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(54) SERIAL WAFER HANDLING MECHANISM

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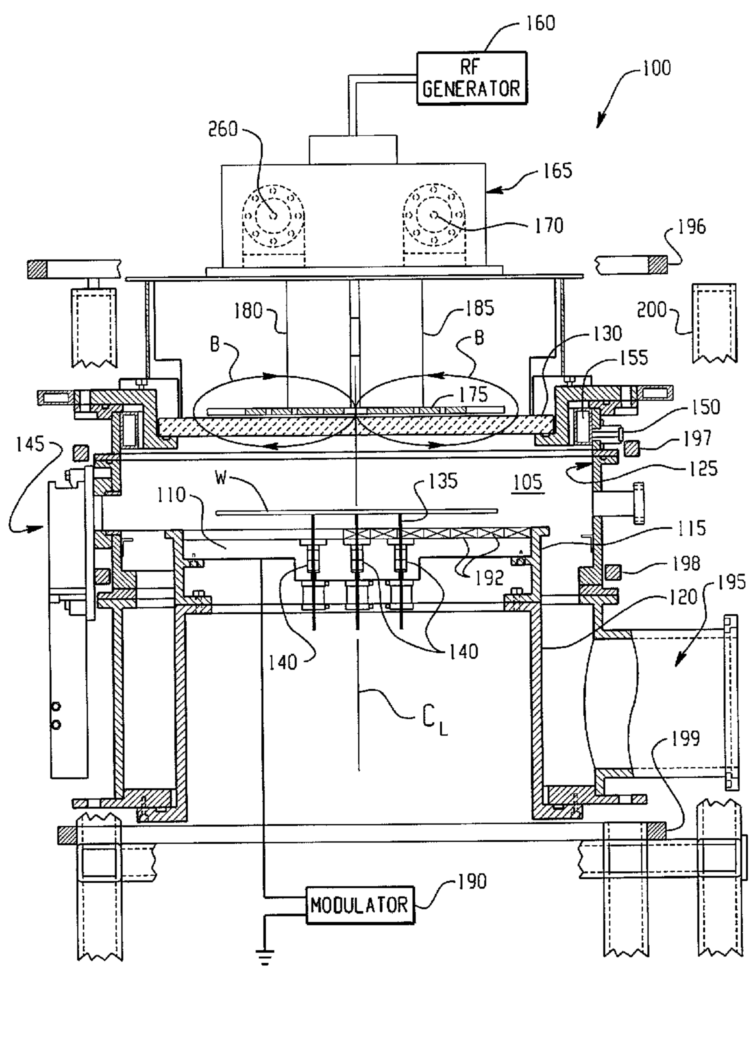
(57) **ABSTRACT**

A wafer handling system for a wafer processing apparatus includes a wafer load lock chamber, a wafer processing chamber and a transfer chamber operatively coupled to the wafer load lock chamber and the wafer processing chamber. The transfer chamber includes a wafer transfer mechanism comprising a transfer arm pivotably coupled to a portion of the transfer chamber which forms an axis. The transfer arm is operable to rotate about the axis to transfer a wafer between the wafer load lock chamber and the process chamber in a single axis wafer movement. The invention also includes a method of transferring a wafer to a wafer processing apparatus. The method includes loading a wafer into a wafer load lock chamber and rotating a transfer arm into the wafer load lock chamber to retrieve the wafer therein. The method further includes rotating the transfer arm out of the wafer load lock chamber and into a process chamber to deposit the wafer therein, wherein the rotating of the transfer arm occurs in a single axis wafer movement.



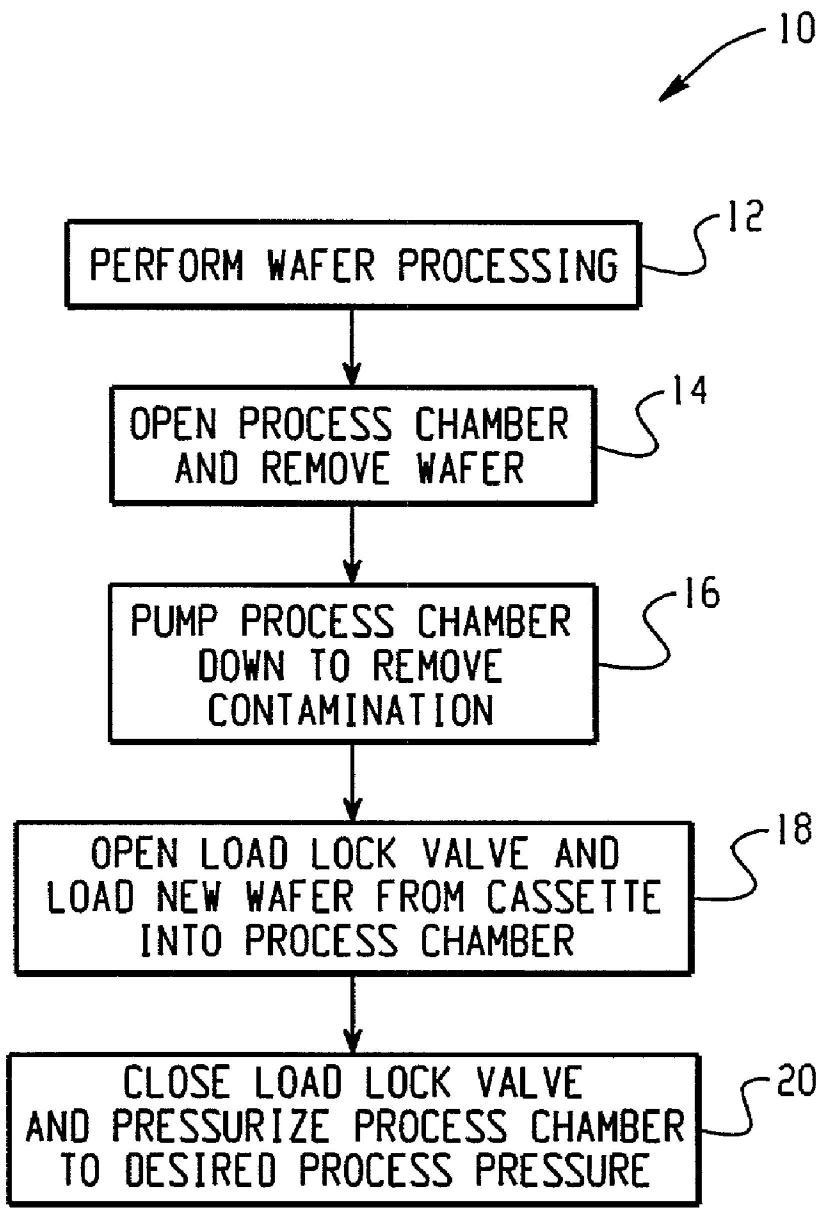
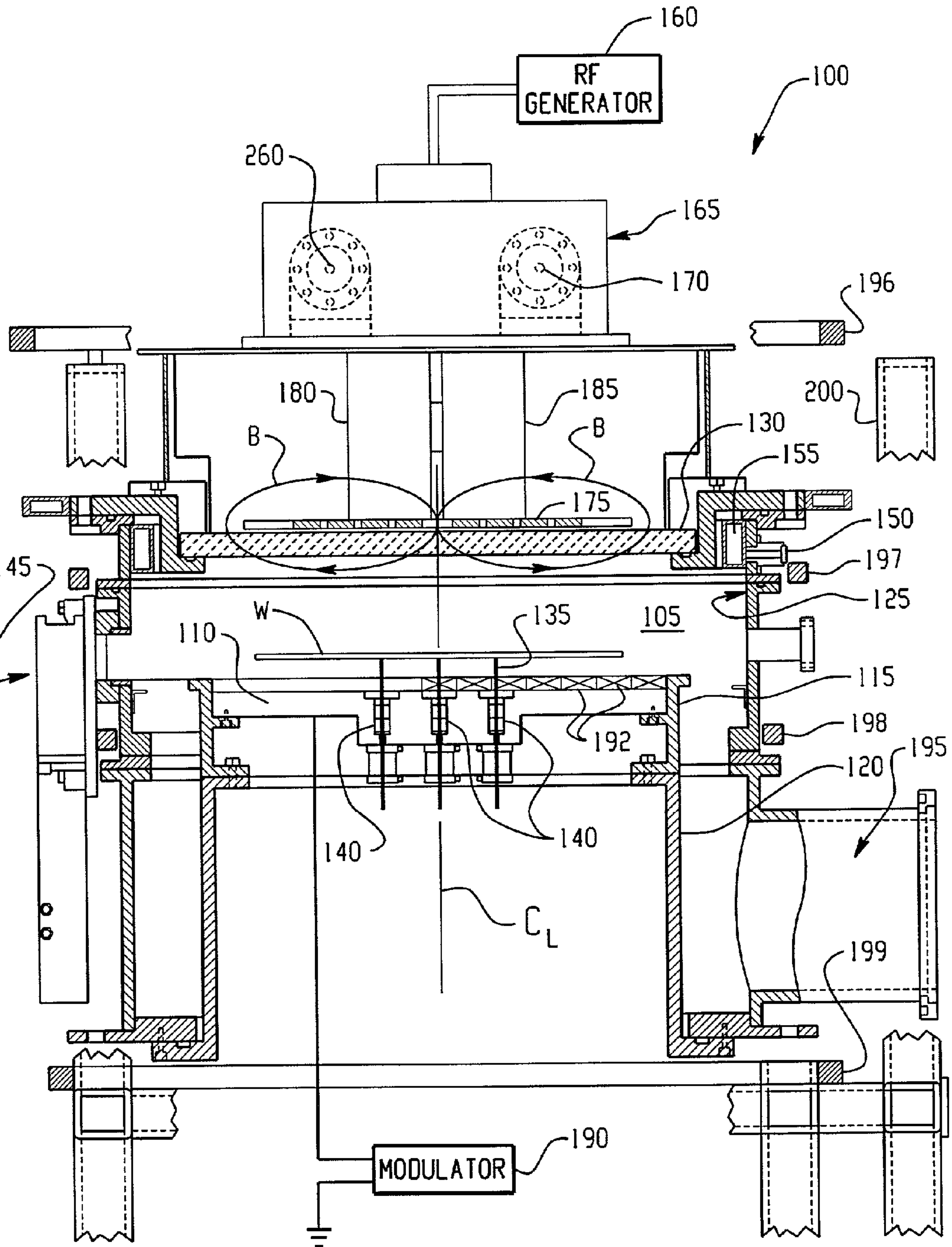


Fig. 1

(PRIOR ART)


160
RF GENERATOR
100
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170
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185
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B
B
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C_L
199
MODULATOR
190

Fig. 2

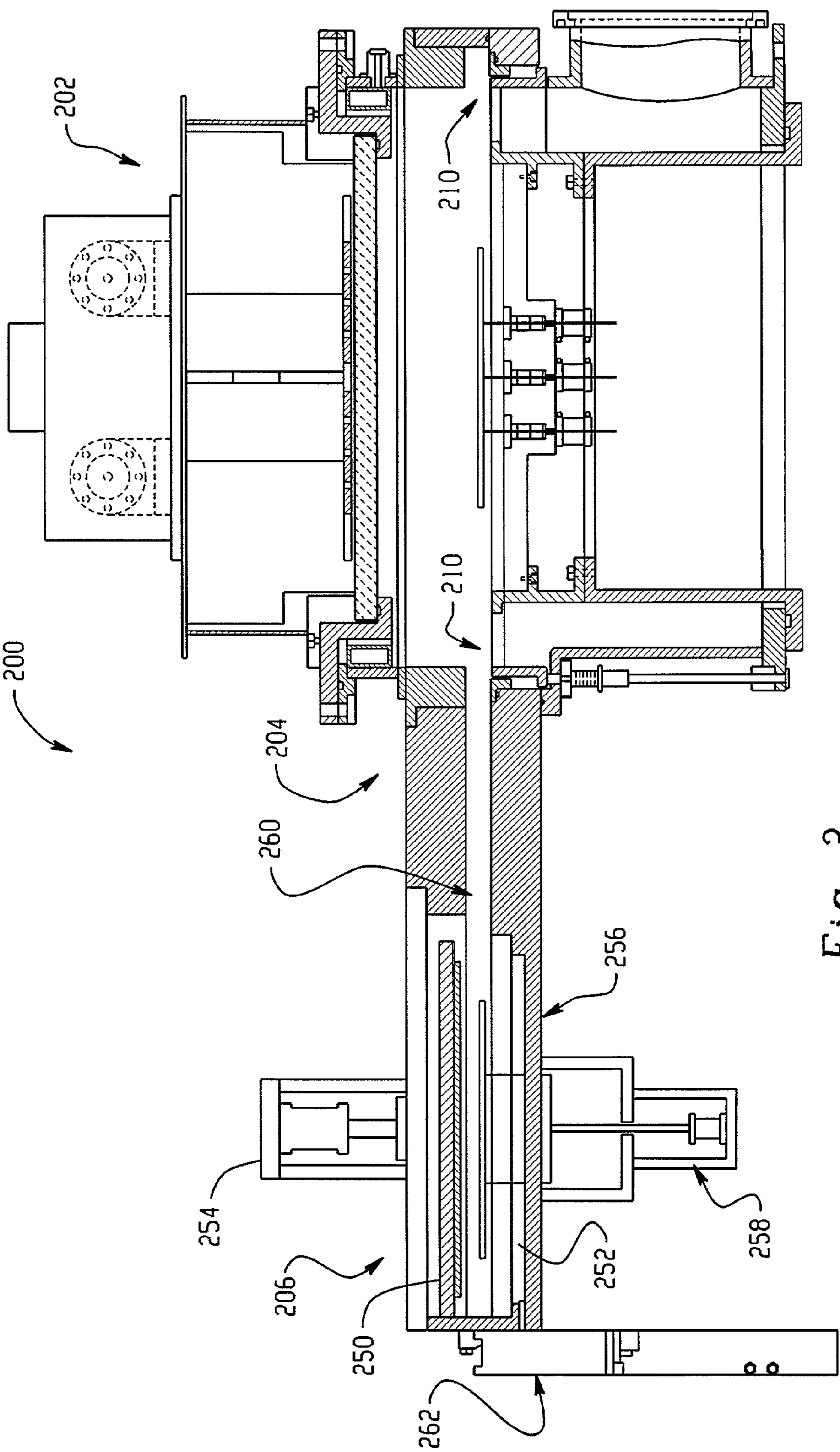

Fig. 3

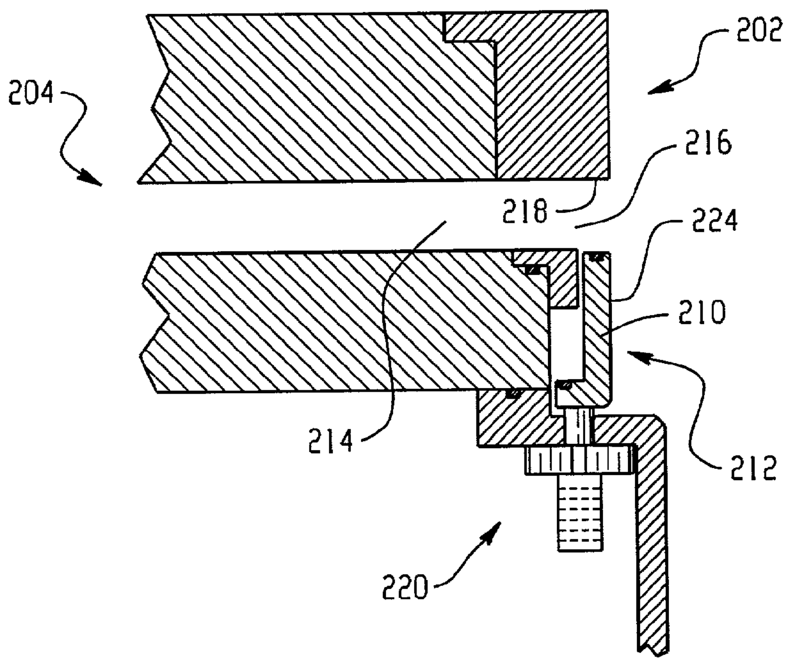

Fig. 4A

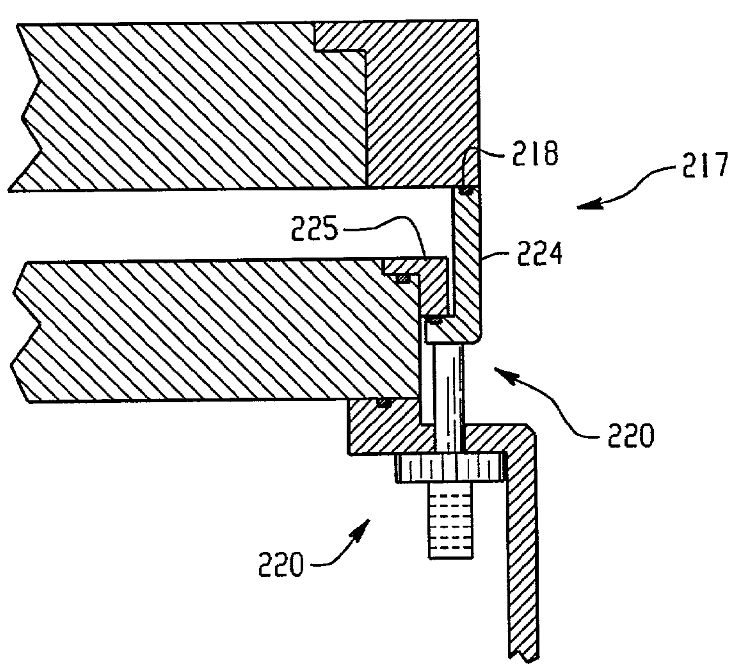

Fig. 4B

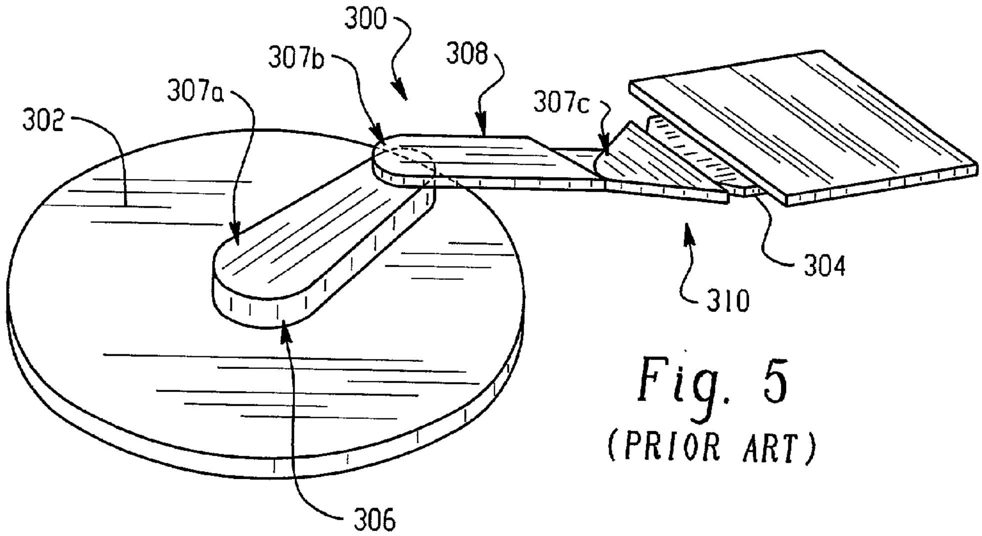

Fig. 5
(PRIOR ART)

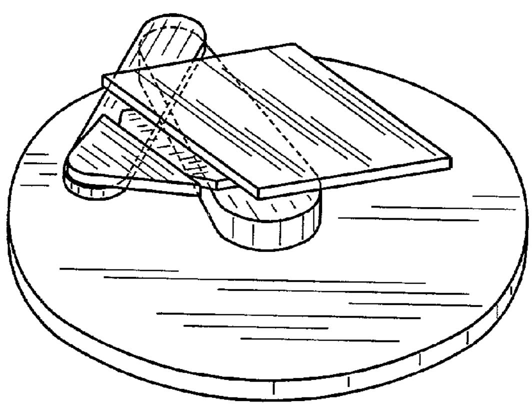

Fig. 6
(PRIOR ART)

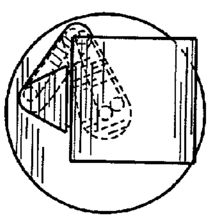

Fig. 7A
(PRIOR ART)

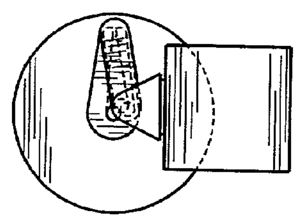

Fig. 7B
(PRIOR ART)

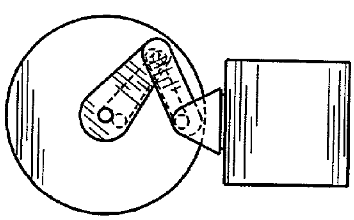

Fig. 7C
(PRIOR ART)

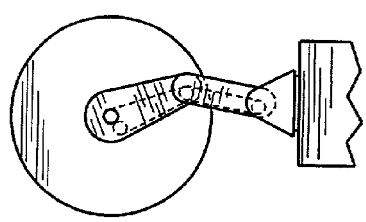

Fig. 7D
(PRIOR ART)

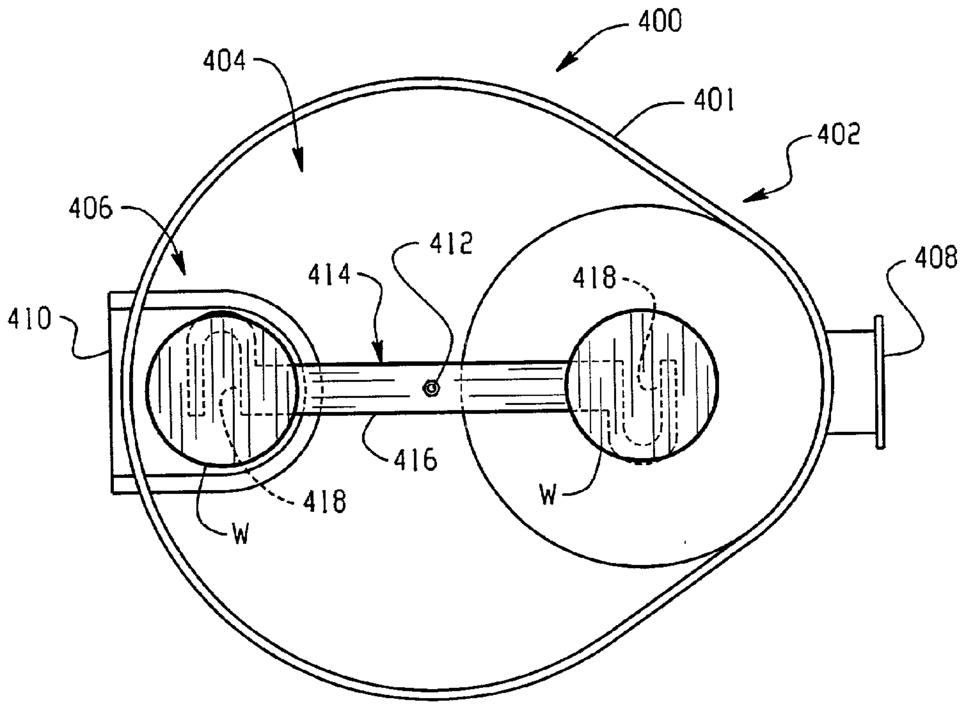
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Fig. 8A

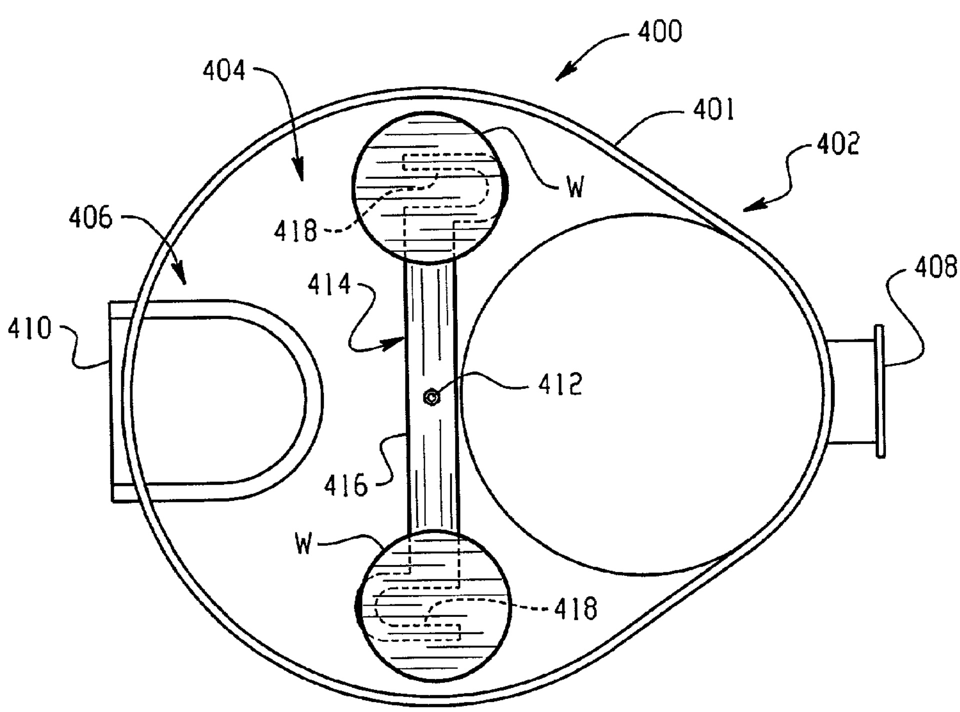
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Fig. 8B

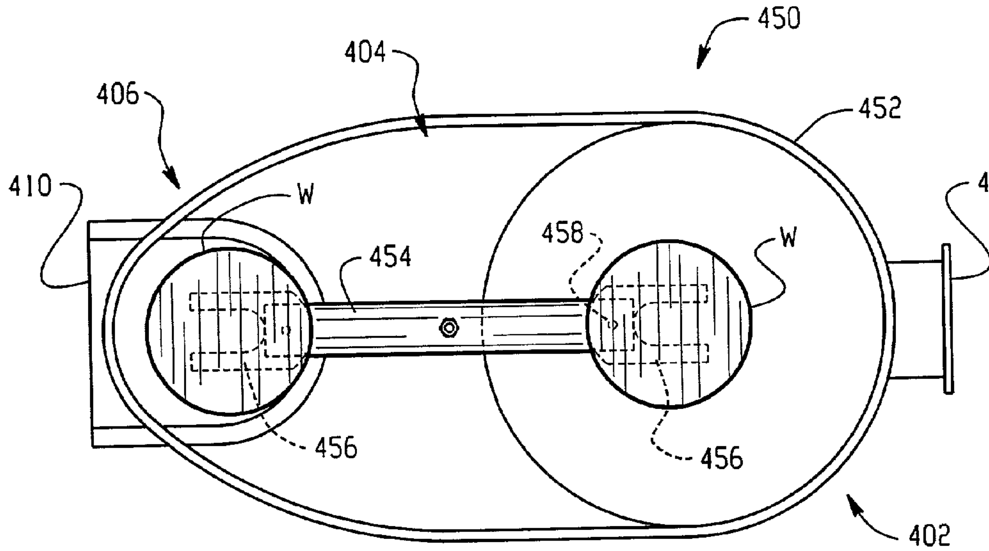
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Fig. 9A

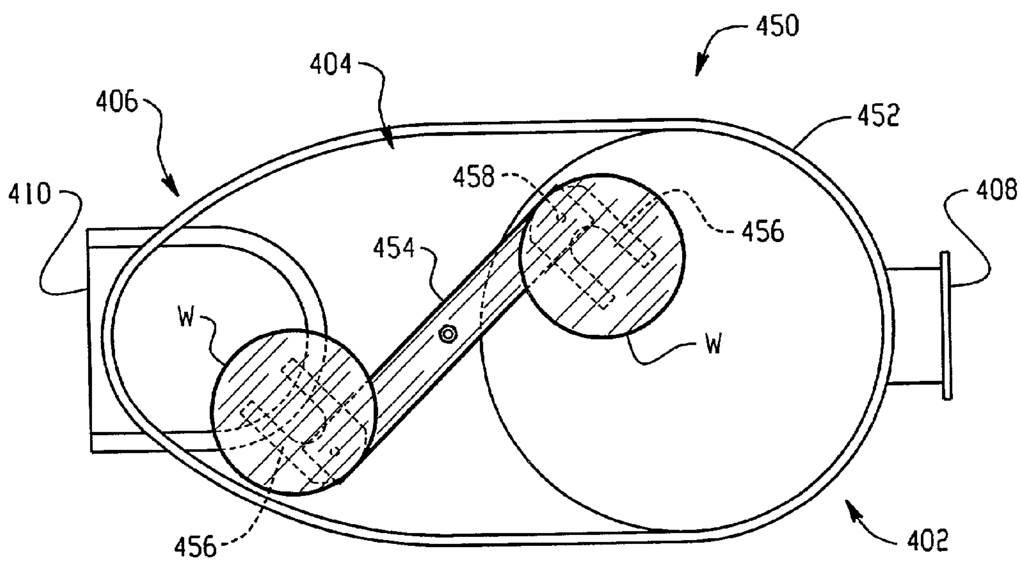
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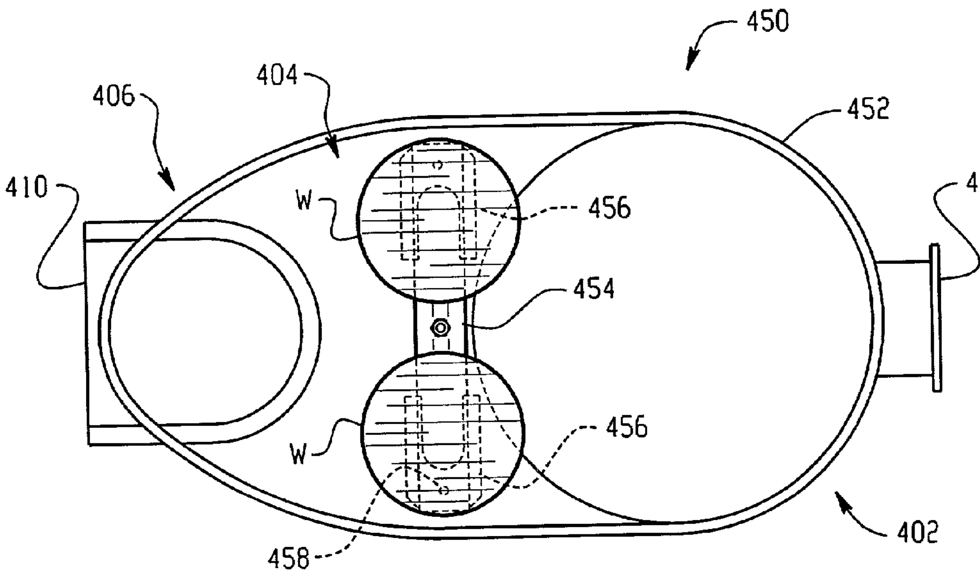
Fig. 9B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458
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Fig. 9C

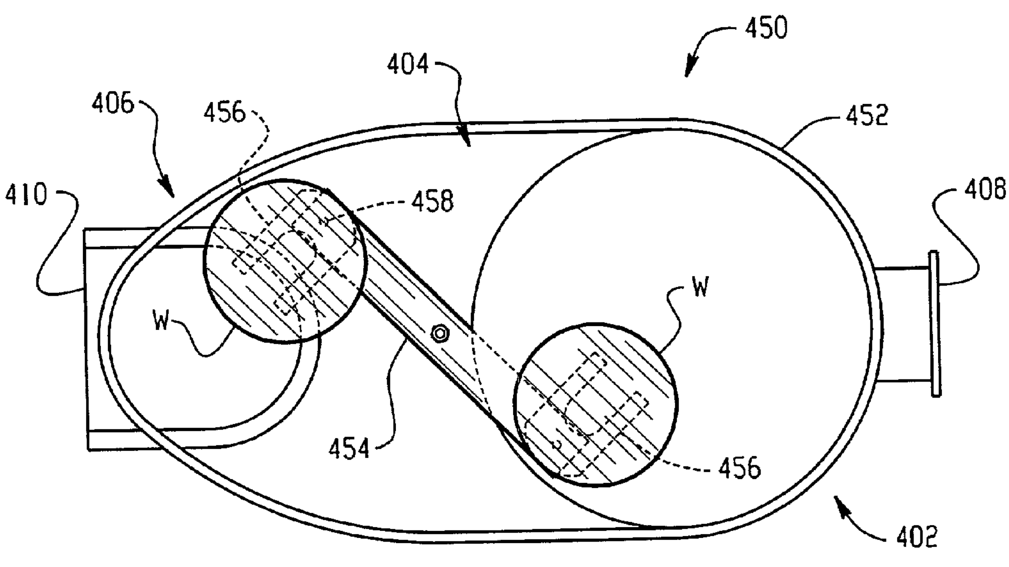
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Fig. 9D

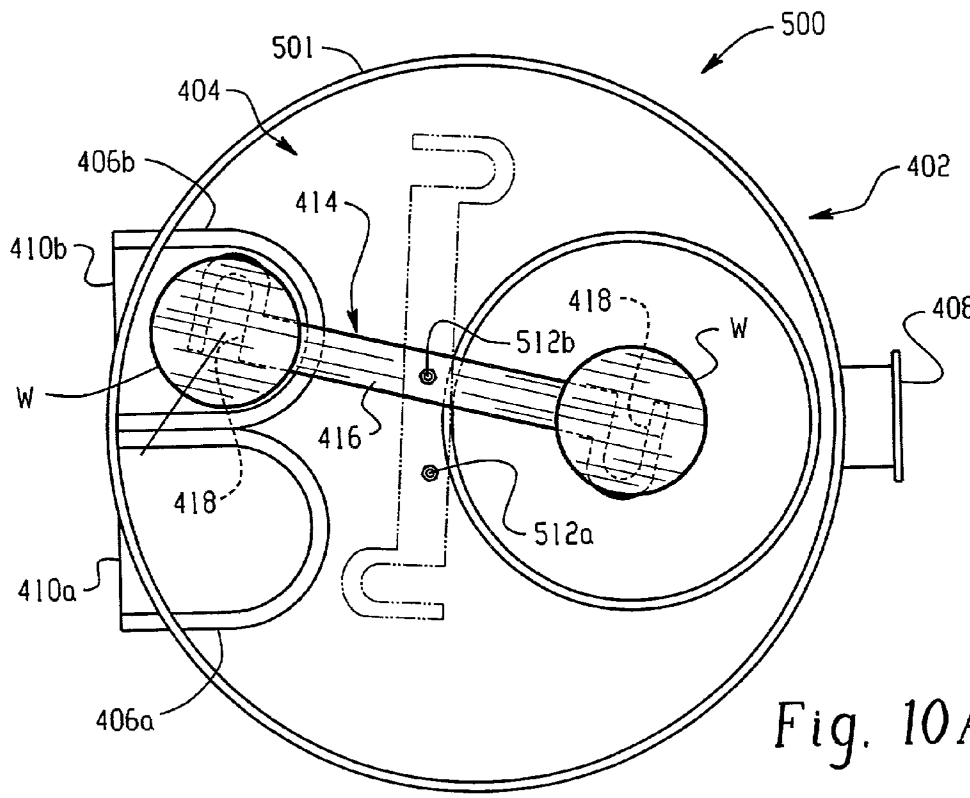

Fig. 10A

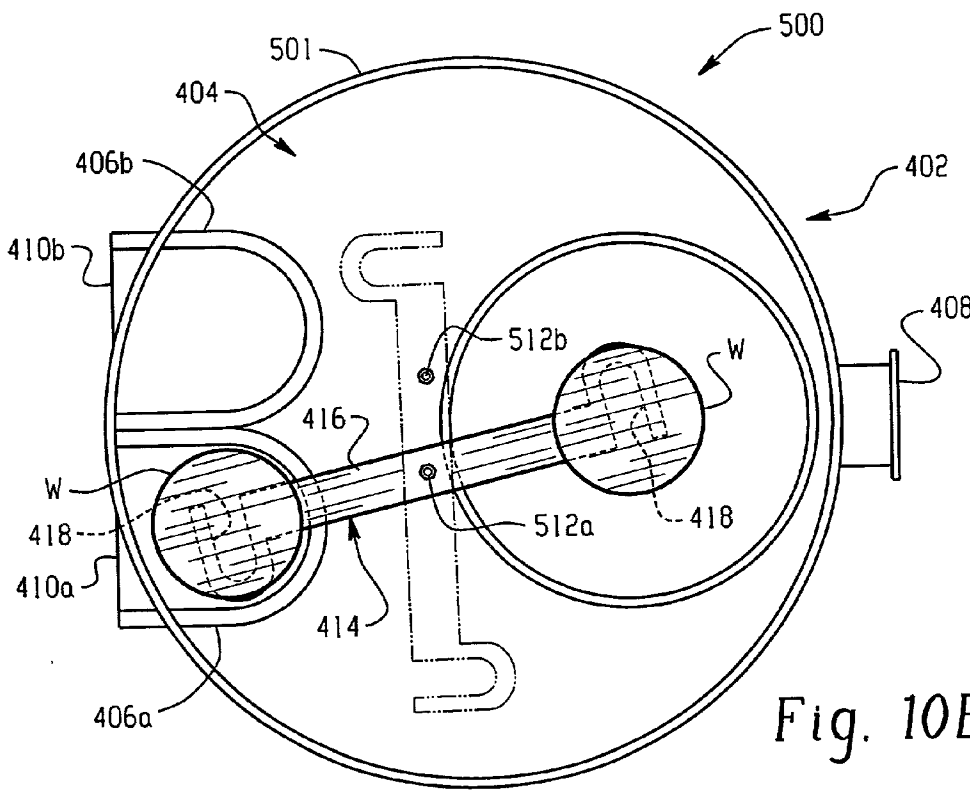

Fig. 10B

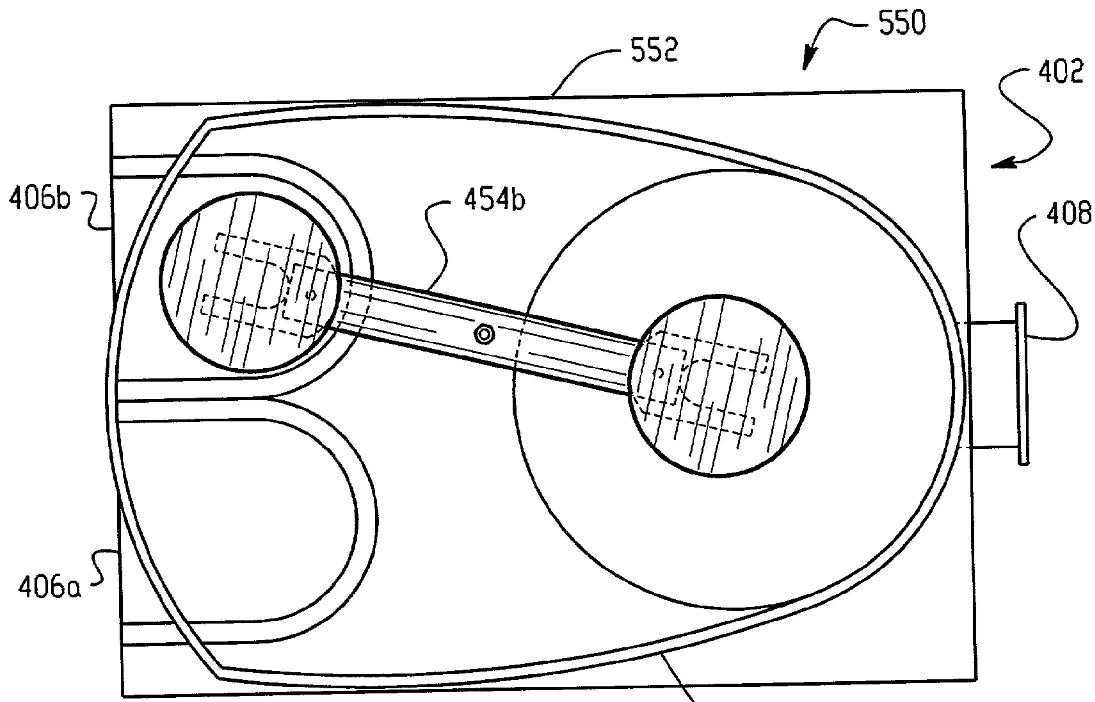

Fig. 11A

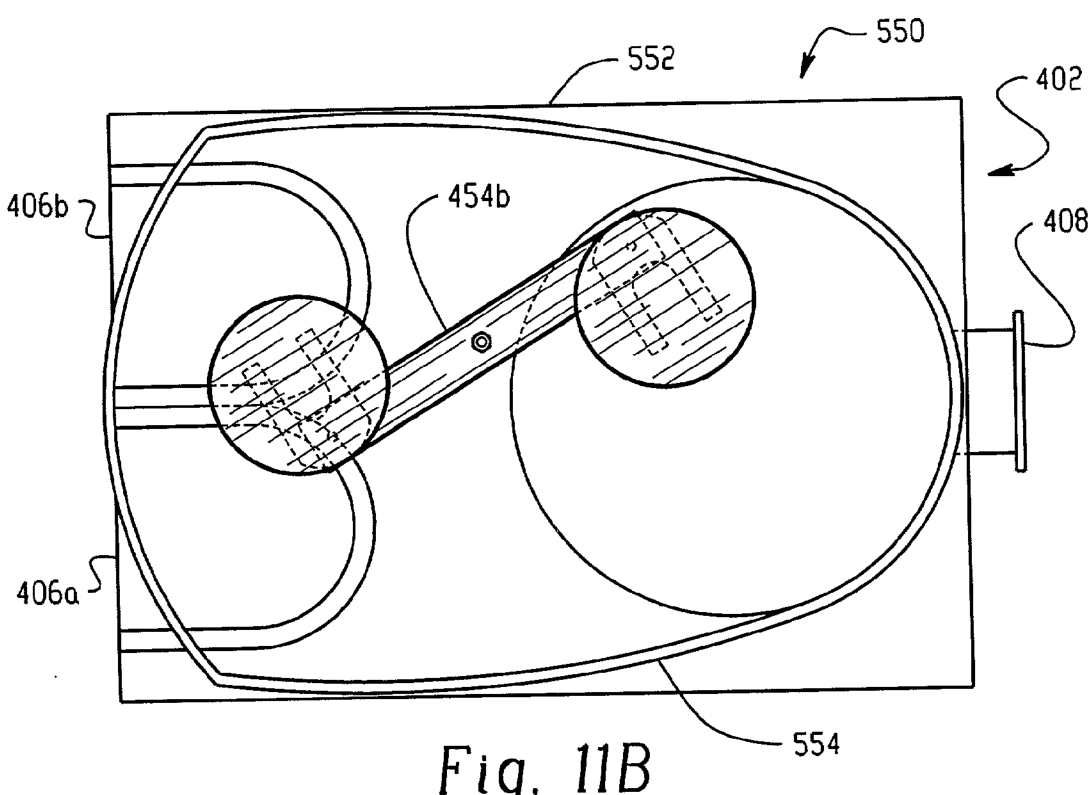

Fig. 11B

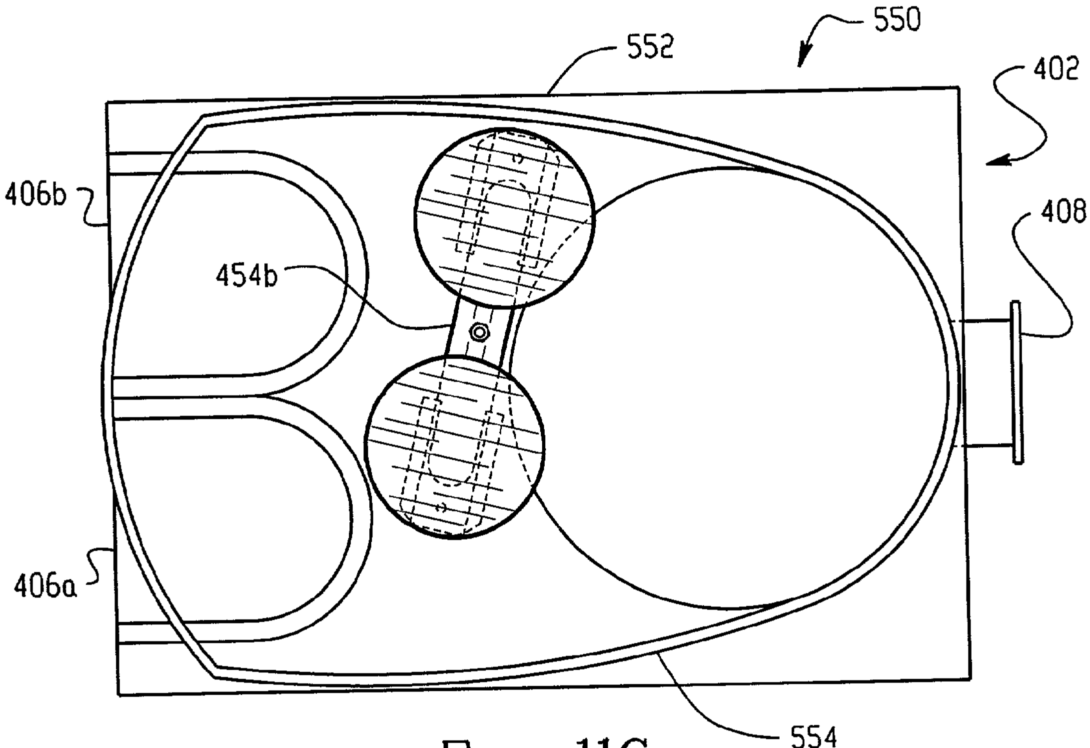

Fig. 11C

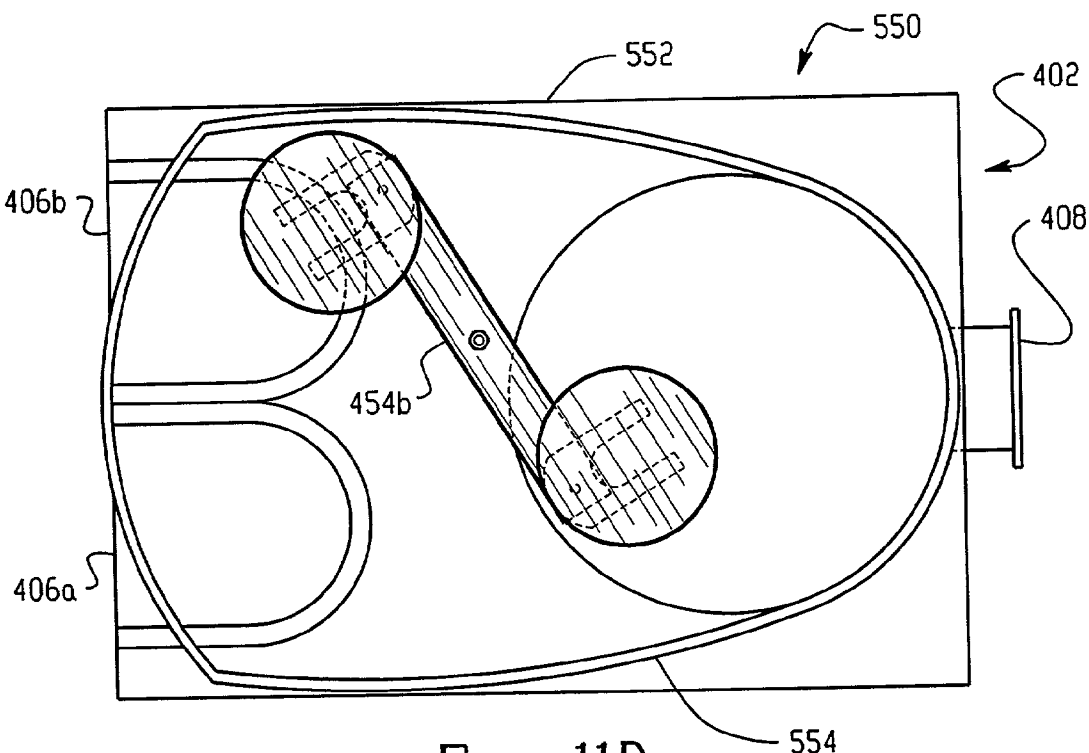

Fig. 11D

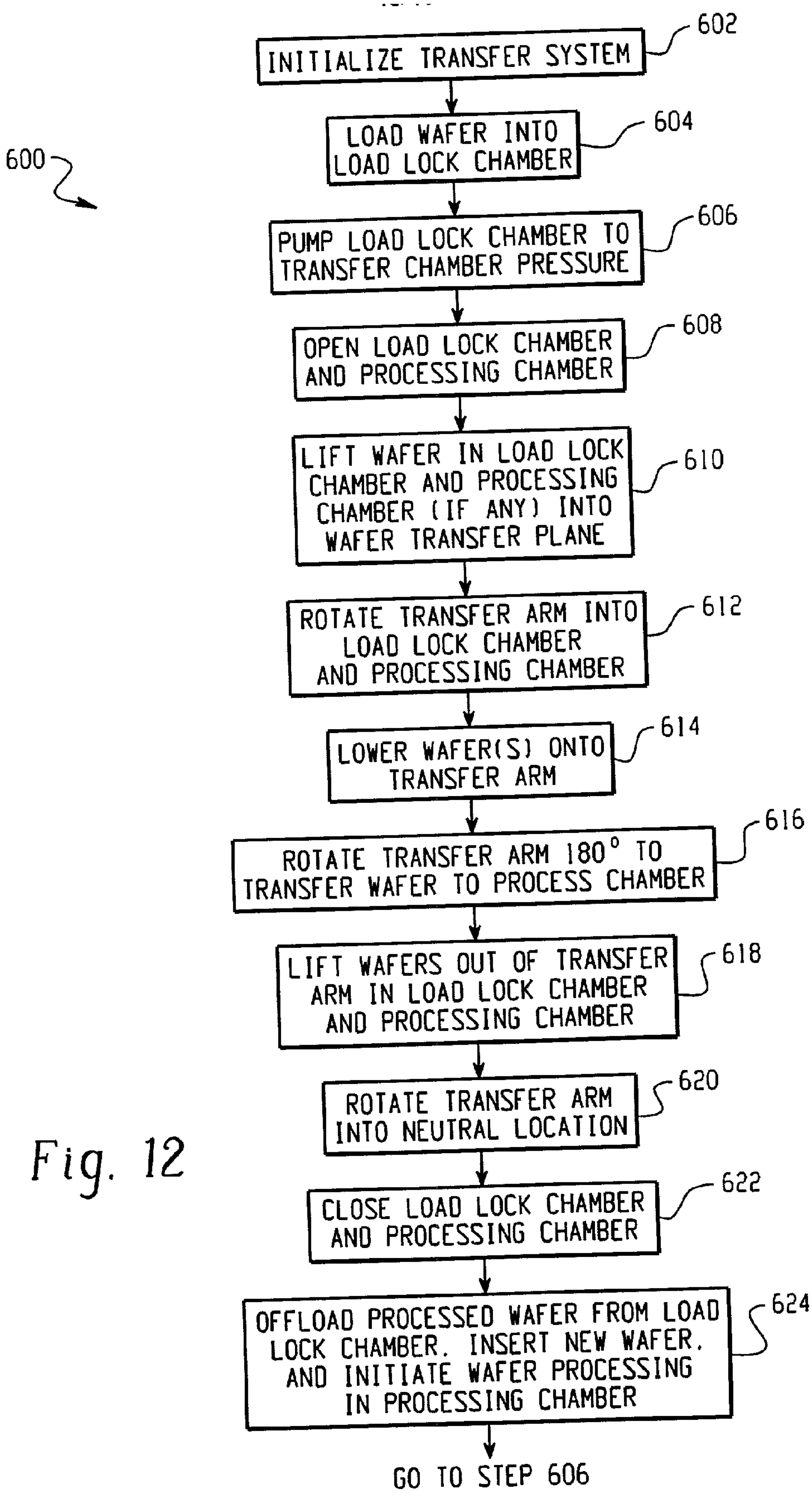
600
INITIALIZE TRANSFER SYSTEM
602
LOAD WAFER INTO LOAD LOCK CHAMBER
604
PUMP LOAD LOCK CHAMBER TO TRANSFER CHAMBER PRESSURE
606
OPEN LOAD LOCK CHAMBER AND PROCESSING CHAMBER
608
LIFT WAFER IN LOAD LOCK CHAMBER AND PROCESSING CHAMBER (IF ANY) INTO WAFER TRANSFER PLANE
610
ROTATE TRANSFER ARM INTO LOAD LOCK CHAMBER AND PROCESSING CHAMBER
612
LOWER WAFER(S) ONTO TRANSFER ARM
614
ROTATE TRANSFER ARM 180° TO TRANSFER WAFER TO PROCESS CHAMBER
616
LIFT WAFERS OUT OF TRANSFER ARM IN LOAD LOCK CHAMBER AND PROCESSING CHAMBER
618
ROTATE TRANSFER ARM INTO NEUTRAL LOCATION
620
CLOSE LOAD LOCK CHAMBER AND PROCESSING CHAMBER
622
OFFLOAD PROCESSED WAFER FROM LOAD LOCK CHAMBER, INSERT NEW WAFER, AND INITIATE WAFER PROCESSING IN PROCESSING CHAMBER
624
GO TO STEP 606

Fig. 12

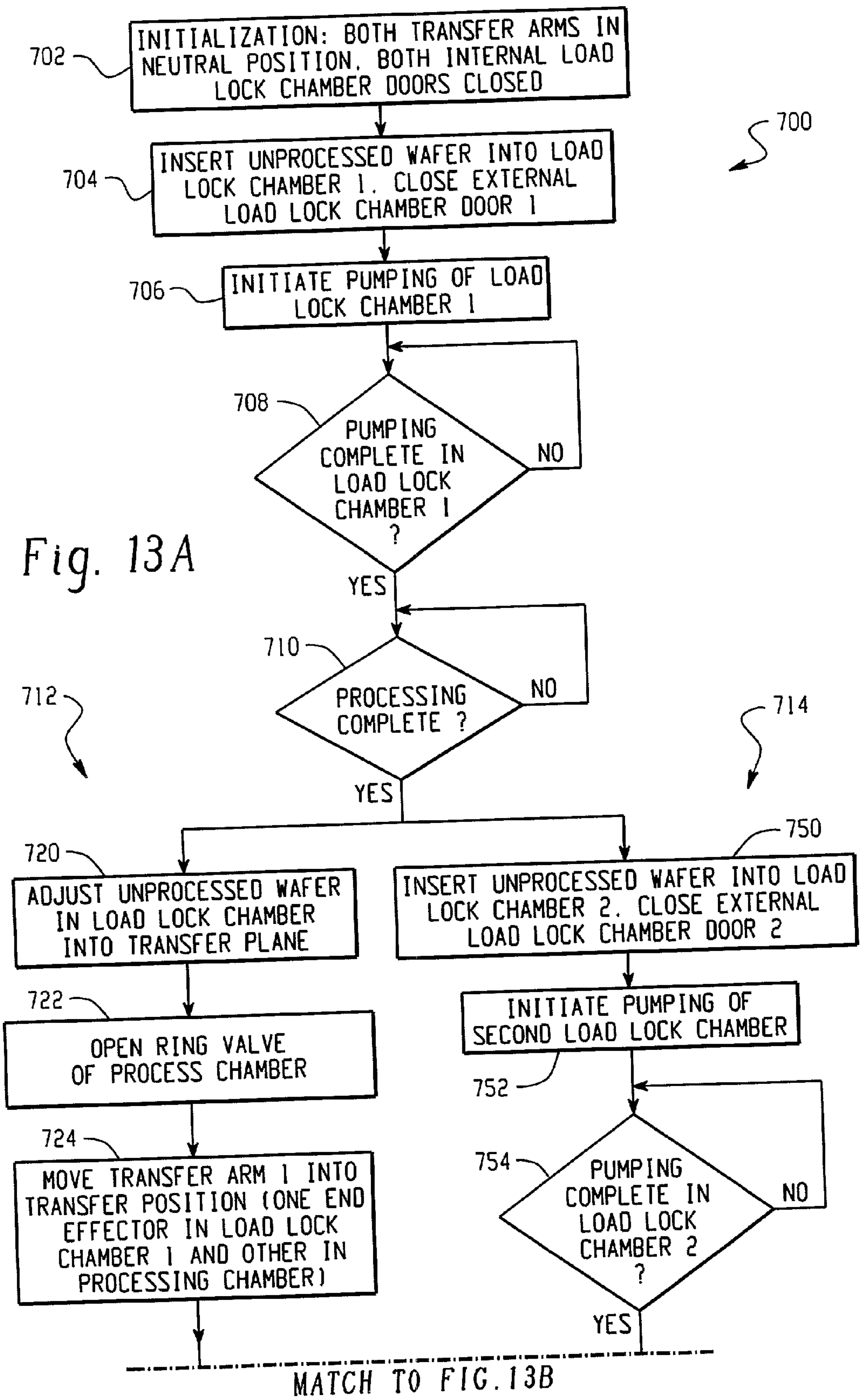
700
702
INITIALIZATION: BOTH TRANSFER ARMS IN NEUTRAL POSITION, BOTH INTERNAL LOAD LOCK CHAMBER DOORS CLOSED
704
INSERT UNPROCESSED WAFER INTO LOAD LOCK CHAMBER 1, CLOSE EXTERNAL LOAD LOCK CHAMBER DOOR 1
706
INITIATE PUMPING OF LOAD LOCK CHAMBER 1
708
PUMPING COMPLETE IN LOAD LOCK CHAMBER 1 ?
NO
YES
710
PROCESSING COMPLETE ?
NO
YES
712
714
720
ADJUST UNPROCESSED WAFER IN LOAD LOCK CHAMBER INTO TRANSFER PLANE
722
OPEN RING VALVE OF PROCESS CHAMBER
724
MOVE TRANSFER ARM 1 INTO TRANSFER POSITION (ONE END EFFECTOR IN LOAD LOCK CHAMBER 1 AND OTHER IN PROCESSING CHAMBER)
750
INSERT UNPROCESSED WAFER INTO LOAD LOCK CHAMBER 2, CLOSE EXTERNAL LOAD LOCK CHAMBER DOOR 2
752
INITIATE PUMPING OF SECOND LOAD LOCK CHAMBER
754
PUMPING COMPLETE IN LOAD LOCK CHAMBER 2 ?
NO
YES
MATCH TO FIG.13B

Fig. 13A

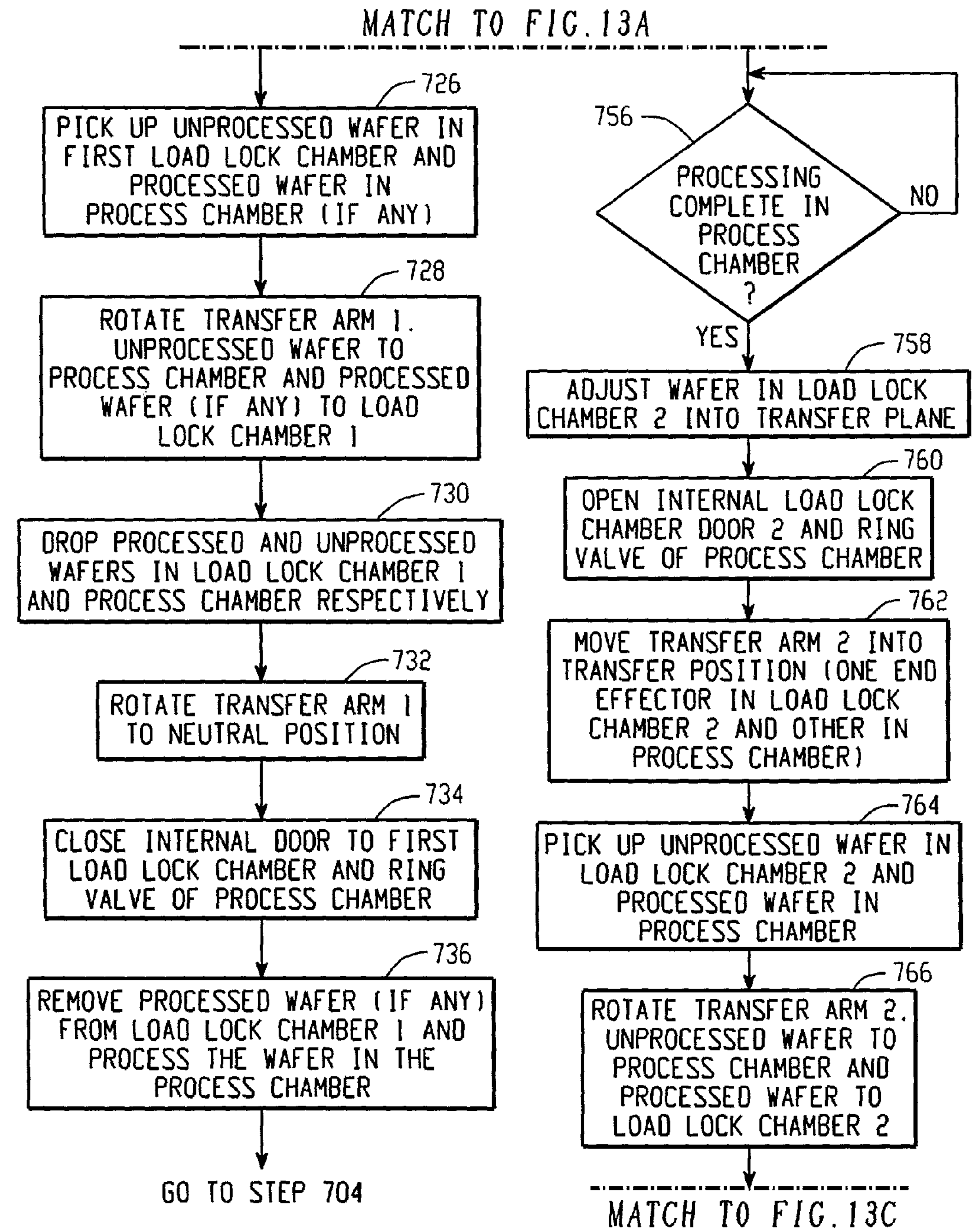
MATCH TO FIG. 13A
726
PICK UP UNPROCESSED WAFER IN FIRST LOAD LOCK CHAMBER AND PROCESSED WAFER IN PROCESS CHAMBER (IF ANY)
728
ROTATE TRANSFER ARM 1. UNPROCESSED WAFER TO PROCESS CHAMBER AND PROCESSED WAFER (IF ANY) TO LOAD LOCK CHAMBER 1
730
DROP PROCESSED AND UNPROCESSED WAFERS IN LOAD LOCK CHAMBER 1 AND PROCESS CHAMBER RESPECTIVELY
732
ROTATE TRANSFER ARM 1 TO NEUTRAL POSITION
734
CLOSE INTERNAL DOOR TO FIRST LOAD LOCK CHAMBER AND RING VALVE OF PROCESS CHAMBER
736
REMOVE PROCESSED WAFER (IF ANY) FROM LOAD LOCK CHAMBER 1 AND PROCESS THE WAFER IN THE PROCESS CHAMBER
GO TO STEP 704
756
PROCESSING COMPLETE IN PROCESS CHAMBER ?
NO
YES
758
ADJUST WAFER IN LOAD LOCK CHAMBER 2 INTO TRANSFER PLANE
760
OPEN INTERNAL LOAD LOCK CHAMBER DOOR 2 AND RING VALVE OF PROCESS CHAMBER
762
MOVE TRANSFER ARM 2 INTO TRANSFER POSITION (ONE END EFFECTOR IN LOAD LOCK CHAMBER 2 AND OTHER IN PROCESS CHAMBER)
764
PICK UP UNPROCESSED WAFER IN LOAD LOCK CHAMBER 2 AND PROCESSED WAFER IN PROCESS CHAMBER
766
ROTATE TRANSFER ARM 2. UNPROCESSED WAFER TO PROCESS CHAMBER AND PROCESSED WAFER TO LOAD LOCK CHAMBER 2
MATCH TO FIG. 13C

Fig. 13B

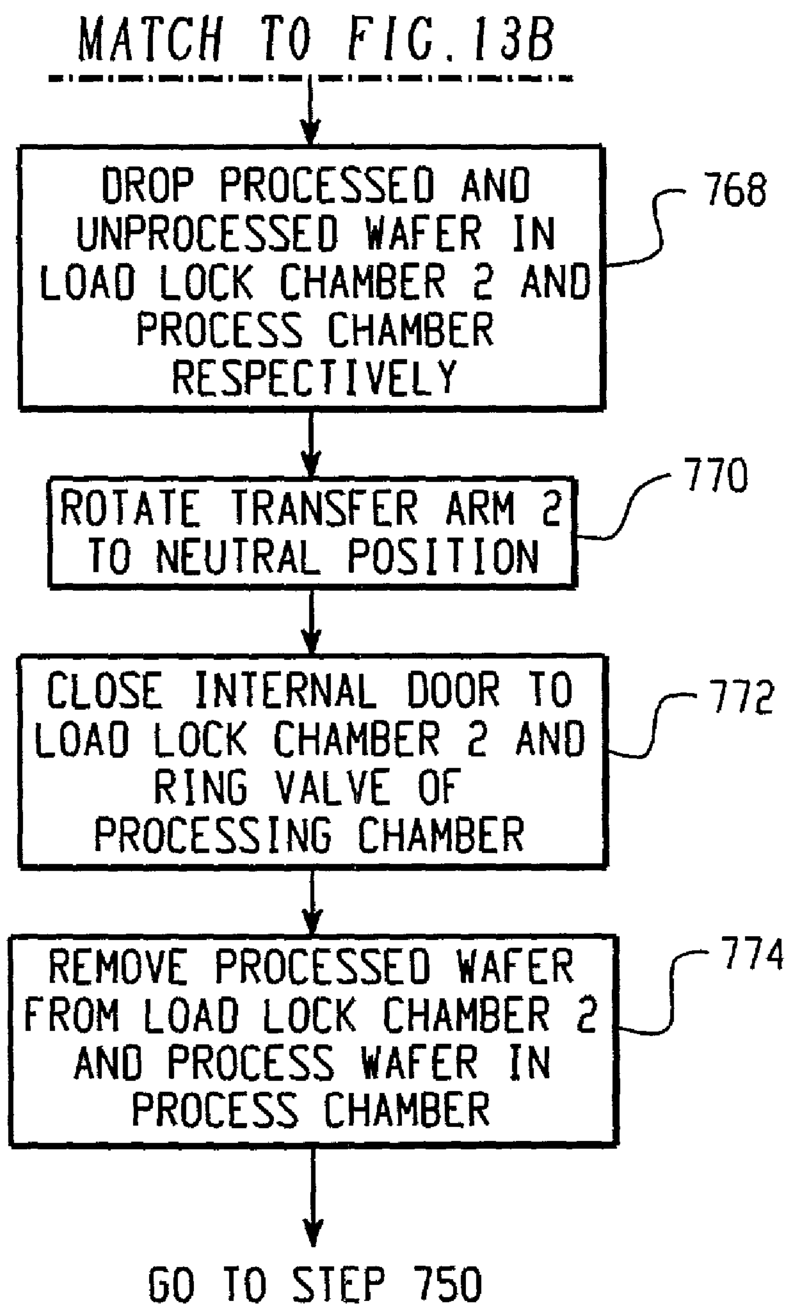
MATCH TO FIG.13B
DROP PROCESSED AND UNPROCESSED WAFER IN LOAD LOCK CHAMBER 2 AND PROCESS CHAMBER RESPECTIVELY
768
ROTATE TRANSFER ARM 2 TO NEUTRAL POSITION
770
CLOSE INTERNAL DOOR TO LOAD LOCK CHAMBER 2 AND RING VALVE OF PROCESSING CHAMBER
772
REMOVE PROCESSED WAFER FROM LOAD LOCK CHAMBER 2 AND PROCESS WAFER IN PROCESS CHAMBER
774
GO TO STEP 750

Fig. 13C

SERIAL WAFER HANDLING MECHANISM

FIELD OF THE INVENTION

[0001] The present invention relates generally to semiconductor processing systems, and more specifically to a system and method for transferring a wafer or other planar type substrate to a processing apparatus.

BACKGROUND OF THE INVENTION

[0002] The fabrication of integrated circuits and other type devices typically employs a series of fabrication steps in which a semiconductor wafer or other type substrate is processed within various processing systems. For example, a semiconductor wafer is subjected to photoresist and other film depositions and patterning steps, implantation and diffusion type processing, etc. The diverse processing steps are executed in a variety of different processing systems, for example, photoresist ashing systems, dry etch systems, ion implantation systems, chemical vapor deposition systems, etc. For each of the above processing systems, control of contamination is imperative for a cost-effective, reliable manufacture of such devices. Furthermore, because design rules for integrated circuits require ever-decreasing critical dimension feature sizes, it is necessary to provide improved control over particulate contamination within such systems.

[0003] Some of the primary sources of particulate contamination in integrated circuit processing are personnel, equipment and chemicals. Particulates generated or "given-off" by personnel are transmitted through the processing environment and may result undesirably in device defects. Particulates within the equipment and chemicals associated therewith are often called process defects and are caused by frictional contact between surfaces in the equipment and impurities within the supply gases or chemicals. One significant source of such process defects is contamination associated with the storage transportation of wafers from one processing system to another.

[0004] Various mechanisms have been developed to isolate the wafer from particles during the storage, transport and processing of wafers in the processing equipment. For example, the Standard Mechanical Interface (SMIF) system has been created to reduce particle contaminations.

[0005] In a typical SMIF system, a box or carrier is placed at the interface port of the processing apparatus; latches release the box door and port door simultaneously. The doors on the carrier mate with the doors on the interface port of the processing equipments and open simultaneously so that particles which may have been on the external door surfaces are trapped between the doors and thus do not contaminate the processing chamber.

[0006] Regardless of the various attempts made to minimize process defects, contamination problems still persist. Another method of reducing process defects associated with such contamination is by constantly evacuating and re-pressurizing the process chamber as wafers are transferred thereto and therefrom. A method for effectuating such contamination reduction is illustrated in prior art **FIG. 1** and designated generally at reference numeral **10**. Typically, a multi-wafer cassette is located local to the processing chamber at ambient atmosphere, while a wafer within the process chamber is processed at a substantially reduced pressure, for example, about 1 millitorr at step **12**. After the processing is complete, the wafer is removed at step **14** by opening the process chamber to allow transfer of the processed wafer back into the multi-wafer cassette.

[0007] Subsequent to the wafer removal, the process chamber is pumped down to a pressure significantly lower than the processing pressure, for example, about 1 microtorr at step **106** in order remove any contamination that may have been introduced by opening the chamber door. A load lock valve is then opened and a new wafer is then loaded into the process chamber at step **18**. The load lock valve is then closed and the chamber is again pressurized to the desired process pressure at step **20**. Although the above method **10** generally is effective at minimizing contamination to a reasonable level, the method **10** involves "pump and vent" cycles between the loading of each wafer into the chamber which negatively impacts processing throughput. As is well known to those skilled in the art, because processing equipment is a significant capital expenditure, low equipment throughput is highly undesirable.

[0008] Another problem associated with certain types of semiconductor processing equipment is related to the doorway or access port into the process chamber. Typically a wafer transfer endstation mates with a rectangular or box-like doorway or access port of the process chamber. The process chamber isolates the internal portion of the chamber from the outside environment during processing by actuating a slot valve associated with the access port. The slot valve-access port interface, however, results in an asymmetry within the process chamber which in some processes, for example, plasma immersion ion implantation, may result in temperature variation, plasma density non-uniformity and other type non-uniformities within the process. Such non-uniformities may negatively impact process control and the like.

[0009] There is a need in the art for a semiconductor processing system and method which minimizes process chamber contamination, increases wafer throughput and improves semiconductor process control.

SUMMARY OF THE INVENTION

[0010] The present invention is directed to a wafer processing system which efficiently handles the transfer of wafers to and from a wafer processing chamber in a manner which reduces chamber contamination, increases wafer throughput and improves process control.

[0011] According to one aspect of the present invention, a wafer processing system and associated method is disclosed which efficiently handles the transfer of a wafer to and from a wafer processing chamber without requiring an evacuation of the processing chamber for each wafer transfer. The system includes a load lock chamber, a process chamber and a transfer chamber therebetween. A portion of the load lock chamber is sealed or otherwise isolated from the transfer chamber and the process chamber when a wafer is transferred thereto. The load lock chamber portion is then evacuated or otherwise pumped to substantially equalize the pressure between the load lock chamber portion and the remaining portion of the load lock chamber, transfer chamber and process chamber. Upon pressure equalization, the load lock chamber portion containing the wafer is brought into fluid communication with the transfer chamber and the process chamber, and the wafer is transferred to the processing chamber via the transfer chamber. According to the present invention, the use of one or more such load lock chambers allows transfer of wafers to the process chamber without the need for an evacuation thereof, thereby minimizing process chamber contamination and increasing wafer throughput.

[0012] According to another aspect of the present invention, a ring valve and associated method is disclosed. The ring valve resides within or is otherwise associated with the process chamber and is operable to move between an open and closed position therein to selectively seal the process chamber from the remainder of the wafer processing system. In the open ring valve position, the interior of the processing chamber forms a top chamber portion and a bottom chamber portion defining an annular spacing therebetween. In the open position, the ring valve exposes a process chamber access port at a portion of the annular spacing through which the transfer chamber is coupled and the process chamber is accessed. In the closed position, the ring valve couples the top and bottom interior chamber portions together, thereby sealing the processing chamber from the transfer chamber and load lock chamber, respectively. In addition, the ring valve has a substantially uniform interior peripheral surface which provides a peripheral uniformity within the processing chamber, thereby facilitating uniform processing conditions therein.

[0013] According to yet another aspect of the present invention, a single axis wafer movement transfer arm and associated method of wafer transfer is disclosed. The transfer arm avoids the multi-axis, multi-jointed articulated robotic arms of prior art systems, thereby reducing the particle generation and contamination associated therewith. The transfer arm includes an elongate member which is rotatably coupled to a portion of the transfer chamber about an axis which permits rotational movement of the transfer arm between the load lock chamber and the process chamber. Preferably, the arm is rotatably coupled to the transfer chamber at a midpoint thereof and contains end effectors at each end for simultaneous wafer transfer between the process chamber and the load lock chamber in an efficient manner.

[0014] Preferably, the transfer arm of the present invention is utilized in conjunction with a dual load lock chamber processing system arrangement. In such case, two such transfer arms are implemented and rotate about separate axes to and from the process chamber from separate load lock chambers. That is, one transfer arm rotates about a first axis while the other transfer arm rotates about a second axis. In the above manner, one load lock chamber may be loaded externally with a wafer and undergo a pump and vent cycle while the other load lock chamber is transferring and receiving thereto wafers with the process chamber. In the above manner, wafers are transferred to and from the process chamber in an efficient manner without substantial contamination associated therewith, thereby improving process yield and throughput.

[0015] To the accomplishment of the foregoing and related ends, the invention comprises the features hereinafter fully described and particularly pointed out in the claims. The following description and the annexed drawings set forth in detail certain illustrative embodiments of the invention. These embodiments are indicative, however, of but a few of the various ways in which the principles of the invention may be employed. Other objects, advantages and novel features of the invention will become apparent from the following detailed description of the invention when considered in conjunction with the drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0016] **FIG. 1** is a flow chart diagram illustrating a prior art method of transferring a wafer to a wafer processing chamber, wherein the process chamber undergoes a pump and vent cycle for each wafer transferred thereto;

[0017] **FIG. 2** is a cross sectional view of an exemplary plasma immersion ion implantation system;

[0018] **FIG. 3** is a system level cross sectional view illustrating a ring valve and multi-chamber processing system for eliminating process chamber pump and vent cycles according to the present invention;

[0019] **FIG. 4***a* is an exploded, fragmentary cross sectional view of a portion of the process chamber of **FIG. 3**, wherein a ring valve is illustrated in an open, retracted position;

[0020] **FIG. 4***b* is an exploded, fragmentary cross sectional view of a portion of the process chamber of **FIG. 3**, wherein a ring valve is illustrated in a closed position to seal the process chamber;

[0021] **FIGS. 5 and 6** are perspective views illustrating a prior art multi-axis, multi-jointed articulated robot arm in extended and retracted positions, respectively;

[0022] **FIGS. 7***a*-**7***d* are top plan views illustrating a plurality of positions of the prior art robot arm of **FIGS. 5 and 6** depicting extended, retracted and intermediate positions, respectively;

[0023] **FIG. 8***a* is a top plan view of a wafer processing system employing a single axis wafer movement transfer arm in a transfer position according to the present invention;

[0024] **FIG. 8***b* is a top plan view of the wafer processing system of **FIG. 8***a* illustrating the single axis wafer movement transfer arm in a neutral position according to the present invention;

[0025] **FIGS. 9***a*-**9***d* are top plan views of a wafer processing system employing a wafer transfer arm which traverses a generally elliptical wafer transfer path in a number of different wafer transfer positions according to the present invention;

[0026] **FIG. 10***a* is a top plan view of a wafer processing system employing multiple load lock chambers and two single axis wafer movement transfer arms, one being in a transfer position and the other in a neutral position according to the present invention;

[0027] **FIG. 10***b* is a top plan view of the wafer processing system of **FIG. 10***a* illustrating the single axis wafer movement transfer arms of **FIG. 10***a* in different positions according to the present invention;

[0028] **FIGS. 11***a*-**11***d* are top plan views of a wafer processing system having two load lock chambers and employing two wafer transfer arms which traverse generally elliptical wafer transfer paths in a number of different wafer transfer positions according to the present invention;

[0029] **FIG. 12** is a flow chart diagram illustrating a methodology for transferring wafers to and from a process chamber without a process chamber pump and vent cycle for each wafer transfer according to the present invention; and

[0030] **FIGS. 13***a***-13***c* are flow chart diagrams illustrating another methodology for transferring wafers to and from a process chamber via multiple load lock chambers without a process chamber pump and vent cycle for each wafer transfer according to the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0031] The present invention will now be described with reference to the drawings wherein like reference numerals are used to refer to like elements throughout. The present invention includes a wafer process chamber, wafer handling system and associated method which incorporates several inventive features that improve the throughput of the wafer processing system, reduce contamination associated with wafer handling and transfer, and improve process control therein.

[0032] The present invention includes a ring valve in conjunction with the process chamber. The ring valve extends peripherally throughout a portion of the process chamber and is operable to move between an open position and a closed position, wherein in the open position an access port is revealed or otherwise defined which allows a wafer to enter or exit the process chamber. In the closed position, the ring valve effectively closes the access port and provides a substantially uniform surface about an interior peripheral portion of the process chamber, thereby facilitating uniform processing conditions within the process chamber and improving process control.

[0033] In addition, the present invention provides for single axis wafer movement between a load lock chamber and a process chamber via a non-jointed wafer transfer arm. The transfer arm preferably includes an elongate transfer member which is rotationally coupled to an axis point in a transfer chamber. The elongate transfer member includes end effectors or other type wafer contact manipulators generally at each distal end thereof which rotate in a wafer transfer plane between a neutral position in the transfer chamber and wafer engagement positions (transfer positions) in the load lock chamber and process chamber to transfer wafers therebetween. Due to the single axis rotation, the non-jointed transfer arm of the present invention reduces substantially the number of moving parts which frictionally engage one another, and thereby reduces particle contamination associated therewith, and allows the system to keep process gas in the transfer chamber at the same pressure as the process chamber.

[0034] Accordingly, the present invention further includes a load lock chamber and transfer chamber associated with the process chamber which allows for selective fluid isolation between the load lock chamber and the process chamber. Consequently, wafers may be transferred to the process chamber via the transfer arm without having to pump and vent the process chamber for each wafer transfer, thereby reducing contamination associated therewith and increasing system throughput.

[0035] The various features of the present invention will be described below in conjunction with a plasma immersion ion implantation system as an exemplary embodiment. It should be understood, however, that the present invention may also be used in conjunction with other type semiconductor or other type substrate processing systems (e.g., photoresist ashing systems, dry etch systems, ion implantation systems, chemical vapor deposition systems, etc.) and such systems are contemplated as falling within the scope of the present invention.

[0036] Referring now to the drawings, **FIG. 2** discloses an exemplary conventional plasma immersion ion implantation system, and is generally designated at reference numeral **100**. The system **100** includes an evacuated process chamber **105** that is defined by an electrically activatable wafer support platen **110** mounted on an insulator **115**, an electrically grounded chamber housing **120** having walls **125** associated therewith, and a quartz window **130**. Plasma which is generated within the chamber **105** contains ions of a desired dopant species (e.g., arsenic) that are implanted into a substrate, such as a semiconductor wafer W located therein, when a negatively charged voltage is applied to the platen **110**. As shown in **FIG. 2**, the wafer W is lifted off of the platen by pins **135** operated by pin assemblies **140**. In this manner the wafer may be positioned vertically in a wafer transfer plane and installed into and removed from the plasma chamber via an access port **145** and a load lock assembly (not shown).

[0037] The plasma is generated in the process chamber **105** as follows. An ionizable dopant gas is introduced into the process chamber **105** by means of an inlet **150** and a perforated annular channel **155** that resides about the upper periphery of the chamber. A radio frequency (RF) generator **160** generates an RF signal (on the order of 13.5 megahertz (MHz)) which is coupled to a matching network **165**. The matching network includes capacitors **170** that capacitively couple the RF signal to a generally planar antenna **175**, having inner and outer circular coils, via leads **180** and **185**. Matching the impedance of the RF generator **160** with the load impedance insures maximum power out of the antenna **175** by minimizing reflection of the RF signal back into the generator. One such type of matching network **165** is known as an “inverted L” network, wherein the capacitance of the capacitors **170** is varied by servomotors, depending upon operating conditions.

[0038] The RF current generated within the antenna **175** creates a magnetic field that passes through the quartz window **130** into the process chamber **105**. The magnetic field lines are oriented in the direction shown by arrows B, based on the direction of current through the antenna coils. The magnetic field penetrating the process chamber **105** through the quartz window **130** induces an electric field in the process chamber. This electric field accelerates electrons, which in turn ionize the dopant gas, which is introduced into the chamber through the annular channel **155**, to create a plasma. The plasma includes positively charged ions of the desired dopant that are capable of being implanted into the wafer W when a suitable opposing voltage is applied to the platen **110** by the modulator **190**. Because the implantation process occurs in a vacuum, the conventional process chamber **105** is evacuated by pumps (not shown) via the pump manifold **195**.

[0039] Electromagnetic coils **196, 197, 198,** and **199** are located outside of the process chamber **105**. The purpose of the coils is to vary the magnetic field within the process chamber **105** to vary the plasma diffusion rate, which alters the radial distribution of plasma density across the surface of the wafer, to insure a uniform implant of ions across the surface of the wafer W. The electromagnetic coils of **FIG. 2** include two larger main coils **196** and **199** disposed above and below, respectively, and two smaller trim coils **197** and **198**, which reside closer in proximity to the process chamber **105**. In addition, the wafer platen **110** includes a dosimetry detector such as a plurality of Faraday current collectors or cups **192** that are used to measure plasma current density and thereby provide an indication of implant dose.

[0040] The process chamber **105** of **FIG. 2** suffers from a non-uniformity within the chamber which negatively impacts process condition uniformity therein. In particular, the access port **145** for receiving wafers for processing includes an OEM slot valve, which is a valve having a generally rectangular opening which mounts to the box-like access port opening **255** in the process chamber **105**. The opening in the slot valve disturbs the cylindrical shape in an interior peripheral portion of the process chamber **105** which may cause non-uniformities in the process conducted therein. For example, in the plasma immersion ion implantation type chamber **105**, the disturbance (non-uniformity) disrupts the plasma density uniformity therein, thereby resulting in potential implantation variations across the wafer.

[0041] The present invention overcomes the disadvantages associated with the prior art slot valve discussed above by employing an annular ring valve within the wafer process chamber. An exemplary ring valve and associated wafer processing system is illustrated in **FIGS. 3 and 4***a*-**4***b*. In **FIG. 3, a** wafer processing system **200** includes a process chamber **202**, a wafer transfer chamber **204**, and a load lock chamber **206**, respectively. The process chamber **202** is similar to the chamber **105** of **FIG. 2** in many respects, however, the rectangular slot valve is replaced with an annular ring valve, designated at reference numeral **210** which peripherally encircles a generally middle interior portion of the process chamber **202**.

[0042] The ring valve **210** is operable effectively to open and close the process chamber **202** by moving between a first, open position (a retracted position) and a second, closed position (an extended position). As illustrated in **FIG. 4***a*, in a first, open position **212**, the ring valve **210** is in a retracted position and resides within an annular lip of the process chamber **202**, thereby opening a chamber access slot **214** and placing a chamber interior region **216** in fluid communication with the transfer chamber **204**. In the open position **212**, a wafer may enter or exit the process chamber **202** in one of many ways. For example, a wafer may enter or exit the process chamber **202** using a multi-axis, multi-jointed articulated transfer arm to transfer a wafer to and from the process chamber **202**. Alternatively, wafer transfer may be effectuated using a transfer arm employing a single axis wafer movement to and from the process chamber **202**, as will be described in greater detail infra.

[0043] The second, closed ring valve position is illustrated in **FIG. 4***b*, designated at reference numeral **217** in which the ring valve **210** sealingly engages a top interior portion **218** of the process chamber **202** about a periphery thereof. Simultaneously, when in the closed position, a bottom portion of the ring valve engages a portion **225** of the process chamber. Preferably, the ring valve **210** is actuated and thereby moved between the open and closed positions via an actuation member **220** which selectively exerts a force upon a bottom portion **220** of the ring valve **210**, as may be desired.

[0044] According to one exemplary embodiment of the present invention, the actuation member **220** includes an internally threaded screw/bore arrangement in which the rotation of an internal screw member within a threaded bore results in a variation in the vertical position of the ring valve **210** within the process chamber **202**. Alternatively, for example, a bellow type fluid actuator may be implemented. Any manner of actuating or otherwise manipulating the vertical position of the ring valve **210** may be utilized and any such actuation device or system is contemplated as falling within the scope of the present invention.

[0045] In the second, closed position **217**, as illustrated in **FIG. 4***b*, the ring valve **210** seals or otherwise fluidly isolates the process chamber **202** from the transfer chamber **204**. In this manner, the ring valve **210** prevents the plasma (or other type processing environment) to generate deposits or otherwise affect the wafer transport system associated with the transfer chamber **204**. The ring valve **210** generally is annular in shape and preferably contains a substantially uniform inner peripheral surface **224**. Consequently, when in the closed position **217**, the access port **214** associated with the process chamber **202** is covered and a substantially uniform periphery exists therein, thereby facilitating uniform processing conditions within the process chamber **202**. In particular, with regards to a plasma immersion ion implantation apparatus, the substantially uniform inner peripheral surface **224** of the ring valve **210** facilitates a uniform plasma density throughout the process chamber **202**, thereby providing a more uniform ion implantation across the surface of the wafer W.

[0046] According to a preferred embodiment of the present invention, the ring valve **210** sealingly engages a top interior portion **218** of the chamber **202** in a center portion thereof and thus defines a top portion and a bottom portion of the process chamber, respectively. Preferably, the ring valve **210** is associated with the bottom portion of the process chamber **202** as illustrated in FIGS. **3**-**4***b*; that is, the actuator member **220** which manipulates the ring valve **210** is associated with the bottom portion of the process chamber **202**. Alternatively, however, the present invention contemplates the ring valve **210** being associated with the top process chamber portion. For example, in such an embodiment the actuator member **220** may be attached to the ring valve **210** and operate to effectively lower a suspended ring valve **210** down from a first, open position to a second, closed position which sealingly engages a bottom interior portion **225** of the process chamber **202**.

[0047] In addition, the ring valve **210** preferably is composed of a material which is the same or similar to the process chamber composition. Thus, the ring valve **210** preferably exhibits a coefficient of thermal expansion which approximates that of the process chamber **202**, thus maintaining an effective sealing engagement for the chamber when the valve **210** is in the closed position over a plurality of process temperatures.

[0048] According to another aspect of the present invention, the wafer processing system **200** of **FIG. 3** provides a transfer chamber **204** in conjunction with the load lock chamber **206** and the process chamber **202** which improves system operation by reducing process chamber contamination. The contamination improvement is effectuated by providing for a wafer transport to the process chamber which does not require a process chamber pump and vent cycle for each wafer transport as in prior art systems. Therefore the wafer processing system **200** allows the process chamber **202** to be maintained at the process environment pressure at all times throughout the wafer transport process. Such feature also advantageously allows wafer processing to commence expediently since the process chamber pressure is maintained during wafer transport.

[0049] The system **200** of **FIG. 3** includes the load lock chamber **206** having a load lock cover **250** which is operable to move between two positions: a first, closed position in which the load lock cover **250** is lowered within a shallow T-shaped recess **252** and sealingly engages and thereby isolates a portion of the load lock chamber **250** (corresponding to the recess **252**) from the transport chamber **204**, and a second, open position (as illustrated in **FIG. 3**) wherein the load lock cover **250** is lifted or otherwise moved out of the recess **252** in order to bring the recess portion **252** of the load lock chamber **206** into fluid communication with the transfer chamber **204**.

[0050] The load lock chamber **206** further includes a load lock cover actuator **254** which is operatively coupled to the load lock cover **250** and operable to move the load lock cover **250** between the open and closed positions, respectively. Any actuation mechanism may be utilized and is contemplated by the present invention. In addition, the load lock chamber **206** includes a plurality of pins **256** operated by a pin assembly **258** to position the wafer W vertically into a wafer transfer plane **260**. Lastly, the load lock chamber **206** includes a pump (not shown) associated therewith which is operable to pump down the recess portion **252** down to a processing pressure (e.g., about 1 millitorr) prior to transferring the wafer W to the process chamber **202**.

[0051] The system **200** operates in the following manner. The load lock cover **250** is initially in a closed position, wherein the cover **250** is sealingly engaged with the shallow T-shaped recess **252**, via the actuator **254**. Thus, the recess portion **252** is fluidly isolated from the transfer chamber **204**. A wafer W is the input into the recess **252** via a side access port **262**. Upon closing the port **262**, the pump (not shown) pumps down the pressure in the recess **252** (i.e., evacuates the recess region) down to the desired process environment pressure. Upon reaching the desired pressure, the load lock cover **250** is lifted via the actuator **254**, thereby placing the recess **252** in fluid communication with the transfer chamber **204**.

[0052] Operation continues by actuating the pins **256** via the pin assembly **258**, wherein the pins **256** contact a bottom portion of the wafer W and lift the wafer into the wafer transfer plane **260**. A wafer transfer assembly (not shown in **FIG. 3**) then takes the wafer W from the load lock chamber **206** and transfers the wafer W to the process chamber **202** (after opening the ring valve **210** associated therewith). Upon the wafer W entering the process chamber **202** and the wafer transfer assembly exiting the process chamber **202**, the ring valve **210** is moved to the closed position, thereby fluidly isolating the process chamber interior from the transfer chamber **204**. Since the transfer chamber **202** has remained at its process pressure throughout this entire process, processing can commence therein immediately without a pump and vent cycle associated therewith, thereby decreasing contamination within the process chamber **202** and improving processing throughput.

[0053] The above feature has been described in conjunction with a single load lock chamber **206**, however, the present invention contemplates such operation with multiple load lock chambers, preferably two such chambers **206**. In such a case, while a wafer is being transferred from one load lock chamber to the processing chamber for processing, the second load lock chamber concurrently contains a wafer and is pumping down to the processing pressure. Consequently, as soon as a wafer is removed from the process chamber **202**, another is immediately transferred thereto from the second load lock chamber, thereby substantially increasing the system throughput while minimizing process chamber contamination since the pump and vent cycle associated with either load lock chamber does not adversely impact a wafer processing and transfer cycle time.

[0054] Another aspect of the present invention relates to a wafer transfer apparatus for transferring a wafer W from a load lock chamber to a process chamber in an efficient, reliable manner. As will become evident in the discussion below, the wafer transfer apparatus of the present invention reduces the number of moving, frictionally engagable components over prior art systems and thereby reduces particulate contamination associated therewith. In addition, the design simplicity advantageously reduces system cost and improves system reliability.

[0055] In order to best understand the various advantageous features of the present invention, a brief description of a prior art type wafer transfer apparatus is provided. **FIGS. 5 and 6** illustrate perspective views of a multi-axis, multi-jointed articulated wafer transfer arm **300** which is capable of movement between an extended position (**FIG. 5**) and a retracted position (**FIG. 6**). In addition, **FIGS.** ***7a-7d*** illustrate a sequence of successive movements between the extended and retracted positions, respectively. As illustrated in **FIGS. 5 and 6**, the transfer arm **300** can rotate about an axis on a platform **302** to move an end effector **304** for alignment with openings in the load lock chamber and process chambers, respectively.

[0056] The prior art transfer arm **300** includes an elongated base arm **306** which is rotatable in a level plane about a base axis **307***a*; a forearm **308** is rotatably coupled to the base arm **306** at an opposite end about a forearm axis **307***b*. The forearm **308** in turn is rotatably coupled to a wrist member **310** for rotation about a wrist axis **307***c*. As seen in FIGS. **5-7***d*, the prior art transfer arm **300** includes multiple arm members which rotate about a plurality of axes **307***a*-**307***c*. Although such an arm **300** provides for compact movements, the plurality of joints and rotational arm members provide the potential for particulate contamination due to the frictional engagement of such arm members against one another and their movement about the multiple axes. In stark contrast, the wafer transfer system of the present invention substantially reduces particulate contamination, reduces cost and improves the system reliability over the prior art by utilizing one or more elongate transfer arms employing a single axis wafer movement between the load lock chamber **206** and the process chamber **202**, respectively.

[**0057**] **FIG. 8***a* is a plan view of a wafer processing system **400**, for example, a system similar to the system **200** of **FIG. 3**. The system **400** includes a system housing **401** which encompasses a process chamber **402**, a transfer chamber **404**, and a load lock chamber **406**. The process chamber **404** includes a gas manifold **408** associated therewith for the introduction of process gases such as a dopant species in the case of a plasma immersion ion implantation system. In addition, the load lock chamber **406** includes an external access port **410** by which a wafer W may enter the system **400** from an external wafer cassette (not shown).

[**0058**] Preferably, within the transfer chamber **404** resides a wafer transfer axis **412** about which a single axis wafer movement transfer arm **414** rotates. The wafer transfer arm **414** includes an elongate transfer member **416** having generally U-shaped end effectors **418** at each distal end thereof. The transfer arm **414** rotates about the axis **412** at least 180° and may rotate a full 360°, as may be desired. In rotating 180°, the transfer arm **414** is operable to move between two substantially identical transfer positions (as illustrated in **FIG. 8***a*), wherein each of the transfer positions correspond to an end effector **418** within the load lock chamber **406** and the process chamber **402**, respectively. As will be discussed in greater detail below, the transfer positions correspond to method steps in which a wafer W is transferred to or from the process chamber **402** and the load lock chamber **406**. In such an instance, the internal access port between the load lock chamber **406** and the transfer chamber **404** is open as well as the access port (e.g., the ring valve **210** of FIGS. **3**-**4***b*) between the transfer chamber **404** and the process chamber **402**. Therefore in the instance illustrated in **FIG. 8***a*, the load lock chamber **406** and the process chamber **402** are in fluid communication with one another via the transfer chamber **404**.

[**0059**] The transfer arm **412** is also operable to rotate **900** into a neutral position, as illustrated in **FIG. 8***b*, wherein the transfer arm **412** resides within the transfer chamber **404** entirely. In the neutral position, the internal access ports for the load lock chamber **406** and the process chamber **402** typically are closed, for example, wherein a wafer W is undergoing processing within the process chamber and another already processed wafer is being removed from the load lock chamber **406**, replaced with an unprocessed wafer, and being pumped down to a processing environment pressure. Afterwards, when processing in the process chamber **402** is complete and the pump and vent cycle in the load lock chamber **406** is finished, the internal access ports of the respective chambers into the transfer chamber **404** are again opened and the transfer arm **414** may again rotate 90° into the transfer position, pick up the wafers in the chambers **402** and **406** via the end effectors **418**, and rotate another 180° to switch the wafers therebetween.

[**0060**] Note that the transfer arm **414** of the present invention is substantially more simple than the multi-axis, multi-jointed articulated transfer arm **300** of the prior art (FIGS. **5**-**7***d*). Instead, the transfer arm **412** is a single, elongate member which provides single axis wafer movement during wafer transfer about the axis **412**. Such single axis wafer movement reduces particulate contamination by avoiding multi-axis movements and the frictional engagement of multiple moving members inherent in such arrangements.

[**0061**] In the system **400** of **FIGS. 8***a* and **8***b*, the housing **401** is generally circular to accommodate the generally circular transfer movements of the wafer transfer arm **414**. According to an alternative embodiment of the present invention, for systems requiring a more compact housing footprint, a system **450** employing a generally elliptical system housing **452** is provided, as illustrated in **FIGS. 9***a*-**9***d*. In **FIGS. 9***a*-**9***d*, a wafer transfer arm **454** rotates about the axis **412**. The transfer arm **454** differs slightly from the transfer arm **414** of **FIGS. 8***a* and **8***b* in that the arm **454** contains end effectors **456** at each distal end that rotate about an end axis **458** in a controlled manner (i.e., as a function of the rotational position of the arm **454** about the center axis **412**). In the above manner, the length or space footprint which the transfer arm occupies varies as the arm **454** rotates about the axis **412**.

[**0062**] **FIGS. 9***a*-**9***d* illustrate the transfer arm **454** in four different rotational positions to illustrate an exemplary manner in which the transfer system **450** provides a reduced housing footprint. The system **450** further includes a controller (not shown) which controls the rotation of the end effectors **456** about their respective end axes **458**. Preferably, the controller senses a rotational position of the base transfer arm **454** about the center axis **412** and uses the sensed rotational position to control the rotation of the end effectors **456** about their end axes **458**. As illustrated in **FIG. 9***a*, when the transfer arm **454** is in a generally horizontal orientation, the end effectors **456** are rotated to their extended orientations, while in **FIG. 4***c*, when the transfer arm **454** is in a generally vertical orientation, the end effectors **456** are rotated to their retracted orientations. Therefore, as illustrated in **FIGS. 9***a*-**9***d*, the end effectors **456** (and therefore the wafers W) travel between the chambers **402** and **406** in a generally elliptical transfer path.

[**0063**] The wafer transfer arm of **FIGS. 8***a*-**9***d* illustrate wafer transfers between the process chamber **402** and a single load lock chamber **406**. According to another embodiment of the present invention, the wafer transfer system may be employed with multiple load lock chambers (preferably two such chambers) in order to further improve processing throughput over prior art systems. In some processing operations, the processing cycle time is less than the pump and vent cycle time associated with establishing a process environment pressure within the load lock chamber. In such an instance, although the processing of a wafer in the process chamber is complete, the system must wait for the load lock pressure to equalize the process chamber pressure, resulting in dead time in the process chamber where no wafer processing is occurring. According to the alternative embodiment of the present invention, the process chamber maximizes its processing efficiency by maintaining processing of wafers therein substantially constantly, with processing discontinuing only for the time necessary to swap the processed wafer with a new, unprocessed wafer. Using the multiple load lock chambers generally in parallel with one another allows one load lock chamber to pump and vent while the other load lock chamber is swapping wafers with the process chamber. Consequently, as soon as processing is completed, a load lock chamber is ready to "swap in" a new unprocessed wafer.

[0064] An exemplary system for effectuating the above functionality is shown in **FIGS. 10***a* and **10***b*, designated at reference numeral **500**. The system **500** includes a system housing **501** which incorporates the process chamber **402** and the transfer chamber **404** in a manner similar to **FIGS. 8***a* and **8***b*. The system **500** further includes two load lock chambers **406***a* and **406***b* having external access ports **410***a* and **410***b* associated therewith. The load lock chambers **406***a* and **406***b* are operable to pump and vent a wafer therein down to a process environment temperature and wafers are transferred to and from the process chamber **402** via two single axis wafer movement transfer arms **414** which couple to and rotate about separate axes **512***a* and **512***b* within the transfer chamber **404**. As illustrated in **FIG. 10***a*, when one transfer arm **512***b* resides in a transfer position (i.e.,swapping wafers between chambers **406***b* and **402**), the other transfer arm **512***a* (illustrated in phantom for clarity) resides in a neutral position, thereby allowing the other load lock chamber **406***a* to pump down to the process environment pressure.

[0065] Both transfer arms **512***a* and **512***b* of **FIGS. 10***a* and **10***b* preferably swap wafers W between their respective load lock chamber and the process chamber **402** within a wafer transfer plane. In order to avoid the transfer arms **512***a* and **512***b* from interfering with each other, each arm **414** is positioned generally within the wafer transfer plane, however, each is positioned at a slightly different vertical position, as may be appreciated.

[0066] **FIGS. 10***a* and **10***b* illustrate a system housing **501** which is generally circular in shape to accommodate the generally circular transfer paths of the transfer arms **414** about their respective axes **512***a* and **512***b*. Alternatively, if a smaller system housing footprint is needed or desired, a system as illustrated in **FIGS. 11***a*-**11***d*, designated generally at reference numeral **550**, is provided. The system **550** has a generally rectangular system housing **552** including a generally oblong transfer chamber **554**, the process chamber **402** and two load lock chambers **406***a* and **406***b*, respectively. The system **550** operates generally under the operational principles discussed above in conjunction with **FIGS. 9***a*-**9***d* and **FIGS. 10***a* and **10***b*. That is, two transfer arms **560***a* and **560***b* within the transfer chamber **554** operate in conjunction with one another to maximize the utilization efficiency of the processing chamber. In addition, each transfer arm **454***a* and **454***b* are similar to the transfer arm **454** of **FIGS. 9***a*-**9***d* and thus traverse a generally elliptical transfer path.

[0067] The systems **400, 450** of **FIGS. 3 and 8***a*-**9***d* may be utilized in accordance with a method of serially transferring wafers to and from a process chamber. One exemplary method is illustrated in **FIG. 12** and designated at reference numeral **600**. The method begins at step **602** with a system initialization, wherein the transfer arm **414** is rotated into the neutral position, the load lock cover **250** associated with the load lock chamber **206, 406** is actuated into a closed position and the ring valve **210** associated with the process chamber **202, 402** is closed. A wafer W is then loaded into the recess portion **252** via the access port **262, 410** of the load lock chamber **206, 406** at step **604** and the recess portion **252** is then pumped or otherwise evacuated to equalize the pressure between the recess portion **252** of the load lock chamber **206, 406** and the transfer chamber **204, 404**/process chamber **202, 402** at step **606**.

[0068] Once the pressure equalization has been obtained, the load lock cover **250** is lifted via the actuator **254** and the ring valve **210** is moved to an open or retracted position **212** via the actuator **220** at step **608**, thereby bringing the recess portion **252** of the load lock chamber **206, 406** into fluid communication with the process chamber **202, 402**. The wafer W within the load lock chamber **206, 406** is then lifted into the wafer transfer plane **260** via the pin assembly **256** at step **610** and the transfer arm **414** is rotated from the neutral position of **FIG. 8***b* into the transfer position of **FIG. 8***a* at step **612**. The wafer W is then lowered onto the end effector **418** of the transfer arm **414** at step **614** via the pin assembly **256** and the transfer arm **414** is rotated **1800** to thereby transfer the wafer W from the load lock chamber **206, 406** to the process chamber **202, 402** in an efficient, single axis wafer movement at step **616**.

[0069] The method **600** of **FIG. 12** continues at step **618** where the pin assembly within the process chamber **202, 402** lifts the wafer W off of the transfer arm **414**. The transfer arm **414** then rotates 90° into the neutral position as illustrated in **FIG. 8***b* at step **620**, followed by closing the load lock cover **250** and the ring valve **210** at step **622**, wherein wafer processing and the transfer of another unprocessed wafer into the load lock chamber recess **252** is initiated at step **624**. The method **600** then returns to step **606** and the recess portion **252** of the load lock chamber **206, 406** is pumped down to the process environment pressure and the various method steps are repeated. In this next case, a wafer resides in both the load lock chamber **206, 406** and the process chamber **202, 402**. Thus at step **610**, both wafers are lifted into the wafer transfer plane and both wafers are lowered onto respective ends of the transfer arm at step **614**. Lastly, step **618** will include the off-loading of both wafers.

[0070] The method **600** of **FIG. 12** advantageously reduces particulate contamination and increases throughput over prior art systems by maintaining the process chamber at the process environment pressure throughout the load process **600**. Thus the process chamber **202, 402** avoids a pump and vent cycle each time a wafer is transferred thereto. Although the method **600** provides several advantages over prior art systems, process throughput may be further improved using multiple load lock chambers such as those illustrated in **FIGS. 10***a*-**11***d*. A method **700** of transferring and processing wafers in a processing system is illustrated in **FIGS. 13***a*-**13***c*.

[0071] At step **702** of **FIG. 13***a* the system **500, 550** is initialized; that is both transfer arms **414** are in neutral positions, both load lock covers **250** are closed and the ring valve **210** is closed. Thus the recess regions **252** within the load lock chambers **406***a* and **406***b* are fluidly isolated from the rest of the system. An unprocessed wafer W is then inserted into one of the load lock chambers **410***a* via an external access port at step **704** and the recess portion **252** of the load lock chamber **410***a* is then pumped down to the process chamber pressure at step **706**. Once pumping is complete at step **708** and processing is complete at **710** (not presently relevant because no wafer is in the process chamber **202**, **402** at this time), two different sets of steps **712** and **714** begin to occur in parallel because two load lock chambers exist.

[**0072**] Step set **712** includes the step of moving the unprocessed wafer W within the load lock chamber **410***a* into the wafer transfer plane **260** by lifting the load lock cover **250** and actuating the pin assembly **256** via the actuator **258** at step **720**. The ring valve **210** is then opened at step **722** and the transfer arm **414** associated with the first axis **512***a* moves the wafer W from the load lock chamber **410***a* to the process chamber **202**, **402** at steps **724**, **726** and **728** (see **FIGS. 13***a* and **13***b*). Note that initially no wafer is in the process chamber **202**, **402**, however, subsequently, the wafer transfer of steps **724**-**728** will include two wafers (i.e., a wafer swap).

[**0073**] The wafer W is deposited in the process chamber **202**, **402** (and later in both chambers) via the pin assembly therein at step **730**. The transfer arm **414** associated with the axis **512***a* is then rotated into the neutral position at step **732**. Once in the neutral position, the transfer arm **414** associated with the axis **512***a* will not interfere with the load lock chamber **406***a*. The load lock cover **250** for the load lock chamber **406***a* and the ring valve **210** of the process chamber **202**, **402** are then closed at step **734**. At this time no processed wafer was swapped so no wafer removal occurs at the first load lock chamber **406***a* at step **736**, however, later in the process **700** such a swap will occur.

[**0074**] In parallel with the step set **712** is another set of steps **714** associated with the second load lock chamber **406***b*. While the first load lock chamber **406***a* is swapping its wafer with the process chamber **202**, **402**, another unprocessed wafer W is inserted into the second load lock chamber **406***b* via the external access port **410***b* at step **750**. The external port **410***b* is closed and the chamber **406***b* is then pumped down at step **752**. Once the pumping is complete at step **754** and the processing is complete at step **756** (corresponding to the wafer transferred initially from the first load lock chamber **406***a*), the wafer W in the second load lock chamber **406***b* is moved into the wafer transfer plane **280** at step **758** (**FIG. 13***c*) when the cover **250** is lifted via the actuator **254** at step **760** and the transfer arm **414** associated with second axis **512***b* swaps the unprocessed wafer from the second load lock chamber **406***b* with the processed wafer via steps **762**-**768**. The transfer arm **414** associated with the second axis **512***b* is then moved to the neutral position at step **770**, the doors close at step **772** and processing commences.

[**0075**] Note that although the first unprocessed wafer W entered the process chamber **202**, **402** via the first load lock chamber **406***a* and the transfer arm **414** associated with the first axis **512***a*, the wafer, upon being processed, exits the process chamber **202**, **402** and gets transferred to the second load lock chamber **406***b* via the transfer arm **414** associated with the second axis **512***b*. Therefore according to the exemplary method **700** of the present invention, wafers enter and exit from different load lock chambers. Thus, once the ring valve **210** is closed at step **772** of **FIG. 13***c*, the unprocessed wafer W from the second load lock chamber **406***b* will be processed and the processed wafer will be removed from the second load lock chamber at step **774**. The method **700** then continues at step **750**.

[**0076**] As can be seen from the above, the method **700** of the present invention enhances the utilization efficiency of the process chamber **202**, **402** by immediately swapping a new unprocessed wafer therein as soon as wafer processing is complete. Because both load lock chambers **406***a*, **406***b* work generally in parallel, while one is swapping wafers with the process chamber **202**, **402** the other is getting a new unprocessed wafer and initiating a pump and vent cycle without impacting the process environment in the process chamber.

[**0077**] Although the invention has been shown and described with respect to a certain preferred embodiment or embodiments, it is obvious that equivalent alterations and modifications will occur to others skilled in the art upon the reading and understanding of this specification and the annexed drawings. In particular regard to the various functions performed by the above described components (assemblies, devices, circuits, etc.), the terms (including a reference to a "means") used to describe such components are intended to correspond, unless otherwise indicated, to any component which performs the specified function of the described component (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which performs the function in the herein illustrated exemplary embodiments of the invention. In addition, while a particular feature of the invention may have been disclosed with respect to only one of several embodiments, such feature may be combined with one or more other features of the other embodiments as may be desired and advantageous for any given or particular application.

What is claimed is:

1. A wafer handling system for a wafer processing apparatus, comprising:

at least one wafer load lock chamber;

a wafer processing chamber;

a transfer chamber operatively coupled to the wafer load lock chamber and the wafer processing chamber, the transfer chamber including a wafer transfer mechanism comprising a transfer arm pivotably coupled to a portion of the transfer chamber forming an axis,

wherein the transfer arm is operable to rotate about the axis to transfer a wafer between the wafer load lock chamber and the process chamber in a single axis wafer movement.

2. The system of claim 1, wherein the transfer arm comprises an elongate member having an end effector on at least one generally distal end thereof, wherein the end effector interfaces with the wafer to effectuate the wafer transfer between the load lock chamber and the process chamber.

3. The system of claim 2, wherein the end effector is a generally U-shaped member.

4. The system of claim 2, wherein the elongate member is coupled to the axis at a midpoint thereof, and wherein the elongate member has an end effector on each generally distal end such that when the transfer arm is in a transfer position, one end effector is within the load lock chamber and the other end effector is within the process chamber.

5. The system of claim 1, wherein the transfer arm is operable to rotate between a plurality of positions, wherein in a first position the transfer arm is within at least one of the load lock chamber and the process chamber and in a second position the transfer arm is within the transfer chamber.

6. The system of claim 1, wherein the wafer processing chamber comprises a plasma immersion ion implantation apparatus.

7. The system of claim 1, further comprising an end effector coupled to the transfer arm at a generally distal end of thereof and defining an end axis thereat, and wherein the end effector is rotatably coupled to the generally distal end of the transfer arm for rotational movement about the end axis.

8. The system of claim 7, further comprising a controller associated with the system for sensing a rotational position of the transfer arm and controlling a rotational movement of the end effector about the end axis as a function of the rotational position, thereby effectuating a generally elliptical end effector transfer path when transferring the wafer between the load lock chamber and the process chamber.

9. The system of claim 1, wherein the wafer load lock chamber further comprises a load lock cover operable to move between two positions,

wherein a first position fluidly isolates a portion of the wafer load lock chamber from the transport chamber, thereby allowing a pressure in the portion of the wafer load lock chamber to differ from a pressure in the transport chamber during a wafer transfer from an ambient pressure environment external the wafer load lock chamber to the isolated portion of the wafer load lock chamber, and

wherein a second position of the load lock cover brings the portion of the wafer load lock chamber into fluid communication with the transport chamber for transfer of a wafer between the wafer load lock chamber and the processing chamber via the transfer arm.

10. The system of claim 9, further comprising a pump associated with the portion of the wafer load lock chamber, wherein the pump is operable to reduce a pressure within the portion of the wafer load lock chamber when the load lock cover is in the first position, thereby substantially matching a pressure in the portion of the wafer load lock chamber with a pressure in the transfer chamber and the processing chamber.

11. The system of claim 1, wherein the wafer load lock chamber further comprises:

an external access port for receiving a wafer into the wafer load lock chamber; and

a selectively positionable isolation member within the wafer load lock chamber, positionable between an isolation position and a non-isolation position, wherein in the isolation position the isolation member sealingly engages a portion of the wafer load lock chamber associated with the external wafer load lock chamber access port, thereby permitting the transfer of a wafer to or from the wafer load lock chamber from an external ambient environment via the wafer load lock chamber access port without impacting processing conditions within the transfer chamber and the processing chamber, and

wherein when the isolation member is in the non-isolation position the portion of the wafer load lock chamber is in fluid communication with the transfer chamber.

12. The system of claim 11, further comprising an actuator operatively coupled to the isolation member, wherein the actuator is operable to selectively position the isolation member in the isolation position and the non-isolation position, respectively.

13. The system of claim 1, further comprising another wafer load lock chamber operatively coupled to the transfer chamber.

14. The system of claim 13, wherein the transfer chamber further comprises another transfer arm pivotably coupled to a portion of the transfer chamber forming another axis, and wherein the another transfer arm is operable to rotate about the another axis to transfer a wafer between the another wafer load lock chamber and the process chamber in a single axis wafer movement.

15. The system of claim 14, wherein axes of the transfer arm and the another transfer arm are different.

16. The system of claim 15, further comprising load lock covers associated with the wafer load lock chambers, respectively, wherein each load lock cover is operable to move between two positions,

wherein a first position fluidly isolates a portion of the respective wafer load lock chamber from the transport chamber, thereby allowing a pressure in the portion of the wafer load lock chamber to differ from a pressure in the transport chamber during a wafer transfer from an ambient pressure environment external the respective wafer load lock chamber to the isolated portion of the wafer load lock chamber, and

wherein a second position of the load lock cover brings the portion of the respective wafer load lock chamber into fluid communication with the transport chamber for transfer of a wafer between the respective load lock chamber and the processing chamber via the respective transfer arm.

17. The system of claim 15, wherein the each wafer load lock chamber further comprises:

an external access port for receiving a wafer into the wafer load lock chamber; and

a selectively positionable isolation member within the wafer load lock chamber, positionable between an isolation position and a non-isolation position, wherein in the isolation position the isolation member sealingly engages a portion of the wafer load lock chamber associated with the external load lock chamber access port, thereby permitting the transfer of a wafer to or from the wafer load lock chamber from an external ambient environment via the load lock chamber access port without impacting processing conditions within the transfer chamber and the processing chamber, and

wherein when the isolation member is in the non-isolation position the portion of the wafer load lock chamber is in fluid communication with the transfer chamber.

18. A method of transferring a wafer to a wafer processing apparatus, comprising the steps of:

loading a wafer into a wafer load lock chamber;

rotating a transfer arm into the wafer load lock chamber to retrieve the wafer therein; and

rotating the transfer arm out of the wafer load lock chamber and into a process chamber to deposit the wafer therein, wherein the rotating of the transfer arm occurs in a single axis wafer movement.

19. The method of claim 18, further comprising the steps of:

sealing a portion of the wafer load lock chamber from the process chamber before loading the wafer into the wafer load lock chamber; and

evacuating the sealed portion of the wafer load lock chamber, thereby substantially equalizing a pressure therein with a pressure in the process chamber.

20. The method of claim 19, further comprising the steps of:

unsealing the portion of the wafer load lock chamber after the sealed portion has been evacuated; and

adjusting a vertical position of the wafer to place the wafer in a wafer transfer plane before rotating the wafer transfer arm into the wafer load lock chamber.

21. The method of claim 20, further comprising opening the process chamber before rotating the transfer arm.

22. The method of claim 18, wherein the transfer arm comprises an elongate member having a rotational axis generally at its midpoint and end effectors at each generally distal end, and wherein rotating the transfer arm into the wafer load lock chamber and rotating the transfer arm into the process chamber occurs in the same step, wherein each respective end effector moves between the wafer load lock chamber and the process chamber, respectively.

23. A method of transferring a wafer to a wafer processing apparatus, comprising the steps of:

(a) fluidly isolating a portion of a wafer load lock chamber from a transfer chamber and a process chamber, respectively;

(b) loading a wafer into the isolated portion of the wafer load lock chamber from an external source;

(c) evacuating the portion of the wafer load lock chamber until a pressure therein substantially matches a pressure in the process chamber;

(d) establishing fluid communication between the portion of the wafer load lock chamber and the process chamber via the transfer chamber;

(e) rotating a transfer arm into a transfer position, wherein the transfer arm comprises an elongate member with end effectors at each generally distal end with a rotational axis at about is midpoint, wherein the transfer position comprises one end effector being located within the wafer load lock chamber and the other end effector being located within the process chamber;

(f) retrieving the wafer from the load lock chamber and a wafer from the process chamber, if any, using the end effectors;

(g) rotating the transfer arm so that the end effector which previously was located within the wafer load lock chamber is now in the process chamber and the end effector which previously was located in the process chamber is now in the wafer load lock chamber, wherein the rotation of the transfer arm comprises a single axis movement;

(h) depositing the wafer in the process chamber and the wafer, if any, in the wafer load lock chamber;

(i) rotating the transfer arm into a neutral position, wherein both end effectors are located in the transfer chamber;

(j) fluidly isolating the portion of the wafer load lock chamber;

(k) processing the wafer in the process chamber;

(l) removing the wafer from the isolated portion of the wafer load lock chamber substantially while the wafer is being processed in the process chamber; and

(m) repeating the steps of (b) through (I) until all desired wafers are processed.

24. A method of transferring wafers to and from a wafer process chamber, comprising the steps of:

inserting a first wafer into a first load lock chamber;

equalizing a pressure between the first load lock chamber and a process chamber;

transferring the first wafer from the first load lock chamber to the process chamber via a first transfer arm by rotating the first transfer arm in a single axis wafer movement;

processing the first wafer in the process chamber; and

transferring the first wafer from the process chamber to a second load lock chamber via a second transfer arm by rotating the second transfer arm in a single axis wafer movement.

25. The method of claim 24, further comprising the steps of:

inserting a second wafer into the second load lock chamber;

equalizing a pressure between the second load lock chamber and the process chamber while the first wafer is being processing in the process chamber; and

transferring the second wafer from the second load lock chamber to the process chamber via the second transfer arm when the first wafer is being transferred from the process chamber to the second load lock chamber.

26. The method of claim 25, further comprising the steps of:

inserting a third wafer into the first load lock chamber;

equalizing a pressure between the first load lock chamber and the process chamber while the second wafer is being processing in the process chamber; and

transferring the third wafer from the first load lock chamber to the process chamber via the first transfer arm when the second wafer is being transferred from the process chamber to the first load lock chamber.

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