3. Description

3.1 Introduction

The **Plasmalab** System 100 is a modular plasma processing system. It can be configured to carry out Reactive Ion Etching (RIE), Plasma Enhanced Chemical Vapour Deposition (PECVD), Inductively Coupled Plasma (ICP) and Electron Cyclotron Resonance (ECR) processes.

The system can be tailored to suit different rates of throughput using transfer and load lock chambers with manual or automatic loading.

Combinations of processes can be achieved by using a transfer chamber robot to serve up to four process chambers.

3.2 PC 2000 Hardware and software with licence

3.2.1 Hardware

The system is controlled and monitored by a PC compatible computer with a Microsoft Windows Operating System. The computer is fitted with a floppy disk drive and a CD-ROM drive to allow software updates. An Arcnet interface card, for communicating with the Programmable Logic Controllers (PLCs), is fitted in one of the expansion slots. If required, a modem can be fitted to use the 'PC Anywhere' software.

3.2.2 PC 2000 software and single-user licence

The PC 2000 control software runs as a Windows-based application allowing multiple levels of system control: SYSTEMS MANAGER, SYSTEMS ENGINEER, PROCESS DEVELOPER, MAINTENANCE ENGINEER, PROCESS EDITOR and OPERATOR, all of which are accessed by password entry.

The system status is displayed on graphic mimic diagrams with all operational parameters and status displays accessible through pop-up windows selected using the mouse. All the major process parameters are accessible from the recipe and process step set-up pages, including definition of gases on each line and calculation of mass flow settings in sccm's. The software includes data logging to disk of user-selectable run-time process parameters for off-line verification and analysis of process conditions.

Processing recipes can be formulated and stored in the computer and the system can be run in fully automatic mode using the recipes. Alternatively, the system can be run in the manual mode with each phase of the process controlled and initiated separately. All the parameters can be monitored in real time using the PC 2000 software.

3.3 94-100-0-RIE RIE base unit

The **Plasmalab** System 100 process module base unit houses the process chamber, electronic sub systems, control units, services and power supplies.

The module is mechanically MESC compatible and is constructed using proven Oxford Instruments Plasma Technology hardware designs.

The system is fully interlocked to protect the system hardware from service failure and to protect the operator from electrical shock during maintenance procedures. A lock out valve and associated padlock, mounted on the frame, can be used to prevent operation of all pneumatically operated devices during servicing.

3.3.1 Frame

The frame is constructed from steel with removable access panels. Casters and adjustable feet fitted to the bottom of the frame enable it to be easily manoeuvred, then levelled and locked into position.

3.3.2 Power box assembly

The power box assembly is mounted on the outside of the frame. This distributes mains power to the +24V and ±15V power supply unit, the frame mounted electrical units and the remote auxiliary units. For circuit details of the unit, refer to the relevant drawing in Volume 2 of this manual.

A 24V EMO (Emergency Off) circuit connects all the EMO buttons mounted externally on the machine. If any of these EMO buttons are pressed in, all the power outputs from the power supply boxes are disabled.

NOTE: Freestanding auxiliary units such as water recirculators, Residual Gas Analysers, and the system control PC, are not powered via the base unit power box. These require dedicated electrical service points. These accessories remain live when the system EMO is pressed.

If it is required that all accessories are powered off when the EMO is pressed, the user must supply a power distribution unit with outlets for the accessories, and contact the factory for electrical access to the machine EMO circuit.

3.3.3 System controller

The system is controlled from a remote IBM compatible PC computer terminal using Oxford Instruments Plasma Technology's 'PC 2000' software via a Programmable Logic Controller (PLC) housed in the console cabinet. See Fig 3.1.

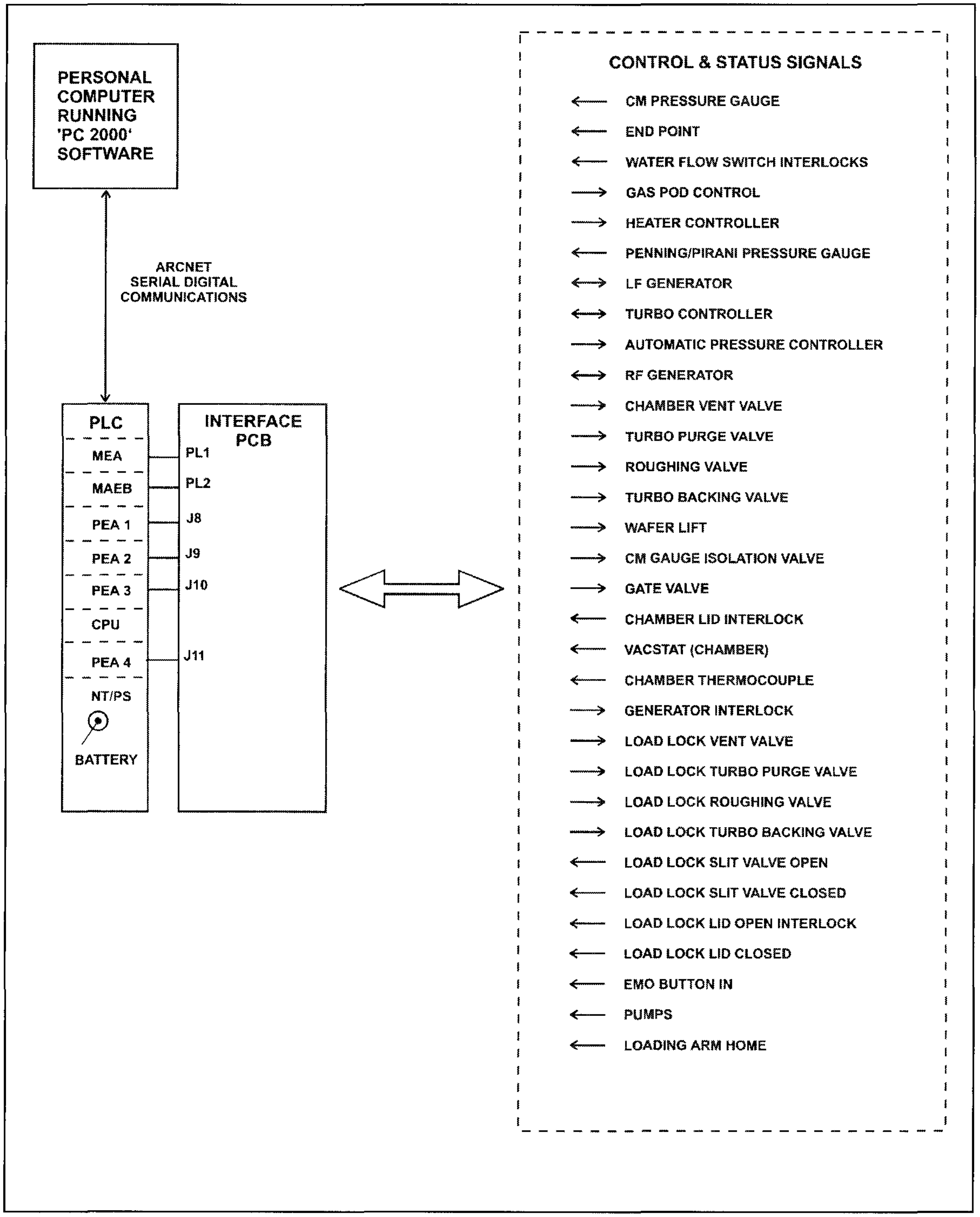

Fig 3.1: Typical control system

The system may be run from the PC terminal in manual mode, that is using direct 'real time' control over the process, or in automatic mode where the system performs the entire process according to previously entered recipes. The extensive Oxford Instruments Plasma Technology process library supports all **Plasmalab** System 100 configurations. A full description of the 'PC 2000' control instructions is provided in Section 5.

For details of the control wiring, see the relevant drawings in Volume 2 of this manual.

3.3.4 Interlocks

There are two types of interlocks used on the **Plasmalab** System 100, hardware and software. In all areas, the hardware interlock will override any software interlock. The hardware interlocks, and their effect on the system components in the case of an interlock becoming open circuit are as follows:

The electrical interlocks are divided into two circuits controlling the power to the system.

1) The mains power connection is made to a system Power Distribution Unit. The Power Distribution Unit will disable all of its power outputs under the following conditions:

    a) If the Emergency Off button is pressed.

    b) If there is an interruption of the power input to the system.

    c) If the Power Distribution Unit external facility interlock sensor link becomes open circuit.

    NOTE: The Power Distribution Unit external facility interlock sensor link enables the interlocks of external sensors, e.g. gas detectors, exhaust scrubbers, etc., to be monitored by the Power Distribution Unit. External interlock contacts connected to this link should be Normally Closed, i.e. faulting to an Open Circuit.

2) The system internal 24V supply, comprises a process line, a chamber lid line and a water flow switch (where fitted):

    The 24V process line, which controls the process gases and plasma power supply units, will be disabled if the Vacuum Safety Switch is open circuit, i.e. Chamber Pressure > 600 mbar.

    The 24V chamber lid line will be disabled if the chamber lid is OPEN, leaving the system controller operational, but disabling all system components.

	Emergency Off / Electrical Fail		24V Process line		24V Chamber lid line	
Interlock	**Fail**	**Restore**	**Fail**	**Restore**	**Fail**	**Restore**
System/Controller	OFF	Restart Required	ON		ON	
RF Generator	OFF	Powered, NOT active	OFF	Powered, NOT active	OFF	Powered, NOT active
Process Gases	OFF	Powered, NOT active	OFF	Powered, NOT active	OFF	Powered, NOT active
Automatic Pressure Controller Valve	CLOSED	CLOSED	** NO CHANGE	NO CHANGE	CLOSED	CLOSED
Load lock Slit Valve	HOLD	* HOLD	HOLD	HOLD	HOLD	HOLD
Pumps	OFF	Pumps must be restarted	NO CHANGE	NO CHANGE	OFF	Pumps must be restarted
* If closed, stays closed. If open, will stay open until the loading arm is at its home position; then it will close.						
** If 'high pressure' is signalled during process, APC opens and process step aborts. High pressure at other times does not alter the APC.						

Table 3.1: Consequences of open circuit interlocks

Other machine protection switches include:

a) A water flow switch. Low flow is reported to the system controller, which disables specific devices until flow is restored.

b) Pump overload detection. If the primary pump stops because the over-current protection switch opens, then the system aborts.

The software also monitors the position of the wafer handling mechanisms, ensuring safe operation.

3.3.5 Services

For details of the services required for the base unit, refer to Section 2 of this manual.

3.4 94-100-3-41C ICP 180 chamber kit with gate valve

The ICP chamber kit comprises the following components:

Process chamber.

Pumping port isolation valve and automatic pressure controller suitable for use with a turbomolecular pump.

The ICP process chamber, shown in Fig 3.2, is machined from a single aluminium block with the minimum number of O-rings to provide the highest vacuum integrity.

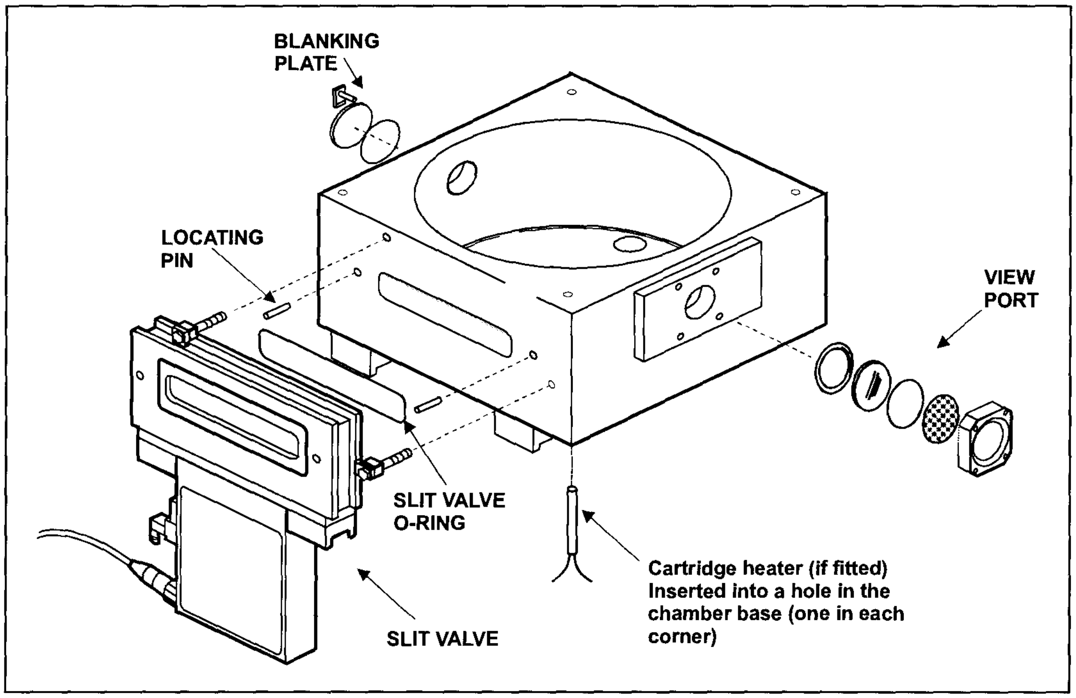

Fig 3.2: 94-100-3-41C process chamber

The chamber is fitted with the following ports:

a) Single view port fitted with an RF shield for viewing the plasma. Note that the view port is mounted on a blanking plate, which can be removed to provide access to the chamber interior.

b) Pumping port.

c) Wafer transfer port to which is attached a pneumatically operated gate valve.

d) Wafer clamp port.

e) Process gas inlet port.

f) Two ports for the connection of vacuum measurement components.

The pneumatically operated gate valve, for connecting to the selected wafer insertion device, is attached to the chamber by six claw bolts and is positioned by two locating pins (dowels). Sealing is provided by a rectangular O-ring.

3.4.1 94-100-3-00/21P Process chamber electrical heating kit

The electrical heating kit comprises four cartridge heaters; inserted into holes at the corners in the base of the process chamber, see Fig 3.2. Heater control is via a unit mounted on the console, where the temperature can be set manually. A temperature in the range 50°C to 60°C is recommended for most processes.

WARNING

IF THE PROCESS CHAMBER TEMPERATURE IS SET TO A VALUE ABOVE 60°C, CONTACT WITH IT CAN CAUSE BURNS.

BEFORE OPERATING THE CHAMBER ABOVE 60°C, ENSURE THAT EXTERNAL HEAT SHIELDS ARE FITTED.

3.4.2 94-100-3-00/05 200mm Pumpdown pipe heater kit

This heating kit is applied to the pump-down pipe to give optimum vacuum performance and to minimise the deposition of loosely adherent material, which might generate particulates.

3.5 94-100-5-12A Cryo / heated –150/400C helium-assisted lower electrode

The helium-assisted lower electrode, shown in Fig 3.3, is fabricated from aluminium. The electrode is fitted with an integral dark space shield.

The lower electrode is heated by an embedded 1250W element and cooled by liquid nitrogen flowing through embedded tubing.

Wafer lift

The wafer is lifted clear of the table (15mm) for transferring into a load lock or transfer chamber by the wafer lift assembly. Compressed air flowing into the air cylinder forces its piston and plunger upwards. The plunger contacts the base of the bellows which is connected to a push rod. The 3-pin wafer support, mounted on top of the push rod, rises lifting the wafer clear of the table. The push rod is lowered by the force exerted by the return spring.

Wafer clamp

The wafer clamp comprises a clamping ring attached to a lifting mechanism, and a clamping plate. The clamping plate, attached to the clamping ring via three pillars and screws, comprises an aluminium annulus with a quartz circular insert.

The wafer clamp is raised and lowered by two air cylinders, attached to the outside of the process chamber; one located at each side of the wafer clamp. The piston of each air cylinder is attached to a push rod, which passes through the base of the process chamber. Within the process chamber, a circular plate mounted on the top of the push rod, is attached to the wafer clamp by three M5 setscrews and compression springs. Rotating the setscrews changes the compression of the springs and consequently the clamping force exerted on the wafer. See Section 6 for the clamping force adjustment procedure.

Note that clamping plates are available with inserts for various sized wafers. Before loading a wafer into the process chamber, ensure that the correct clamping plate is fitted. See Section 6 for the clamping plate changeover procedure.

Table top plate

In some systems, the table top plate is fixed to the table by a ring of cap-head bolts. If your system has a table of this type, refer to the following text and note.

The bolt heads are concealed behind screw covers, which require a special tool (supplied with the system) for removal. (Tool part number: MD91D21726.)

NOTES:

1) When re-fixing the table top, do not over-tighten the bolts which will cause the table top to bow. Check with a straight edge after tightening: if the table top is not flat, release the bolt tensions until it is.

2) The screw covers (MD91D21723) are aluminium. When removing the covers, it is recommended to use a little iso-propyl alcohol (IPA) to prevent the thread from jamming.

Helium backing

The purpose of helium backing is to set the temperature of the wafer close to that of the temperature-controlled table by heat transfer. Helium is fed from a number of small holes in the table underneath the wafer (which is clamped to the table) from where it flows radially to the periphery of the wafer. Helium is the preferred gas, because it has a very good heat transfer ability. The use of other gases is possible, preferably inert gases.

The supply of helium is fed by a pressure control device, which receives an analogue setpoint from the machine's control system. The pressure control device adjusts the gas flow through itself to control the pressure at its output side. The pressure is controlled within the range 0 to 50 Torr. A pressure of greater than 20 Torr could damage very thin substrates.

If the wafer is clamped down successfully the chamber pressure will show a slight rise of a few milliTorr when the helium is producing a pressure of 10 Torr on the wafer.

If there is a massive pressure rise and the Turbo Controller display shows a high load, then the wafer is insufficiently clamped and in order to achieve the set pressure the controller is using an excessive gas flow.

The helium pressure is released into the process chamber at the end of a process (using a normally-open valve). This prevents the wafer moving when it is unclamped.

Tip: ***Finish a process with a ten-second pumping step without helium. This will reduce wafer mishandling.***

A flow meter in the helium supply also reads the gas flow necessary to maintain the pressure. A typical process uses 5 - 20 sccm to maintain 10 -15 Torr behind the wafer.

Tip: ***Some wafers mate very well with the electrode top surface and use less than 2 sccm to maintain 10 Torr. This can give a control problem, with the helium feeding in pulses. Roughening the aluminium electrode with an abrasive pad can increase the helium flow by a few sccm and allow proper control.***

Do not turn on the helium unless the wafer is clamped.

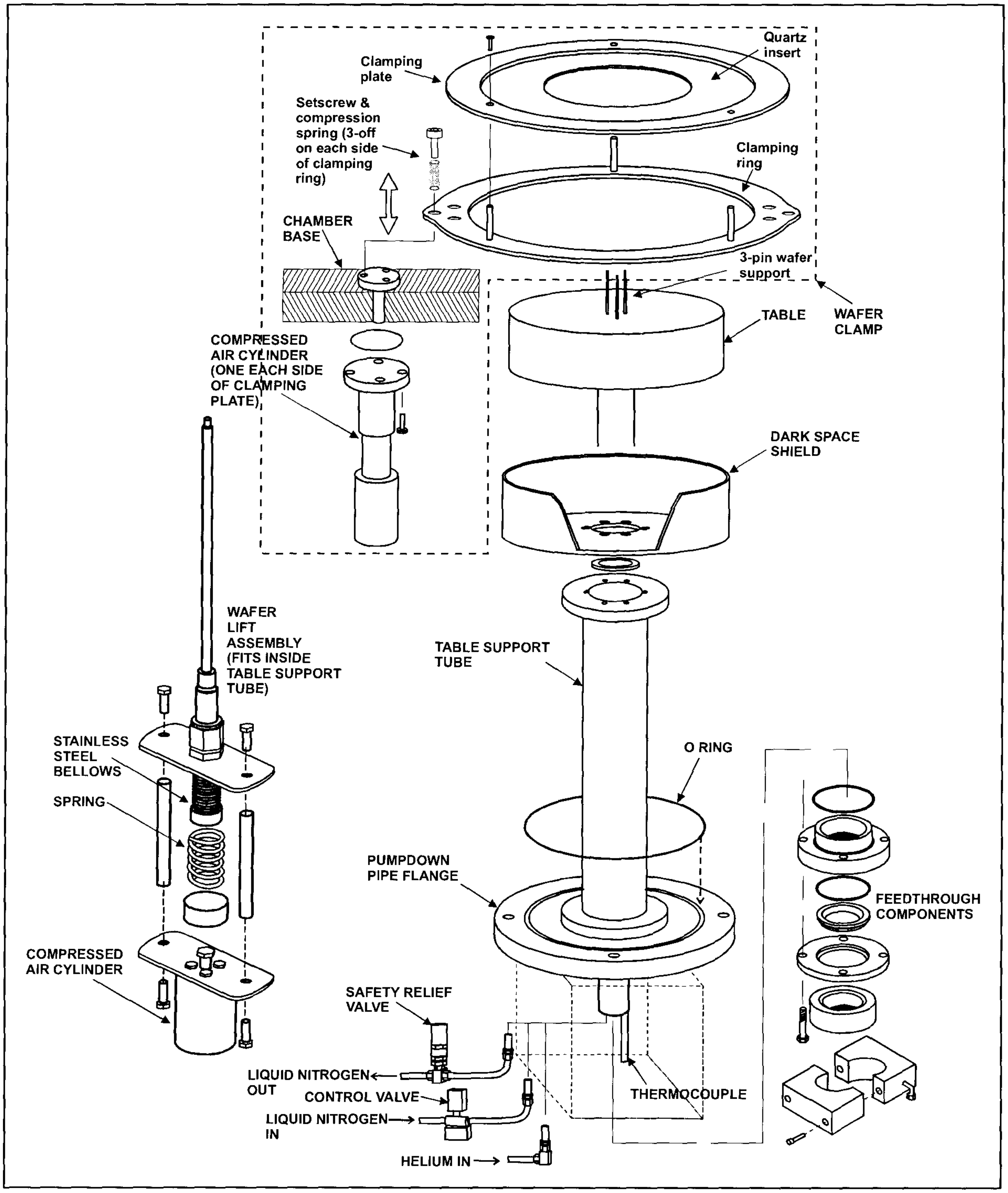

Fig 3.3: 94-100-5-12A Cryo / heated -150 / 400C He lower electrode

3.6 94-100-6-500/200 500W RF generator / OIPT AMU kit

This kit comprises a 500W RF Generator and an OIPT Automatch Unit.

The RF generator produces a 13.56MHz output, which is fed via the automatch unit to the lower electrode to produce the plasma. The automatch unit adjusts the impedance of its output to match the impedance of the lower electrode to ensure maximum power transfer.

For details of these units, refer to the manufacturer's literature in Volume 3 of this manual.

The automatch unit can be manually adjusted if necessary, see Operator Adjustments in Section 5 of this manual.

3.7 94-100-6-56 ICP 180 Inductively Coupled Plasma Source

The inductively coupled plasma source is 180mm in diameter, which gives uniformity suitable for use with wafers up to four inches in diameter. An RF generator (3kW 13.56MHz) and automatch unit are included. A quartz or alumina discharge chamber is supplied, according to the process specification. For full details of this source, refer to the ICP 180 manual (provided as a supplement to this manual – refer to the contents list).

3.8 Vacuum system

The vacuum system is shown in Fig 3.4.

The process chamber is pumped by an Alcatel ATP900 turbomolecular pump via an Automatic Pressure Controller (APC). The turbomolecular pump is backed via an isolation valve by an Alcatel 2063 C2 rotary vane pump.

The process chamber process pressure is measured by a temperature compensated 100-mTorr Capacitance Manometer gauge. Note that the CM gauge output does not stabilise until it has been switched on and under vacuum for 15 minutes.

Base pressure is measured by an active Penning gauge, which is disabled at pressures above 10 mTorr.

A Vacuum Switch monitors the chamber pressure. When the pressure falls below 600 mbar, its contacts close to enable the 24V process line and allow the process gases and the RF to operate.

The automatic load lock is pumped by an Alcatel 2015 C2 rotary vane pump. A Pirani gauge measures pressure.

For details of the vacuum pumps and gauges, refer to the manufacturer's literature in Volume 3 of this manual.

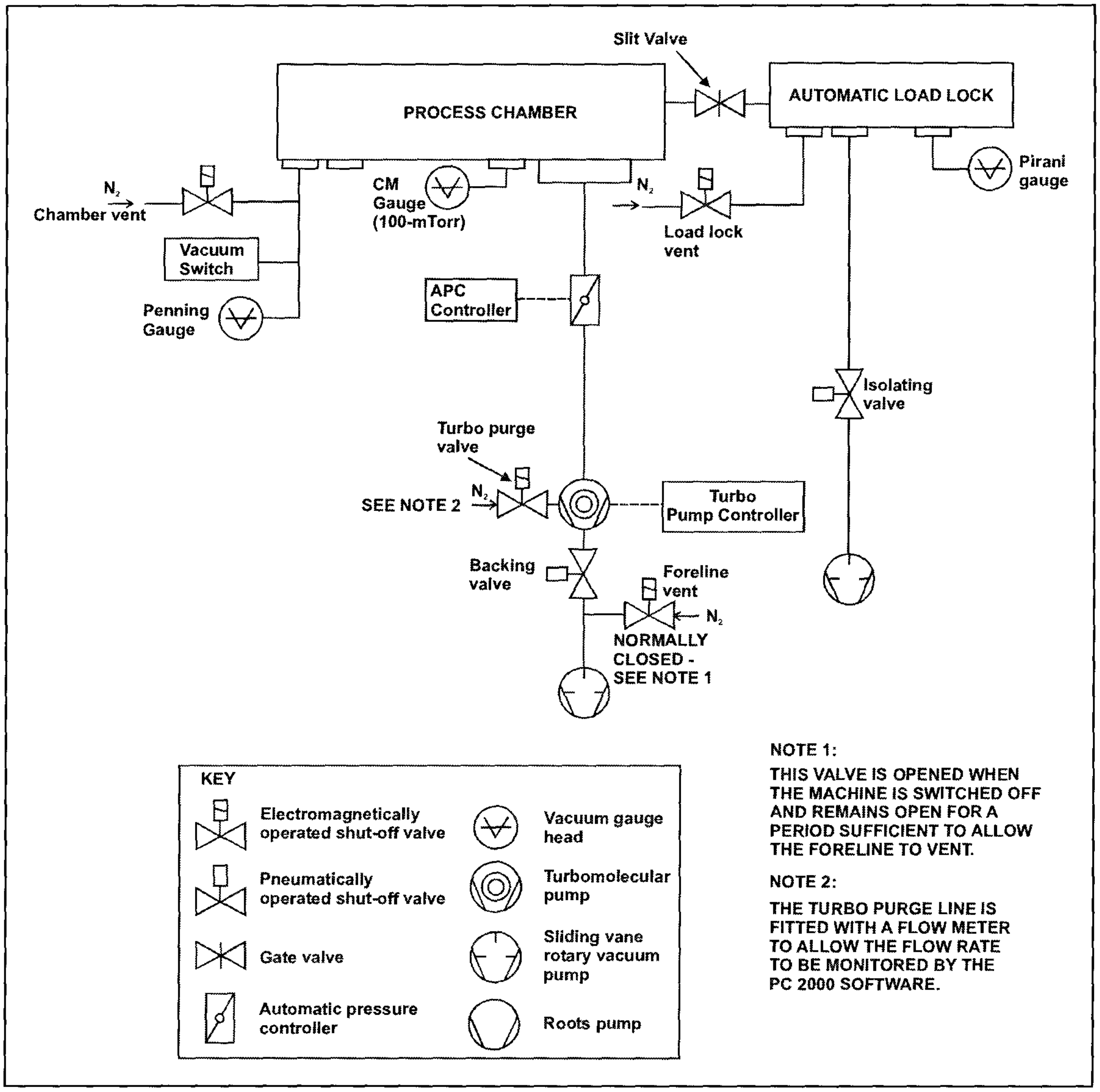

Fig 3.4: UC Davis 94-721001 vacuum system

3.9 Gas handling system

> **WARNING**
>
> **CONTACT WITH TOXIC GASES CAN CAUSE DEATH OR SERIOUS INJURY.**
>
> **USERS SHOULD PERFORM THEIR OWN RISK ASSESSMENT OF HAZARDOUS GASES TO BE USED ON THE SYSTEM.**
>
> **BEFORE VENTING THE PROCESS CHAMBER, ALWAYS ENSURE THAT THE SYSTEM IS ADEQUATELY PURGED AND PUMPED; SEE 'VENTING THE SYSTEM' IN SECTION 5 OF THIS MANUAL.**

3.9.1 94-81-9-51/8 Gas pod (PLC version)

The purpose of the gas pod is to feed a mixture of process gases, at specified flow rates, to the process chamber. Selection of gases and flow rates are determined by the system controller. A 'clean gas' line can be incorporated to feed an etch gas mixture into the process chamber to remove process residues.

The gas pod, shown in Fig 3.5, comprises a steel case with a removable cover. An extraction collar at the top of the case enables any leaked gas to be safely removed by a laboratory extraction system. The back panel of the case is fitted with fixing holes for wall or frame mounting.

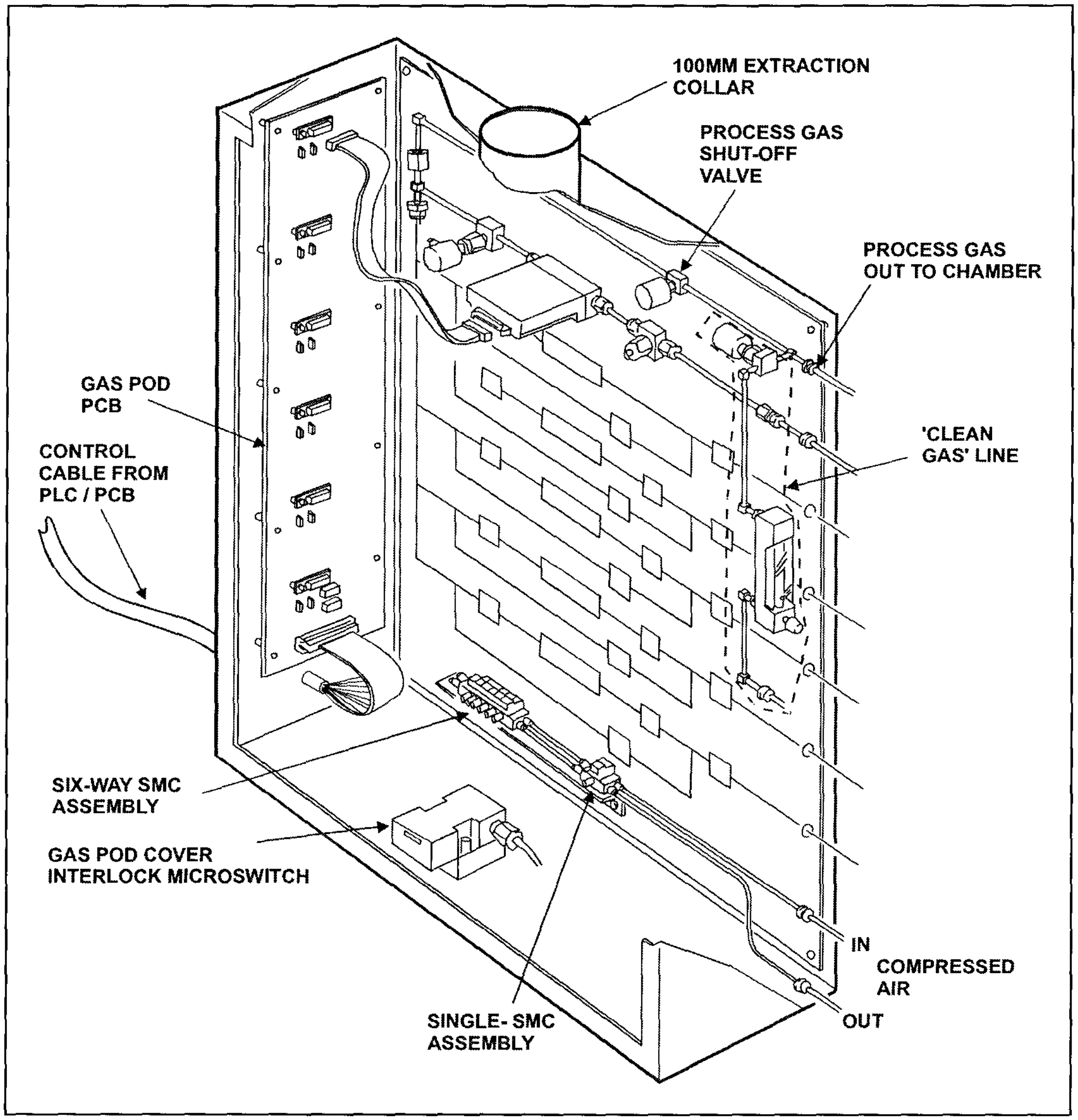

Fig 3.5: 94-81-9-51 Gas pod

The case incorporates stations for up to six gas lines. The outputs from the gas lines are fed into a common manifold which is connected to the process chamber gas line. Pneumatically operated shut-off valves in each gas line are driven by associated SMC valves, powered by compressed air and controlled by signals from the system controller. A separate SMC valve, controlled by an interlock microswitch, prevents the opening of any gas shut-off valve when the case cover is not fitted, or when either of the system interlock lines are open.

The Gas Pod PCB receives signals from the system controller, to control the SMC valves, and the Mass Flow Controllers (MFC) fitted in the gas lines. For a circuit diagram of the Gas Pod PCB, refer to drawing SE81D15942 in Volume 2 of this manual.

The 'clean gas' line flow rate can be set either manually by a variable valve (as shown in Fig 3.5) or by an MFC. Note that the 'clean gas' is usually supplied from a cylinder containing the required gas mixture. An alternative method is to mix separate gases in optional additional gas lines.

WARNING

THE CONNECTION FROM THE GAS POD MANIFOLD TO THE PROCESS CHAMBER SHOULD NOT INCLUDE ANY SHUT OFF VALVE, UNLESS THIS HAS BEEN CLEARED WITH OXFORD PLASMA TECHNOLOGY. A BLOCKAGE HERE COULD CAUSE PROCESS GASES TO MIX AND CROSS CONTAMINATE IN THE HIGH PRESSURE GAS DELIVERY PIPEWORK.

3.9.2 94-81-9-11 Standard non-toxic gas line

The standard non-toxic gas line is shown in Fig 3.6. All gas fittings are VCR and all stainless steel pipework connections are welded. The 'gas in' tube passes into the side of the case, protected by a grommet. A ferrite core, fitted to the 'gas in' tube, reduces the susceptibility of the gas pod electronics to signals from nearby transmitting devices, e.g. mobile phones, modems, etc..

Gas from the customer's cylinder/regulator/filter flows into the gas in tube to the filter.

The gas flows through the 2-µm filter to the mass flow controller (MFC). The MFC controls the flow of gas as commanded by the system controller. The gas then flows through the pneumatically controlled outlet shut-off valve and into the gas out manifold where it is mixed with the other process gases before flowing into the process chamber.

WARNING

THE CLOSED INLET VALVE REMAINS SHUT FOR DIFFERENTIAL PRESSURE UP TO 5 BAR. A FAILURE UPSTREAM WHICH PRODUCES LINE PRESSURES ABOVE THIS WILL NOT BE CONTAINED. IF THIS PRODUCES A HAZARD, THE CUSTOMER IS WARNED TO FIT ADDITIONAL PROTECTION UPSTREAM.

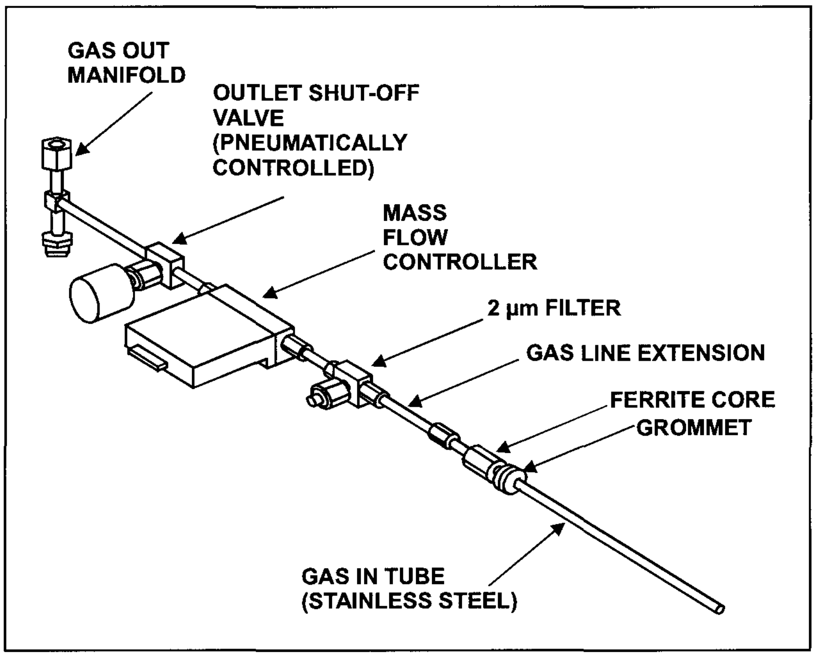

Fig 3.6: 94-81-9-11 Standard non-toxic gas lines

3.9.3 94-81-9-21 Standard toxic gas line

The standard toxic gas line is shown in Fig 3.7. All gas fittings are VCR and all stainless steel pipework connections are welded. The gas in tube passes into the side of the gas pod case, protected by a grommet.

Gas from the customer's cylinder/regulator/filter flows into the gas in tube to the filter.

WARNING

THE CLOSED INLET VALVE REMAINS SHUT FOR DIFFERENTIAL PRESSURE UP TO 210 BAR. A FAILURE UPSTREAM WHICH PRODUCES LINE PRESSURES ABOVE THIS WILL NOT BE CONTAINED. IF THIS PRODUCES A HAZARD, THE CUSTOMER IS WARNED TO FIT ADDITIONAL PROTECTION UPSTREAM.

With the Inlet Valve and Outlet Valve open and the Bypass Valve closed, the gas flows through the 2 µm filter to the mass flow controller (MFC). The MFC controls the flow of gas as commanded by the system controller. The gas then flows through the outlet valve and into the gas out manifold where it is mixed with the other process gases before flowing into the process chamber.

With the Bypass Valve open, the gas flows through the bypass line directly to the gas out manifold. This facility is provided to enable the toxic gas line to be evacuated by pumping down the process chamber. This is necessary to prevent air entering the gas line and contaminating it during a gas cylinder changeover, and to service the gas line in the event of an MFC or filter blockage.

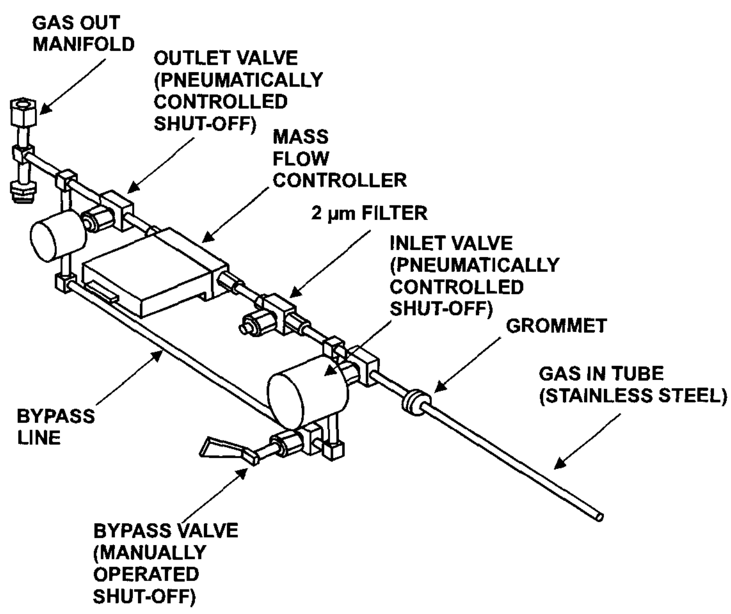

Fig 3.7: 94-81-9-21 Standard toxic gas line

3.9.4 94-81-9-00/4 Gas line interlock kit

The gas line interlock kit is a pneumatically controlled hardware interlock, which prevents the simultaneous flow of process gases, which if combined could produce a hazardous mixture.

3.10 94-100-10-05C Single wafer automatic load lock

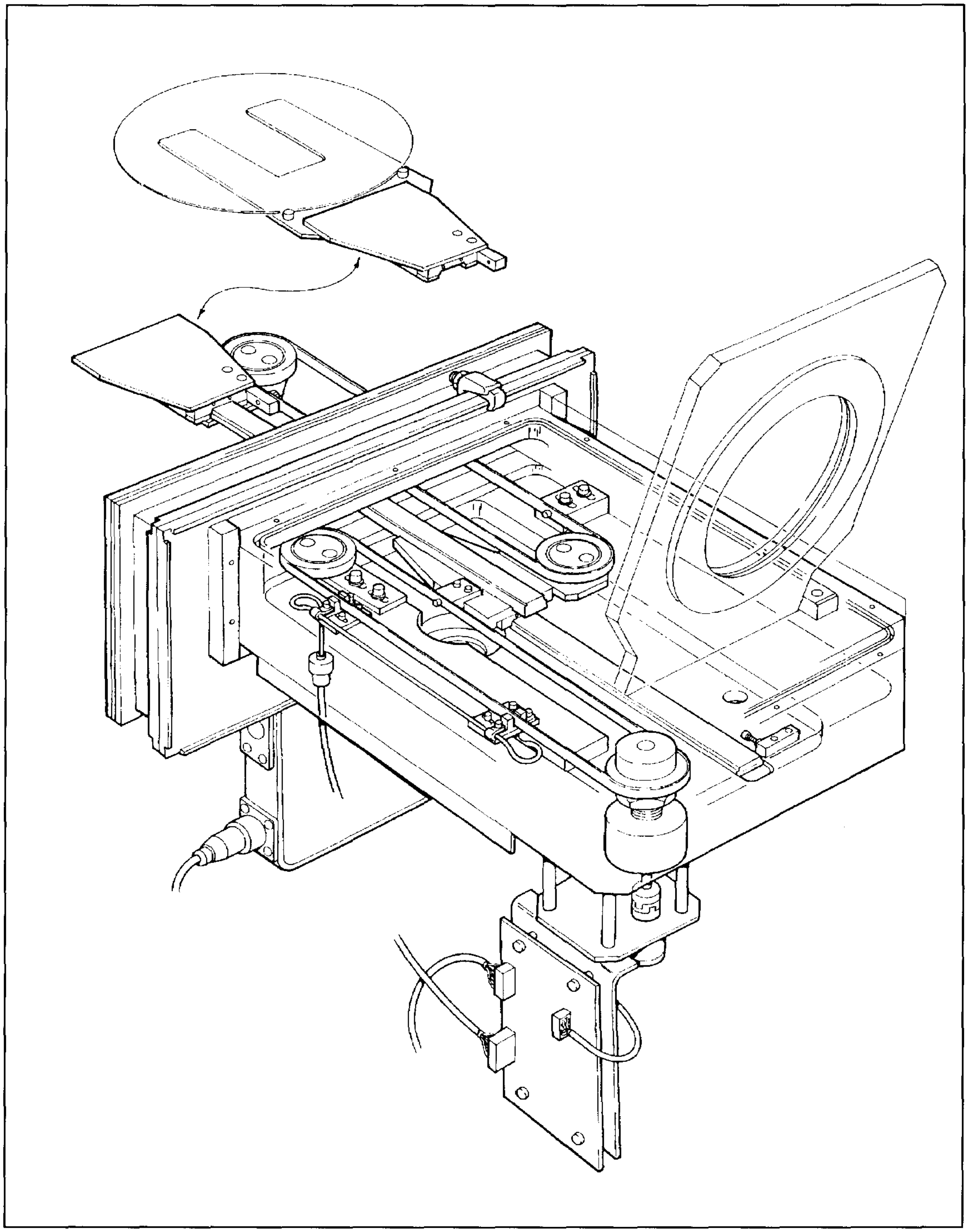

Fig 3.8: Single wafer automatic load lock

The automatic load lock, shown in Fig 3.8, enables wafer loading and unloading to be automatically achieved under vacuum. These operations are controlled by computer, requiring minimum operator involvement. The Oxford Instruments Plasma Technology design results in a very compact load lock (395 mm long with 400 mm of wafer support travel). The load lock is capable of handling MESC[1] standard wafers up to 200 mm diameter.

3.10.1 Wafer transfer mechanism operating principle

The operating principle of the automatic load lock wafer transfer mechanism is shown in Fig 3.9. This simplified illustration shows the three major components of the mechanism: the fixed track, the carriage and the wafer support.

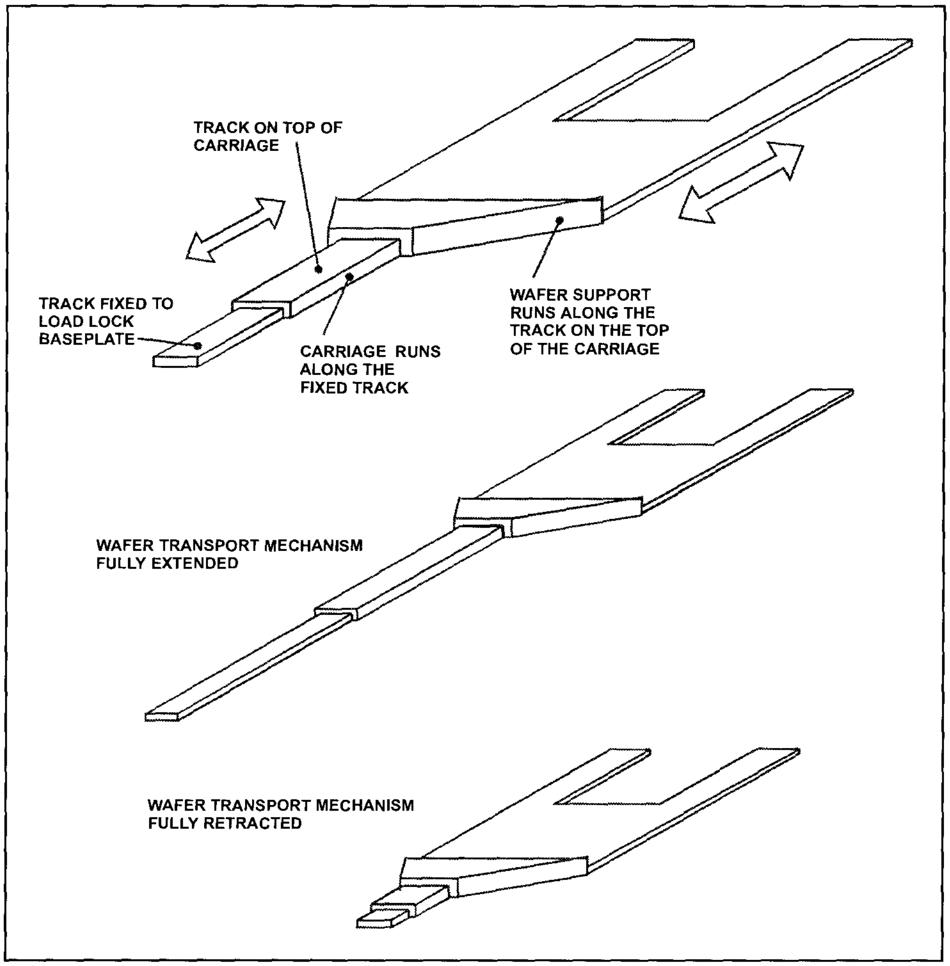

Fig 3.9: Simplified wafer transport mechanism operation

The fixed track is mounted on the load lock's baseplate and provides the bearing surface on which the carriage runs. The carriage also has a top bearing surface on which the wafer support runs.

When the mechanism is driven, the carriage runs along the fixed track and the wafer support runs along the carriage's track simultaneously. This enables the wafer support to travel from its fully retracted position (entirely contained in the load lock) to its fully extended position (wafer load/unload position in the processing chamber).

[1] Modular Equipment Standards Committee

3.10.2 Functional Description

The load lock, shown in Fig 3.10, is fabricated from aluminium and incorporates a hinged lid containing a view port. The chamber is pumped by a rotary pump or a turbomolecular pump with the pressure being detected by an appropriate vacuum gauge mounted on the chamber base plate. A pneumatically operated gate valve enables the load lock chamber to be isolated from the processing chamber.

The wafer is transported from the load lock into the processing chamber on a wafer support, which runs on a carriage, which in turn runs on a track.

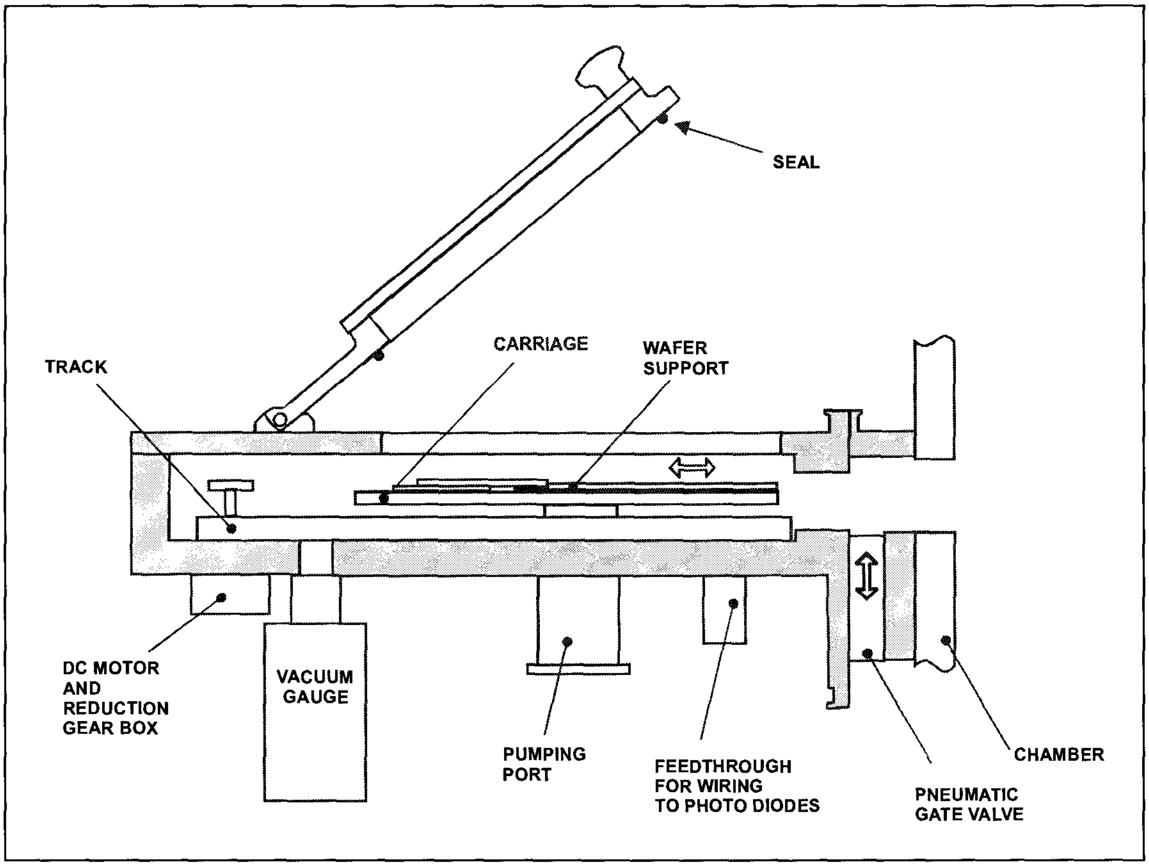

Fig 3.10: Automatic load lock, side view

The wafer transport mechanism, shown in Fig 3.9, comprises the following main components:

a) A Direct Current (DC) motor and associated reduction gearbox located outside the load lock with the drive shaft entering the load lock through a vacuum seal.

b) Two steel belts each carried by two pulley wheels.

c) A track fixed to the load lock baseplate.

d) A carriage, which runs linearly along the track. The carriage is attached to Steel Belt 1.

e) A wafer support mounted on the carriage. The wafer support runs linearly along the carriage and is attached to Steel Belt 2.

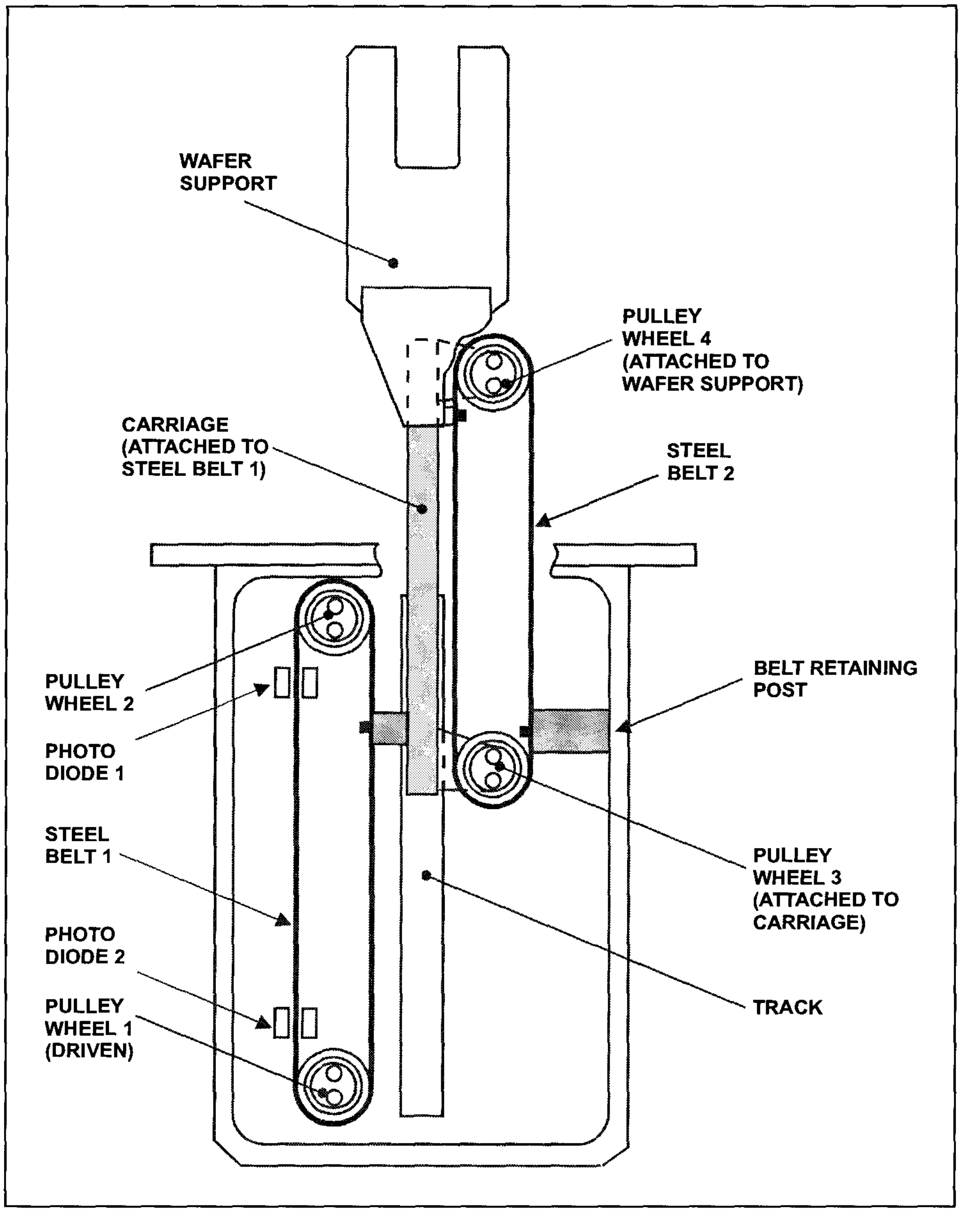

Fig 3.11: Automatic load lock wafer transport mechanism

Before operation, the Wafer Support is fully retracted into the load lock. To load a wafer into the process chamber the following sequence of events occurs:

1) The operator opens the load lock door, places the wafer onto the Wafer Support, and then closes the load lock door.

2) The load lock chamber is pumped down to base pressure.

3) The pneumatically operated gate valve is opened.

4) The DC Motor drives Steel Belt 1 via Pulley Wheel 1. Note that Pulley Wheels 1 and 2 are mounted on the load lock baseplate. As Steel Belt 1 is driven, it moves the Carriage, which is attached to it.

5) As the carriage travels, it causes Steel Belt 2 to travel around Pulley Wheels 3 and 4. Note that Pulley Wheels 3 and 4 are attached to the carriage and Steel Belt 2 is prevented from moving with respect to the load lock chassis by the retaining post.

As Steel Belt 2 travels with respect to the Carriage, it causes the Wafer Support attached to it to travel along the Carriage.

6) As the Wafer Support reaches the end of its travel, a hole in Steel Belt 1 is detected by Photo Diode 2 to stop the DC Motor.

7) The wafer is lifted from the wafer support by a wafer lift within the processing chamber, the wafer support is withdrawn from the chamber, and the wafer is lowered onto the processing table by the wafer lift.

8) As the Wafer Support reaches its fully retracted position within the load lock, the hole in Steel Belt 1 is detected by Photo Diode 1 to stop the DC motor.

9) The gate valve is closed and the load lock can be vented if required.

The above sequence of events is repeated to remove the wafer from the processing chamber.

3.10.3 Wafer support (end effector)

The automatic load lock end effector (wafer support) can accommodate wafer diameters of 3″ to 8″. See Section 6 (Maintenance) for the end effector wafer size adjustment procedure.