that terminates in an upturned lip 3205. Upstanding portion 3185 includes an annular extension 3210 that extends radially inward to engage a corresponding annular notch 3215 disposed in an exterior wall of contact mount member 3110. A V-shaped notch 3220 is formed at a lower portion of the upstanding portion 3185 and circumvents the outer periphery thereof. The V-shaped notch 3220 allows upstanding portion 3185 to resiliently deform during assembly. To this end, upstanding portion 3185 resiliently deforms as annular extension 3210 slides about the exterior of contact mount member 3110 to engage annular notch 3215. Once so engaged, contact mount member 3110 is clamped between annular extension 3210 and the interior wall of transverse portion 3190 of outer body member 3100.

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Further transverse portion 3200 extends beyond the length of contact portions 3150 of the flexure contacts 3090 and is dimensioned to resiliently deform as a wafer, such as at 3025, is driven against them. V-shaped notch 3220 may be dimensioned and positioned to assist in the resilient deformation of transverse portion 3200. With the wafer 3025 in proper engagement with the contact portions 3150, upturned lip 3205 engages wafer 3025 and assists in providing a barrier between the electroplating solution and the outer peripheral edge and backside of wafer 3025, including the flexure contacts 3090.

Flexure contacts 3090 resiliently deform as the wafer 3025 is driven against them. Contact portions 3150 are initially angled upward in the illustrated manner. Thus, as the wafer 3025 is urged against contact portions 3150, flexures 3090 resiliently deform so that contact portions 3150 effectively wipe against surface 3230 of wafer 3025. In the illustrated embodiment, contact portions 3150 effectively wipe against surface 3230 of wafer 3025 a horizontal distance designated at 3235. This wiping action assists in removing and/or penetrating any oxides from surface 3230 of wafer 3025 thereby providing more effective electrical contact between flexure contacts 3090 and the seed layer at surface 3230 of wafer 3025.

Although flexure contacts 3090 are formed as discrete components, they may be joined with one another as an integral assembly. To this end, for example, the upstanding portions 3135 of the flexure contacts 3090 may be joined to one another by a web of material, such as platinized titanium, that is either formed as a separate piece or is otherwise formed with the

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flexures from a single piece of material.

As illustrated in FIGS. 29 and 30, the rotor assembly 3075 may be comprised of a rotor base member 3205 and a removable contact assembly 3210. In at least one embodiment, the rotor base member 3205 is annular in shape to match the shape of the semiconductor wafer 3025. A pair of latching mechanisms 3215 is disposed at opposite sides of the rotor base member 3205. Each of the latching mechanisms 3215 includes an aperture 3220 disposed through an upper portion thereof that is dimensioned to receive a corresponding electrically conductive shaft 3225 that extends downward from the removable contact assembly 3210.

The removable contact assembly 3210 is shown in a detached state in FIG. 29. To secure the removable contact assembly 3210 to the rotor base member 3205, an operator aligns the electrically conductive shafts 3225 with the corresponding apertures 3220 of the latching mechanisms 3215. With the shafts 3225 aligned in this manner, the operator urges the removable contact assembly 3210 toward the rotor base member 3205 so that the shafts 3225 engage the corresponding apertures 3220. Once the removable contact assembly 3210 is placed on the rotor base member 3205, latch arms 3230 are pivoted about a latch arm axis 3235 so that latch arm channels 3240 of the latch arms 3230 engage the shaft portions 3245 of the conductive shafts 3225 while concurrently applying a downward pressure against flange portions 3247. This downward pressure secures the removable contact assembly 3210 with the rotor base member 3205. Additionally, as will be explained in further detail below, this engagement results in the creation of an electrically conductive path between electrically conductive portions of the rotor

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base assembly 3205 and the electroplating contacts of the contact assembly 3210. It is through this path that the electroplating contacts of the contact assembly 3210 are connected to receive power from a plating power supply.

FIGS. 31A and 31B illustrate further details of the latching mechanisms 3215 and the electrically conductive shafts 3225. As illustrated, each latching mechanism 3215 is comprised of a latch body 3250 having aperture 3220, a latch arm 3230 disposed for pivotal movement about a latch arm pivot post 3255, and a safety latch 3260 secured for relatively minor pivotal movement about a safety latch pivot post 3265. The latch body 3250 may also have a purge port 3270 disposed therein to conduct a flow of purging fluid through corresponding apertures of the removable contact assembly 3210. An O-ring 3275 is disposed at the bottom of the flange portions of the conductive shafts 3225.

FIGS. 32A - 32C are cross-sectional views illustrating operation of the latching mechanisms 3215. As illustrated, latch arm channels 3240 are dimensioned to engage the shaft portions 3245 of the conductive shafts 3225. As the latch arm 3230 is rotated to engage the shaft portions 3245, a nose portion 3280 of the latch arm 3230 cams against the surface 3285 of safety latch 3260 until it mates with channel 3290. With the nose portion 3280 and corresponding channel 3290 in a mating relationship, latch arm 3230 is secured against inadvertent pivotal movement that would otherwise release removable contact assembly 3210 from secure engagement with the rotor base member 3205.

FIGS. 33A - 33D are cross-sectional views of the rotor base member 3205 and

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removable contact assembly 3210 in an engaged state. As can be seen in these cross-sectional views, the electrically conductive shafts 3225 include a centrally disposed bore 3295 that receives a corresponding electrically conductive quick-connect pin 3300. It is through this engagement that an electrically conductive path is established between the rotor base member 3205 and the removable contact assembly 3210.

As also apparent from these cross-sectional views, the lower, interior portion of each latch arm 3230 includes a corresponding channel 3305 that is shaped to engage the flange portions 3247 of the shafts 3225. Channel 3305 cams against corresponding surfaces of the flange portions 3247 to drive the shafts 3225 against surface 3310 which, in turn, effects a seal with O-ring 3275.

As illustrated in FIGS. 34 and 35, the rotor assembly 3075 includes an actuation arrangement whereby the wafer or other workpiece 3025 is received in the rotor assembly by movement in a first direction, and is thereafter urged into electrical contact with the contact assembly contact by movement of a backing member 3310 toward the contact assembly, in a direction perpendicular to the first direction. FIG. 36 is an exploded view of various components of the rotor assembly 3075 and stationary assembly 3070 of the processing head 3030.

As illustrated, the stationary assembly 3070 of the processing head 3030 includes a motor assembly 3315 that cooperates with shaft 3360 of rotor assembly 3075. Rotor assembly 3075 includes a generally annular housing assembly, including rotor base member 3205 and an inner housing 3320. As described above, the contact assembly is secured to rotor base member 3205.

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By this arrangement, the housing assembly and the contact assembly 3210 together define an opening 3325 through which the workpiece 3125 is transversely movable, in a first direction, for positioning the workpiece in the rotor assembly 3175. The rotor base member 3205 preferably defines a clearance opening for the robotic arm as well as a plurality of workpiece supports 3330 upon which the workpiece is positioned by the robotic arm after the workpiece is moved transversely into the rotor assembly by movement through opening 3325. The supports 3330 thus support the workpiece 3025 between the contact assembly 3210 and the backing member 3310 before the backing member engages the workpiece and urges it against the contact ring.

Reciprocal movement of the backing member 3310 relative to the contact assembly 3210 is effected by at least one spring which biases the backing member toward the contact assembly, and at least one actuator for moving the backing member in opposition to the spring. In the illustrated embodiment, the actuation arrangement includes an actuation ring 3335 which is operatively connected with the backing member 3310, and which is biased by a plurality of springs, and moved in opposition to the springs by a plurality of actuators.

With particular reference to FIG. 34, actuation ring 3335 is operatively connected to the backing member 3310 by a plurality (three) of shafts 3340. The actuation ring, in turn, is biased toward the housing assembly by three compression coil springs 3345 which are each held captive between the actuation ring and a respective retainer cap 3350. Each retainer cap 3350 is held in fixed relationship with respect to the housing assembly by a respective retainer shaft 3355. By this arrangement, the action of the biasing springs 3345 urges the actuation ring 3335 in a

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direction toward the housing, with the action of the biasing springs thus acting through shafts 3340 to urge the backing member 3335 in a direction toward the contact assembly 3210.

Actuation ring 3335 includes an inner, interrupted coupling flange 3365. Actuation of the actuation ring 3335 is effected by an actuation coupling 3170 (FIG. 35) of the stationary assembly 3070, which can be selectively coupled and uncoupled from the actuation ring 3335. The actuation coupling 3370 includes a pair of flange portions 3375 that can be interengaged with coupling flange 3365 of the actuation ring 3335 by limited relative rotation therebetween. By this arrangement, the actuation ring 3335 of the rotor assembly 3075 can be coupled to, and uncoupled from, the actuation coupling 3370 of the stationary assembly 3070 of the processing head 3030.

With reference again to FIG. 34 and 35, actuation coupling 3370 is movable in a direction in opposition to the biasing springs 3345 by a plurality of pneumatic actuators 3380 (shown schematically) mounted on a stationary, upper plate 3381 (see FIG. 25) of the stationary assembly 3070. Each actuator 3380 is operatively connected with the actuation coupling 3370 by a respective linear drive member 3385, each of which extends generally through the upper plate 3381 of the stationary assembly 3070. There is a need to isolate the foregoing mechanical components from other portions of the reactor assembly 3020. A failure to do so will result in contamination of the processing environment (here, a wet chemical electroplating environment). Additionally, depending on the particular process implemented in the reactor 3020, the foregoing components can be adversely affected by the processing environment.

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To effect such isolation, a bellows assembly 3390 is disposed to surround the foregoing components. The bellows assembly 3390 comprises a bellows member 3395, which in at least one embodiment is made from Teflon, and has a first end thereof secured at 3400 and a second end thereof secured at 3405. Such securement is implemented in the illustrated embodiment using the illustrated liquid-tight, tongue-and-groove sealing arrangement. The convolutes 3410 of the bellows member 3395 flex during actuation of the backing plate 3310.

FIG. 35 illustrates the disposition of the processing head 3030 in a condition in which it may accept a workpiece, while FIG. 34 illustrates the disposition of the processing head 3030 in a condition in which it is ready to process the workpiece in the reactor bowl 3035.

Operation of the processing head 3030 will be appreciated from the above description. Loading of workpiece 3025 into the rotor assembly 3075 is effected with the rotor assembly in a generally upwardly facing orientation, such as illustrated in FIG. 26 with the processing head in a condition shown in FIG. 35. Workpiece 3025 is moved transversely through the opening 3325 defined by the rotor assembly 3075 to a position wherein the workpiece is positioned in spaced relationship generally above supports 3330. A robotic arm 3415 is then lowered (with clearance opening 3325 accommodating such movement), whereby the workpiece is positioned upon the supports 3330. The robotic arm 3415 can then be withdrawn from within the rotor assembly 3075.

The workpiece 3025 is now moved perpendicularly to the first direction in which it was moved into the rotor assembly. Such movement is effected by movement of backing member

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3310 generally toward contact assembly 3210. In the illustrated embodiment the pneumatic actuators 3380 act in opposition to biasing springs 3345 which are interposed between the inner housing 3320 and the spring plate 3311 of the backing member 3310. Thus, actuators 3380 are operated to allow conjoint movement of the actuator coupling 3370 and the actuator ring 3335 to permit springs 3345 to bias and urge the backing member 3310 toward contact 3210. In the illustrated embodiment, the connection between actuation ring 3335 and backing member 3310 by shafts 3340 permits some "float". That is, the actuation ring and backing member are not rigidly joined to each other. This preferred arrangement accommodates the common tendency of the pneumatic actuators 3380 to move at slightly different speeds, thus assuring that the workpiece is urged into substantial uniform contact with the electroplating contacts of the contact assembly 3210 while avoiding excessive stressing of the workpiece, or binding of the actuation mechanism.

With the workpiece 3025 firmly held between the backing member 3310 and the contact assembly 3210, lift and rotate apparatus 3080 of FIG. 26 rotates the processing head 3030 and lowers the reactor head into a cooperative relationship with reactor bowl 3035 so that the surface of the workpiece is placed in contact with the surface of the plating solution (i.e., the meniscus of the plating solution) within the reactor vessel.

Depending on the particular electroplating process implemented, it may be useful to insure that any gas which accumulates on the surface of the workpiece is permitted to vent and escape. Accordingly, the surface of the workpiece may be disposed at an acute angle, such as on

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the order of two degrees from horizontal, with respect to the surface of the solution in the reactor vessel. This facilitates venting of gas from the surface of the workpiece during the plating process as the workpiece, and associated backing and contact members, are rotated during processing. Circulation of plating solution within the reactor bowl 3035, as electrical current is passed through the workpiece and the plating solution, effects the desired electroplating of a metal layer on the surface of the workpiece.

The actuation of the backing member 3310 is desirably effected by a simple linear motion, thus facilitating precise positioning of the workpiece, and uniformity of contact with the contacts of the contact assembly 3210. The isolation of the moving components using a bellows seal arrangement further increases the integrity of the electroless plating process

A number of features of the present reactor facilitate efficient and cost-effective electroplating of workpieces such as semiconductor wafers. By use of a contact assembly having substantially continuous contact in the form of a large number of sealed, compliant discrete contact regions, a high number of plating contacts are provided while minimizing the required number of components. The actuation of the backing member 3310 is desirably effected by a simple linear motion, thus facilitating precise positioning of the workpiece, and uniformity of contact with the contact ring. The isolation of the moving components using a bellows seal arrangement further increases the integrity of the electroplating process.

Maintenance and configuration changes are easily facilitated through the use of a detachable contact assembly 3210. Further, maintenance is also facilitated by the detachable

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configuration of the rotor assembly 3075 from the stationary assembly 3070 of the reactor head. The contact assembly provides excellent distribution of electroplating power to the surface of the workpiece, while the preferred provision of the peripheral seal protects the contacts from the plating environment (e.g., contact with the plating solution), thereby preventing build-up of plated material onto the electrical contacts. The perimeter seal also desirably prevents plating onto the peripheral portion of the workpiece.

In connection with the previously noted examples of processing stations that incorporate a workpiece housing which is rotated by a motor for distributing processing fluid across at least one face of a workpiece by centrifugal force, illustrated in FIGS. 12-19 and FIGS. 20-24, the lift and rotate assembly 200 would function suitably so long as the lift and rotate assembly 200 minimally provided for lifting the processing head relative to the processing chamber. In connection with the illustrated embodiment of the processing station that incorporated the processing head having a plurality of contacts in the form of discrete flexures or a Belville ring contact, the lift and rotate assembly 200 preferably provides for both lifting and rotating the processing head relative to the process chamber.

It will be readily recognized that additional types of processing chambers would similarly benefit from incorporating the lift and rotate assembly of the present application. Furthermore numerous modifications may be made to the foregoing system without departing from the basic teachings thereof.

Although the present invention has been described in substantial detail with reference to

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one or more specific embodiments, those of skill in the art will recognize that changes may be made thereto without departing from the scope and spirit of the invention as set forth in the appended claims.



CLAIMS

What is Claimed is:

1. An integrated workpiece processing tool comprising:
a workpiece processing tool frame including a tool platform; and
a plurality of workpiece processing stations, each workpiece processing station including
a processing chamber received by the tool platform, and a process head;
wherein the process head associated with each processing chamber is supported by an
assembly, which is coupled to the workpiece tool frame without encroaching upon the tool
platform.
2. An integrated workpiece processing tool in accordance with claim 1 wherein the
process head of at least a first one of said plurality of workpiece processing stations includes a
contact assembly comprising:
a plurality of contacts disposed to contact a peripheral edge of a surface of a workpiece,
the plurality of contacts executing a wiping action against the surface of the workpiece as the
workpiece is brought into engagement therewith, and
a barrier disposed interior of the plurality of contacts and including a member disposed to
engage the surface of the workpiece to effectively isolate the plurality of contacts from fluids
located within the corresponding workpiece processing chamber.



3. An integrated workpiece processing tool in accordance with claim 2 wherein the contact assembly further comprises:

an outer body member formed from a dielectric material;

a contact support member facilitating support of the plurality of contacts, the contact support member being disposed radially interior of the outer body member and being formed from a conductive material.

4. An integrated workpiece processing tool in accordance with claim 3 wherein the plurality of contacts are in the form of discrete flexures, each of the discrete flexures being disposed in a corresponding flexure channel defined between the contact support member and outer body member.

5. An integrated workpiece processing tool in accordance with claim 3 wherein the plurality of contacts are in the form of a Belville ring contact having a common portion disposed in a notch at an interior face of the contact support member.

6. An integrated workpiece processing tool in accordance with claim 2 wherein the process head further includes a backing member and a drive mechanism, the backing member and the contact assembly being moveable relative to one another by the drive mechanism



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between a workpiece loading state and a workpiece processing state, the workpiece being urged against the plurality of contacts of the contact assembly by the backing member in the workpiece processing state.

7. An integrated workpiece processing tool in accordance with claim 2 wherein the process head further comprises a stator portion and a rotor portion, and wherein the contact assembly is detachably connected to the rotor portion by at least one latching mechanism.

8. An integrated workpiece processing tool in accordance with claim 2 wherein the assembly supporting the process head of the at least first one of said plurality of workpiece processing stations includes a lift mechanism for lifting the process head with respect to process chamber, and a rotate mechanism for rotating the process head with respect to the process chamber.

9. An integrated workpiece processing tool in accordance with claim 2 wherein the process head of at least a second one of said plurality of workpiece processing stations comprises:

a rotor motor; and

a workpiece housing connected for rotation by the motor, the workpiece housing including therein a substantially closed processing chamber in which one or more processing



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fluids are distributed across at least one face of a workpiece by the centrifugal force generated during rotation of the housing.

10. An integrated workpiece processing tool in accordance with claim 9 wherein the workpiece housing comprises:

an upper chamber member having an interior chamber face, the upper chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

a lower chamber member having an interior chamber face, the lower chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

the upper chamber member and the lower chamber member being joined to one another to form the substantially closed processing chamber, the processing chamber generally conforming to the shape of the workpiece, the substantially closed processing chamber having at least one fluid outlet disposed at a peripheral region thereof to facilitate escape of fluid from the processing chamber through action of centrifugal force.

11. An integrated workpiece processing tool in accordance with claim 9 wherein the assembly supporting the process head of the at least second one of said plurality of workpiece processing stations includes a lift mechanism for lifting the process head with respect to the process chamber.



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12. An integrated workpiece processing tool in accordance with claim 1 wherein the process head of at least one of said plurality of workpiece processing stations comprises:

a rotor motor; and

a workpiece housing connected for rotation by the motor, the workpiece housing including therein a substantially closed processing chamber in which one or more processing fluids are distributed across at least one face of a workpiece by the centrifugal force generated during rotation of the housing.

13. An integrated workpiece processing tool in accordance with claim 12 wherein the workpiece housing comprises:

an upper chamber member having an interior chamber face, the upper chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

a lower chamber member having an interior chamber face, the lower chamber member including a centrally disposed fluid inlet opening in the interior chamber face thereof;

the upper chamber member and the lower chamber member being joined to one another to form the substantially closed processing chamber, the processing chamber generally conforming to the shape of the workpiece, the substantially closed processing chamber having at least one fluid outlet disposed at a peripheral region thereof to facilitate escape of fluid from the processing chamber through action of centrifugal force.



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14. An integrated workpiece processing tool in accordance with claim 12 wherein the assembly supporting the process head of the at least one of said plurality of workpiece processing stations includes a lift mechanism for lifting the process head with respect to the process chamber.

15. An integrated workpiece processing tool in accordance with claim 1 wherein the workpiece processing tool frame further includes:

an exposed surface against which at least a portion of said workpiece processing station including the assembly supporting the process head is received, said exposed surface comprising

a socket adapted for receiving a first pin of a workpiece processing station, and

a saddle adapted for receiving a second pin of the workpiece processing station.

16. An integrated workpiece processing tool in accordance with claim 15 wherein said socket includes a spherical recess adapted for receiving the first pin.

17. An integrated workpiece processing tool in accordance with claim 15 wherein



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said socket includes an adjustment mechanism for adjusting the position of said socket with respect to said exposed surface.

18. An integrated workpiece processing tool in accordance with claim 17 wherein said adjustment mechanism includes a jack screw.

19. An integrated workpiece processing tool in accordance with claim 15 wherein said saddle includes a cylindrical recess adapted for receiving the second pin.

20. An integrated workpiece processing tool in accordance with claim 15 wherein said saddle includes an adjustment mechanism for adjusting the position of said saddle with respect to said exposed surface.

21. An integrated workpiece processing tool in accordance with claim 20 wherein said adjustment mechanism includes a jack screw.

22. An integrated workpiece processing tool in accordance with claim 15 wherein said exposed surface further comprises a first adjustable surface against which a third pin of the workpiece processing station is adapted to be received.



23. An integrated workpiece processing tool in accordance with claim 22 wherein said exposed surface further comprises a second adjustable surface against which a fourth pin of the workpiece processing station is adapted to be received.

24. A lift and rotate assembly for use in a workpiece processing station comprising:

a body;

a process head adapted for receiving a workpiece; and

a rotating mechanism including a motor, for rotatably coupling the process head to the body, wherein the motor is located within the process head, and the shaft of the motor is coupled to and rotationally fixed with respect to the body.

25. A lift and rotate assembly in accordance with claim 24 wherein the body of the lift and rotate assembly includes a first portion and a second portion, the second portion being movable with respect to the first portion and is coupled to the rotating mechanism, and wherein the lift and rotate assembly further comprises a lift mechanism, coupled to said first and second portion of said body, for lifting the second portion of said body coupled to said rotating mechanism.



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26. A lift and rotate assembly in accordance with claim 25 wherein the lift mechanism includes a guide block coupled to a linear guide motor.

27. A lift and rotate assembly in accordance with claim 26 wherein the lift mechanism includes a ball screw coupled to the linear guide motor and upon which the guide block rides.

28. A lift and rotate assembly in accordance with claim 25 wherein the lift mechanism includes a counterbalance mechanism coupled between the first portion of said body and the second portion of said body for exerting a force in a direction opposite to the force of gravity.

29. A lift and rotate assembly in accordance with claim 28, wherein the counterbalance mechanism is a gas spring.

30. A lift and rotate assembly in accordance with claim 25 further comprising a cable assembly for receiving at least one of electrical signals, gases and liquids, and providing at least some of said at least one of electrical signals, gases and liquids to said



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process head.

31. A lift and rotate assembly in accordance with claim 30 wherein said cable assembly includes a common cable loop for feeding additional length of cable along both the lift direction of movement by the lift mechanism and the rotational direction of movement by the rotating mechanism.

32. A lift and rotate assembly in accordance with claim 30 wherein said cable assembly includes a cable track.

33. A lift and rotate assembly in accordance with claim 30 further comprises a connection box through which said cable assembly receives said at least one of electrical signals, gases and liquids.

34. A lift and rotate assembly in accordance with claim 24 wherein said process head includes one or more workpiece contacts adapted for holding a workpiece.

35. A lift and rotate assembly in accordance with claim 33 wherein said one or more workpiece contacts provides an electrical connection with the workpiece.



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36. A lift and rotate assembly in accordance with claim 33 wherein said one or more workpiece contacts is a ring contact.

37. A lift and rotate assembly in accordance with claim 33 wherein said process head includes a second motor adapted for spinning the workpiece in a plane parallel to the face of the process head upon which the workpiece is received.

38. A lift and rotate assembly in accordance with claim 24 further comprising two or more pins adapted for mounting said lift and rotate assembly to a workpiece processing tool frame.

39. A lift and rotate assembly for use in a workpiece processing station comprising:

a body including a first portion and a second portion, the second portion being movable with respect to the first portion;

a lift mechanism coupled between the first portion and the second portion;

a rotating mechanism coupled to the second portion;

a process head coupled to the second portion via said rotating mechanism; and



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a cable assembly for receiving at least one of electrical signals, gases and liquids, and providing at least some of said at least one of electrical signals, gases and liquids to said process head; and

wherein said cable assembly includes a common cable loop for feeding additional length of cable along both the lift direction of movement by the lift mechanism and the rotational direction of movement by the rotating mechanism.

40. A lift and rotate assembly in accordance with claim 39 further comprising two or more pins adapted for mounting said lift and rotate assembly to a workpiece processing tool frame.

41. A method of attaching at least a portion of a workpiece processing station to a tool frame comprising the steps of:

inserting a first pin of the workpiece processing station into a socket located on the external surface of a tool frame; and

resting a second pin of the workpiece processing station into a saddle located on the external surface of a tool frame.



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42. A method in accordance with claim 41 further comprising the step of resting a third pin of the workpiece processing station against a first receiving surface located on the external surface of a tool frame.

43. A method in accordance with claim 42 further comprising the step of resting a fourth pin of the workpiece processing station against a second receiving surface located on the external surface of a tool frame.

44. A method in accordance with claim 43 further comprising the step of adjusting the location of at least one of said socket, said saddle, said first receiving surface and said second receiving surface for adjusting the position of the at least a portion of a workpiece processing station with respect to the tool frame.

45. A method in accordance with claim 42 further comprising the step of securing the workpiece processing station to the tool frame via a clamp.

46. A method in accordance with claim 45 wherein said step of securing the workpiece processing station includes positioning the clamp over the third pin resting against said first receiving surface captivating said third pin thereagainst.

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47. A method in accordance with claim 41 wherein said at least a portion of a workpiece processing station is a lift and rotate mechanism for single wafer processing.

