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# AUTOETCH PLASMA ETCHING SYSTEM

## OPERATION AND MAINTENANCE MANUAL

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## AUTOETCH PLASMA ETCHING SYSTEM DESCRIPTION

### 1.0 System Description

The Lam Research Corporation (LRC) AutoEtch is an in-line, cassette to cassette, fully automated, single wafer, double airlocked, parallel plate plasma etching system. The automatic functions are controlled by a Z80 microprocessor. An etching program may be prepared manually from the keyboard and may be saved on a recipe programming module. The entire system is under automatic, closed-loop feedback control and is double keylocked to prevent accidental alteration of the process.

The AutoEtch has a continuous cathode ray tube display for monitoring the machine status and the process parameters. Also, the system is designed to monitor and report on its own performance through the communications interface modem to a remote diagnostics station.

The operating pressure, RF power, electrode spacing, gas flow rates, and step terminating modes are programmable for each of fifteen independent process steps.

### 1.1 Process Chamber

A wafer is transferred from a send cassette to the entrance station. From the entrance station it moves into an entrance airlock and then into the process chamber where it is etched by a computer controlled gas plasma discharge. The wafer is then moved from the process chamber to the exit airlock, from the exit airlock to the exit station, and is finally transported to the receive cassette. The double airlocks allow the process chamber to remain under vacuum at all times. The process chamber is located behind the operator interface display. The operator interface is hinged and will swing up allowing visual access to the process chamber.

The process chamber is equipped with quartz windows on the front and back. Each window has a wire mesh screen to contain the RF field and a plexiglass cover for UV filtering. The windows allow for observation of the etching process. The front window plate also serves as the mounting point for the capacitance manometer and a pressure switch.

The major sub-systems of the process chamber are: the lower electrode assembly, the electrode gap drive, the upper electrode, and the RF match assembly. The chamber is anodized in order to prevent reaction with the etching gases. Care must be exercised to prevent damage to this anodized coating.

### Lower Electrode Assembly

The lower electrode assembly contains the lower electrode or anode on which the wafer rests during wafer processing. The entrance arm transports the wafer from the entrance airlock into the process chamber and positions it over a lifter. The lifter picks up the wafer and then lowers it onto the anode. When the process cycle is complete, the lifter raises the wafer and sets it on the exit arm which transports it to the exit airlock. This chamber lifter is moved up and down by a pneumatic cylinder. The position of the lifter is sensed by two limit switches on the lifter drive cylinder and this information is fed back to the computer. A resistance thermometer device (RTD), located on the electrode insert assembly, sends temperature data to the CPU which monitors the temperature of the anode.

A temperature controller heats or cools ethylene glycol that is circulating through the lower electrode, maintaining the desired anode temperature. A chiller may also be used to control the anode temperature.

### Electrode Gap Adjustment System

The electrode gap adjustment system provides for adjustment of the space between the cathode and the wafer. The electrode gap is adjusted by moving the upper electrode up or down with four DC motors. The motors drive four lead screws which are ganged and synchronized with a common chain to insure parallelism between the cathode and the anode. The position of the upper electrode is sensed by a 10-turn precision potentiometer. Two limit switches prevent the upper electrode from driving too far in either direction. In addition there are mechanical stops which prevent the upper electrode from making contact with the lower electrode.

A electrical brake system is incorporated to overcome the force exerted on the cathode when the chamber is at vacuum. This force is relatively large and moves the upper electrode downward when power is removed from the drive motors. Without a brake, the cathode would be forced out of position at the same time the DC motors attempt to reposition the cathode, causing an oscillation of the gap adjustment drive system. The gap drive brake automatically locks the gap housing in position whenever power is removed from the four drive motors.

The gap housing has two large flange (Bal) seals which provide a differentially pumped space between the chamber and atmospheric pressure.

### **Upper Electrode Assembly**

The upper electrode assembly consists of an insulator ring, baffles, and the cathode. The process gases flow through a gas manifold, to the baffles in the cathode, through the shower head hole pattern of the cathode into the process chamber directly above the wafer. The cathode is electrically connected to the RF generator by the RF match assembly.

### **RF Match Assembly**

As the process parameters are changed, the electrical impedance of the process chamber will also change. The RF match assembly automatically matches the impedance of the plasma to the RF generator as the power, electrode spacing, gas mixture, and chamber pressure vary. DC motors drive two adjustable air gang capacitors. Limit switches prevent the motors from driving the capacitors beyond their operating range.

## **1.2 "Butterfly" Throttle Valve**

Control of the chamber pressure is achieved by a "butterfly" throttle valve attached to the chamber vacuum manifold at the back of the machine. The throttle valve is controlled by an automatic throttle valve controller (AC-2). Adjustment and calibration of the pressure control assembly is done at the factory. Maintenance should be attempted only by factory trained technicians. In the event of a failure of the pressure control system, contact a LRC Service Engineer for advice or assistance.

The AC-2 controls chamber pressure by comparing the pressure setpoint in the Recipe page with the chamber pressure as monitored by the capacitance manometer.

The chamber vacuum manifold, with a pneumatically operated isolation valve, is attached to the chamber vacuum forline assembly. This valve is normally closed and is activated by the CPU during operation of the system.

## **1.3 Wafer Transport System**

### **Indexers**

The Hine Design Send/Receive Indexers are mounted on the top-front plates of the AutoEtch. The send indexer will load one wafer at a time onto the wafer belt drive system. The receive indexer takes

processed wafers from the belt drive system and stores them in the receive cassette.

### **Wafer Belt Drive System**

Wafers are transported to and from the Indexers by a motor driven belt conveyor system.

### **Entrance and Exit Station Lifters**

The function of the entrance station lifter is to elevate an unprocessed wafer from the send belt to a point above the entrance station airlock arm. The exit station lifter will receive a processed wafer from the exit station airlock arm and lower it to the receiver conveyor belt. The lifters are raised and lowered by pneumatically driven pistons. The wafers are held on the lifters by a vacuum. The vacuum is supplied from the airlock vacuum manifold and is controlled by a solenoid valve actuated by the computer.

An infrared sensor on the entrance station is used to inform the computer that a wafer is present. There is an additional infrared sensor mounted ahead of the entrance station which is used to sense the presence of more than one wafer (double wafer detector). If two wafers are detected, the load point lifter will not raise and the process will stop. The computer monitors these sensors at .25 second intervals.

The vacuum chuck will stress each wafer as it lifts it into position at each station. The force exerted by the vacuum chuck will fracture a weak or defective wafer. This prevents weak wafers from going into the chamber.

### **Airlocks**

The AutoEtch airlocks act as a buffer between the clean room environment and the process chamber. The airlocks allow the process chamber to always remain at vacuum. Wafers are loaded and unloaded from the process chamber through the airlocks. Closing the inner doors isolates the airlocks from the process chamber and allows them to be vented.

Once an airlock is vented to atmospheric pressure, its outer door will open and the arm will be commanded to load or unload a wafer. Closing the outer door isolates the airlock from atmosphere and allows the airlock to be evacuated. When the airlock pressure reaches a set crossover pressure, the inner doors will open. Wafers

can now be loaded into the chamber or unloaded from the chamber into the airlock.

The inner and outer doors of the airlocks are operated by two air cylinders, a gear train, and a linkage mechanism. The linkage mechanism is designed to insure that the door is mechanically locked once the linkage is driven past center. The positions of the doors are determined by two limit switches which sense the positions of the air cylinder shaft.

The airlock arm is driven by two air cylinders in series. Translation of the linear motion of the cylinders to the motion that is required to extend and retract the arm from the airlock is achieved through a mechanical gear train. The position of the arm is sensed by three limit switches and this position information is sent to the computer. Hardware interlocks insure that the airlock doors cannot be closed until the arm is centered in the airlock.

The inner and outer doors are also prevented from opening against a differential pressure of 50 Torr or greater. The outer door cylinder solenoid will activate only when the airlock reaches atmospheric pressure. The inner door will not open until the airlock vacuum is within the programmed pressure selected on the "machine" Parameters page.

The airlocks are isolated from the airlock vacuum pump by isolation valves. A "soft pump" feature provides a delay time for the opening of the airlock isolation valves during which pumping on the airlock is initiated through a 1/4" nylon line to the vacuum manifold. The airlock isolation valves are pneumatically driven to close and isolate the airlock if electrical power is lost. The airlocks also have a "soft vent" feature which allows  $N_2$  to be dispensed evenly into the airlock when it is vented.

Maintenance or repair of the airlock system should be attempted only by factory trained technicians. Request assistance from an LRC Service Engineer before attempting to repair the airlock mechanism.

#### 1.4 Gas System

The gas panel assembly, located on the right hand side of the system, regulates the flow of five gases independently. The gas panel has an actual capacity to accommodate six gases since two gases may share the fifth flow controller. These gases flow into the chamber, according to the flow rates selected on the Recipe page, to create the various plasmas. The gases are connected to the rear panel with VCR fittings

and each passes through a two micron filter before entering a mass flow controller (MFC).

When not being controlled, the MFC's go to a "normally open" (N.O.) state and then shut down to regulate the flow of gas. There is a pneumatically actuated, normally closed, valve upstream and downstream from each MFC. There are also two valves (V6) which route the gases either to the process chamber or into the chamber vacuum manifold.

There is an  $N_2$  manifold in the gas panel which is used to purge the gas lines and to vent the airlocks. The gas lines have pressure relief valves which prevent the chamber or airlocks from becoming pressurized to more than one psi greater than ambient pressure.

On Poly machines the gas panel houses a  $CCL_4$  tank. This tank holds the  $CCL_4$  or other process liquids under vacuum and stores the gas until it is called for in a process. On the  $CCL_4$  tank are two 3-way valves. One is used to open the tank to the chamber vacuum manifold line to pump the tank down to vacuum. The other valve is used to fill the tank with  $CCL_4$ , and to feed the  $CCL_4$  gas to the chamber when called for in a process. Both the fill and process lines are plumbed to the rear of the gas panel. The process line is plumbed from the rear of the gas panel up to gas inlet line #1. This outside line may be wrapped with heat tape to keep the  $CCL_4$  from condensing. The  $CCL_4$  tank also has a float level switch which will activate the "LOW  $CCL_4$  LEVEL" audible alarm when the tank level is low.

The desired flow of gas is programmed on the Recipe page and results in an analog signal being sent to the MFC. The required amount of gas will then flow from the facility supply, through the gas panel MFC's, to the process chamber. The line between the gas panel and the process chamber is a .25 inch stainless steel flex tube housed in a corrugated tube. In the event of a leak, the corrugated tube will allow the process gases to be safely exhausted from the AutoEtch through an external exhaust connection on the rear of the gas panel assembly. There is a scrubber failure switch attached to the gas panel which will activate an audible alarm whenever the pressure in the gas panel enclosure is less than .7 inch water column below ambient pressure.

### 1.5 Temperature Control System

The lower and/or upper electrodes will be maintained at a specified temperature as required for the process. The function of the temperature control system is to add or remove heat from the electrodes by circulating an electrically non-conductive ethylene glycol coolant (temperature controller) or deionized water (chiller).

The anode temperature controller consists of two pumps, two check valves, a heater, a heat exchanger and a coolant reservoir. To heat the electrode, the heater line pump will circulate the coolant through the heater, through the electrode, and back to the reservoir. A check valve prevents the coolant from circulating through the cooling system when the heater line pump is on. To cool the electrode the cooling line pump will circulate the coolant from the reservoir, through the heat exchanger, to the lower electrode, and back to the reservoir. In this instance the check valve in the heater line will prevent the coolant from flowing through the heating system. The resistance thermometer device (RTD), on the bottom of the electrode, sends temperature information to the computer. The lower electrode temperature is compared to a setpoint value selected by the operator, and the appropriate section of the anode temperature controller is activated.

The temperature controller is protected by two devices. There is a thermal switch in the cooling water line which monitors the temperature of the coolant and a flow switch (3GPM) which monitors the flow of the house cooling water used in the heat exchanger.

A **chiller** may also be used either in conjunction with or independently of the anode temperature controller to cool the anode, the cathode, or the anode and cathode. The chiller consists of a closed-loop dionized water recirculating system. The chiller maintains a preset temperature level as programmed on the chiller itself. The AutoEtch system has a water flow alarm switch which monitors the D.I. water flow from the chiller. If water flow from the chiller drops below 2 gpm, an audible alarm sounds on the AutoEtch and "low water flow" appears on the Status page display on the CRT. This alarm allows process completion of any wafers already in the system but stops the send indexer from releasing any new wafers from the cassette.

In addition to problems associated with the flow of D.I. water this alarm may also be triggered when D.I. water resistivity deteriorates. The water resistivity alarm and shutdown setpoint on the chiller is set above a 2 Meg Ohm-cm minimum, usually at 5 Meg Ohm-cm. If water resistivity drops below this setpoint, the chiller will shut down, the yellow fault indicator light on the chiller will illuminate, and water flow to the AutoEtch will stop, activating the low water flow alarm.

## 1.6 System Electronics

The AutoEtch electronics consists of a controller drawer assembly, a power distribution box assembly, and interface electronics. The controller drawer houses driver circuitry, a microprocessor card cage, a combination board, other printed circuit boards, and power supplies. A

CPU controls all the functions of the machine and the memory cards contain the instructions. The TTL driver cards operate solenoids, relays, and motors. The analog and digital input boards provide information to the CPU concerning the status of the machine.

The power distribution box assembly distributes the required AC and DC voltages necessary for the system to function properly. The power distribution box is equipped with an interlock switch which shuts the main power OFF when the box door is opened. Maintenance technicians should be aware that line voltages are present in the power distribution box when this interlock is defeated. External to the power distribution assembly box, on the rear of the machine, is the main circuit breaker which will turn OFF all power to the system. Three LCD displays on the distribution box door provide current status for system hours, RF hours, and number of wafers cycled through the system.

The interface electronics system consists of the key switchbox, RTD interface board, end point detector board, gap drive assembly, modem, guard seal interface board, R.F. generator interface board, and the key-board.

The key switch box assembly is encapsulated and should not be tampered with or violated since it contains the special code that identifies the machine on which it is mounted. Maintenance or repair of the key switch box should not be attempted except by LRC factory trained technicians.

The RTD interface board, guard seal interface board, and gap drive assembly are located under the operator interface assembly. A modem is mounted on the back of the system and allows communication between the AutoEtch and the LRC Remote Diagnostic Center.

## 1.7 Pneumatic System

The pneumatic system consists of pneumatic cylinders, pneumatic valves, an air filter, and a distribution manifold. In the event of a failure of the pneumatic system and system power, an adequate amount of air is captured in the system to bring the AutoEtch components to a safe state.

Air is supplied to the pneumatic system through a quick disconnect fitting and a one psi differential pressure check valve. The AutoEtch pressure regulator should be set at 80 psi. The air passes through an air reservoir to a manifold assembly and then to various cylinders.

The pneumatic system has a pressure switch downstream of the one psi pressure check valve which monitors the air supply. If the air pressure drops below 83 psi, the computer will detect this condition and activate an audible alarm.

The components operated by the pneumatic system are the entrance and exit lifters, the inner and outer doors of the airlock assemblies, the entrance and exit airlock arms, the process chamber lifter, the isolation valves, and the gas system pneumatic valves.

### 1.8 Operator Interface

Operator Interface with the AutoEtch is limited to the keyboard on the front of the system. The operation of the keyboard will be discussed in Section 3. The CRT and keyboard assembly is hinged to provide access to the front of the process chamber.

### W A R N I N G

The CRT and keyboard are completely enclosed to insure the safety of operating personnel. Hazardous voltages are present. The protective covers should not be removed without the assistance of a factory trained technician.

### 1.9 Airlock Vacuum System

The airlock vacuum system consists of the airlock vacuum pump assembly and the airlock manifold. The airlock vacuum pump is installed remote from the system. Service to the pump should be limited to changing the oil three times a year or more often as required. The airlock vacuum manifold with the two airlock isolation valves connect the pump to the airlocks through a flexible vacuum line and a coaxial trap. The airlock vacuum pump is exhausted through a .75 inch PVC pipe. Quick disconnect KF flanges are used throughout the vacuum system for ease of serviceability.

### 1.10 RF Generators

The AutoEtch is equipped with ENI RF Power Supplies; solid state, water cooled, 650 Watt or 1.25 Kilowatt generators which are mounted on slides directly above the controller drawer. These generators operate at 13.56 megahertz with an output impedance of 50 ohms. The RF output power is connected to an RF match box where the chamber impedance is matched to the generator output impedance to provide maximum RF power transfer. The generators are automatically controlled by the AutoEtch system. They may be manually operated in the "signal" (direct machine control) mode or from the front panel of the generators. **ENI GENERATORS ARE NOT USER SERVICEABLE.**

**W A R N I N G**

High voltages are present at the output of the generators. Operators and maintenance technicians must use caution when working near these voltages. The RF generators are completely enclosed to insure the safety of operating and maintenance personnel. THE COVER SHOULD NOT BE REMOVED.

**1.11 External Pump Package**

LRC provides an external pump package as an optional accessory for customers who require a packaged vacuum system. This package consists of an Edwards EH 250 Roots Blower and an E2M40F Rotary Pump. Both pumps are for corrosive service and require Fomblin Y6/06 fluid for proper operation.

The pump package is delivered with an electronics package to start and stop both pumps. The control electronics includes thermal overload protection, a local or remote control switch capability, and a cartridge oil filtration system.

Service to the pump package should be limited to changing the oil twice a year or more often if required. The oil should be changed if it becomes dark in color. In addition, the cartridge oil filtration system filters should be replaced regularly.

LRC provides an optional Process Pump Interconnect Kit which can be used in instances where the pump is located within three feet from the AutoEtch.

A user supplied vacuum pump-line and flex exhaust can be used for connecting the AutoEtch system to the pumping stack. The maximum distance for remote location of the pump package is 20 feet.