Plasma Prep™ Reactive Ion Etcher Operation Manual

SPI # 11060-AB/11060-AX

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For further information regarding any of the other products designed and manufactured by SPI Supplies, contact your local representative or directly to SPI Supplies at the address above, or visit **www.2spi.com**

- Carbon and Sputter Coaters
- Plasma Reactor for ashing and etching
- High Vacuum Bench Top Evaporators
- Critical Point Dryers
- Electron Microscopy Supplies, Consumables and Accessories

WARRANTY

The SPI Supplies unit you have purchased is guaranteed to be free of defects in workmanship on the day of shipment. This warranty covers parts and labor for a period of one year, excluding shipping charges or consumables. Breakage of glassware is specifically excluded from this warranty.

Proper use of your unit, according to the operation manual, should result in trouble-free operation. Any improper use of the SPI Supplies unit through modifications or unreasonable operating procedures will void this warranty.

DISCLAIMER

SPI Supplies Plasma-Prep RIE is designed for simplicity of installation and operation. This manual provides full and complete information in both of these areas. SPI Supplies therefore assumes no liability or responsibility of any kind for damage or injury resulting from incorrect installation or operation of the machine.

If any questions arise, call SPI Supplies from the USA/Canada 1-800-2424-SPI or 1-610-436-5400 for assistance. For all other countries, contact our nearest agent or SPI Supplies directly. A listing of our agents may be found on our website at:

http://www.2spi.com/info/agents/

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PLEASE - TAKE A MOMENT TO READ SECTION ONE [1] BEFORE PROCEEDING TO INSTALLATION

GENERAL DESCRIPTION - SPI PLASMA PREP RIE

1-1 GENERAL COMMENTS

The SPI Supplies Plasma Prep Reactive Ion Etcher (RIE) is a table-top plasma chemistry reactor designed to provide anisotropic etch plasma technology at a moderate cost. This simple-to-operate instrument can perform repeatable plasma chemical reactions with a minimum of automation. All controls are manually entered into and monitored by a touch-screen interfaced control system which is equipped with automatic monitors and interlock controls to protect the equipment and the samples in the reactor.

The Plasma Prep RIE comes equipped with an internally housed solid state RF generator. RF power is transferred from the power amplifier via a matching network to the reaction chamber. A variable capacitor provides tuning control. Metering of the forward and reverse power enables tuning of the instrument and is displayed within the information block on the touch-screen display.

The Plasma Prep RIE requires cooling of the stage. A simple water recirculator is typically sufficient for this task. A small water chiller option is also available for this system. Vacuum is supplied by an external mechanical pump. An integrated turbo pump option is available for this system.

1-2 FUNCTIONAL DESCRIPTION

The Plasma-Prep RIE is a small reactor that weighs under 75 pounds fully assembled, less external equipment. With the exception of the vacuum pump and water coolant recirculator, it is a fully self-contained machine. It consists of an RF generator and associated tuning circuits, a vacuum system with solenoid control valves, a constant feed gas supply system, and a quartz reaction chamber.

1-2.1 RF Generator - The RF power source includes a solid state oscillator operating at 13.56 MHz, the FCC-authorized industrial frequency. A solid state linear driver and amplifier supplies continuous wave power to a maximum of 200 watts. Power transfer to the reaction chamber is accomplished via an impedance matching network.

1-2.2 Touch-Screen Programmable Logic Control (PLC) Interface – The Plasma Prep RIE process is operated using programmable controls through the touch-screen user interface. Two screens, which the user may toggle between, contain various vacuum system component controls, process gas flow, and timer controls. Process gas flow volume and power level are set manually. Various system interlocks are programmed into the PLC to prevent injuries to operators and damage to the system and its components.

1-2.3 Vacuum System - The system consists of the chamber connected through the baseplate to a KF40 flange, vacuum pump (not supplied as part of the Plasma Prep RIE), the vacuum hose, appropriate KF clamps and seals, solenoid valves, and the control circuitry. An internal vacuum meter is used to monitor chamber pressure. The system can be upgraded to include a turbo-molecular pump for dry-system requirements and a high-vacuum option. Appropriate vacuum pumps for use with the Plasma Prep RIE are available at: http://www.2spi.com/category/pumps/vacuum

1-2.4 Gas Supply System - The gas supply system for the Plasma Prep RIE consists of a series of solenoid valves, needle valves, stainless steel tube and mixing manifold. This delivery system feeds directly into the reaction chamber through a perforated dispersion-ring designed to distribute process gases uniformly throughout the chamber with minimized turbulence.

1-2.5 Reaction Chamber - The reaction chamber sub-system consists of an upper and lower electrode and a 10-inch cylindrical quartz reaction chamber (See Fig. 2-1). The chamber is sealed on the top and bottom with an L-Gasket which seats against a raised lip on the inner chamber portion. The gas delivery ring feeds through the base-plate around the center plate. The center plate acts as both the sample stage and the cathode antenna. The top plate of the vacuum chamber acts as a seal for the vacuum system, and is connected to ground to complete the circuit as the opposing electrode needed to strike a plasma within the system. Process gas flows through the dispersion-ring centered between the top plate and sample stage. Below the sample stage is the port to the vacuum system. This arrangement provides for the best gas conduction flow and results in repeatable, dependable processing.

1-3 SAFETY INFORMATION

Interlocks - There are a number of interlocks programmed into the machine's PLC to prevent injury to operating personnel. Critical operating examples of these interlocks are:

a. RF Power interlock – Essential vacuum level, timer settings and process gas flow must be activated before voltage can be applied.
b. Process Termination – Vacuum pump, process gas flow and RF power must be powered off before the vacuum chamber can be vented.

*****WARNING*****

USE OF COMPRESSED GAS CYLINDERS MAY BE HAZARDOUS, AND CAUTION MUST BE USED WHEN HANDLING, TRANSPORTING, MOVING AND SECURING THEM TO MINIMIZE CRUSHING, PINCHING, PROJECTILE AND GAS-RELATED HAZARDS.

ADHERE TO ALL SAFETY SPECIFICATIONS AND REGULATIONS ACCOMPANYING SPECIFIC PROCESS AND VENTING GASES TO LIMIT ANY EXPLOSION HAZARDS, CHEMICAL HAZARDS, AND ASPHYXIATION RISKS.

1-4 DESCRIPTION OF PLASMA PROCESS

The "Plasma Process" is accomplished through the use of a low pressure, RF induced gaseous discharge. The material or specimen is loaded into the reaction chamber. The chamber is evacuated to a mild vacuum (approximately 20-50 microns) by a mechanical vacuum pump. A process gas is dispersed into the chamber and around the specimen. Radio frequency power is applied around the chamber (at 13.56MHz). This excites the process gas molecules and changes some of them into chemically active species creating plasma.

The mechanism employed in reactive ion etching varies from the process utilized in our other plasma cleaner and etching systems. Electrons, produced by ionization of gas, gain energy in the electric field. Subsequent collisions between these energetic electrons and neutral gas molecules result in an energy transfer to the molecules producing chemically active atoms, free radicals, ions, and free electrons. With the plasma formed, the electrons disassociated from the gas molecules either ground through the upper lid or contact the sample stage where they create a negative charge. This charge draws the ions within the plasma to the sample and etch the surface both through a sputtering and chemical etching process. The reacted gases and sputtered materials are carried primarily into the vacuum pump. The unique property of this process is that it occurs near ambient temperatures without employing toxic chemicals.

1-1 TABLE OF SPECIFICATIONS

PHYSICAL DIMENSIONS

Height	14 inches (35.5cm)
Width	21 inches (53.3cm)
Length	14.5 inches (36.8cm)

WEIGHT

Assembled	73 pounds (33kg)

EFFECTIVE CHAMBER SIZE

Inside height	5.0 inches (15.0cm)
Inside diameter	9.5 inches (10.54cm)

RF POWER	0 to 200 Watts
RF FREQUENCY	13.56MHz crystal controlled
AC POWER	100 to 240 VAC, 50/60Hz

Vacuum pump specifications dependent on pump purchased. Customer must ensure that the pump used with Plasma Prep RIE matches the voltage rating of the system purchased and be capable of at least 35 liters per minute.

SECTION 2

INSTALLATION AND PREPARATION FOR USE

2-1 FACILITY REQUIREMENTS

The Plasma Prep RIE is designed for table-top use. The facility requirements to operate the Plasma Prep RIE are:

a. Vacuum pump capable of at least 35 liters per minute. We recommend the SPI#10445-AB (with Fomblin® oil) for use with O_2 or CF_4 process gas.

b. Gas supply - oxygen (O_2) or other reactive gas, industrial grade with regulator capable of supplying 5 PSIG, and shut off valve.

c. 100 to 240 VAC 50/60 Hz, 15 amp service.

2-2 SITE REQUIREMENTS

a. Operate machine in a well ventilated area, free of hazards.

b. Clear table-top space with 12 inches of clearance beyond the back of the machine for vacuum hose connection, water lines, power cords and space around cooling fan.

c. The machine's exhaust (the vacuum pump exhaust) should be vented away from operating personnel. Oil mist filters are strongly suggested when the vacuum pump cannot be exhausted out of the immediate work-space.

d. Do not position the machine in direct proximity to high voltage equipment or lines to prevent potential interference.

2-3 ASSEMBLY

The Plasma Prep RIE requires a minimal amount of assembly to operate the finished system. Unpack the PPRIE and all its components. Water circulator lines, vacuum system assembly, process and vent gas lines, and power cords must be fitted to accommodate the system’s work-space.

2-3.1 INSTALLING THE CHAMBER AND TOP-PLATE

1. Ensure a clear work space is available to prepare the vacuum chamber for installation.

2. Using the three provided bolts, attach the hinge-bracket to the baseplate loosely until all bolts are in, then tighten all three bolts.

2-1 Bracket Attachment to Base Plate

3. Coat the flat surfaces of the L-gaskets with a very thin application of vacuum grease. Fit the L-gaskets to the openings of the chamber (orientation of top or bottom of the chamber is not relevant. While maintaining the integrity of the lower L-gasket on the chamber, lower the chamber onto the baseplate of the system around the gas-distribution ring.

4. Carefully place the top-plate onto the L-gasket on the top of the chamber with the hinge bracket oriented to the rear of the machine, parallel to the back of the baseplate. Slide the hinge pin through the bracket and top plate, positioning plastic washers on the hinge pin between metal components. Then open the top place and secure the top plate to the hinge pin using the screw provided.

5. Place the RF screen over the chamber.

2-3.2 CONNECTING VACUUM PUMP

1. Ensure that the pump oil is at a proper level and pump position on the floor. The pump should not be located on the same level as the PPRIE to reduce possible backstreaming of oil. For further information on the operation of the pump, please follow the pump instruction manual.

2. Connect the NW 40 adapter to the vacuum outlet of the PPRIE using the O-ring and clamp provided. Connect flexible metal vacuum pipe to the NW40 flange connections on the rear of PPRIE and to the vacuum pump using the O-ring and clamp provided. Ensure that the pump plug is plugged into the back of the system using the “Pump Outlet”.

2-3.3 CONNECTING PROCESS GAS LINES

1. Connect the desired regulated gas supply hoses to the quarter-inch fitting GAS 1, GAS 2, and VENT (See Figure 3-4), located at rear of the machine.

2-3.4 INSTALLING THE WATER CIRCULATOR

1. Connect hoses for water circulation from the water circulator to the ports identified as “H_2O”.

2. Remove cover and fill using de-ionized water in water circulator.

3. Replace the top cover.

4. Power water circulator on independent power control to control to allow cooling of system after the power has been shut off and to conserve energy when the Plasma Prep RIE is running, but not in need of cooling.

SECTION 3

OPERATION

3-1 CONTROLS AND INDICATORS

Upon turning on the power to the PPRIE, the startup screen will appear briefly, and will automatically switch to one of the two toggle screens: the timer screen, and the run screen. The toggle screen button allows one to switch between these two screens. Black boxes are interactive buttons; Information is presented in the black letters with a white background.

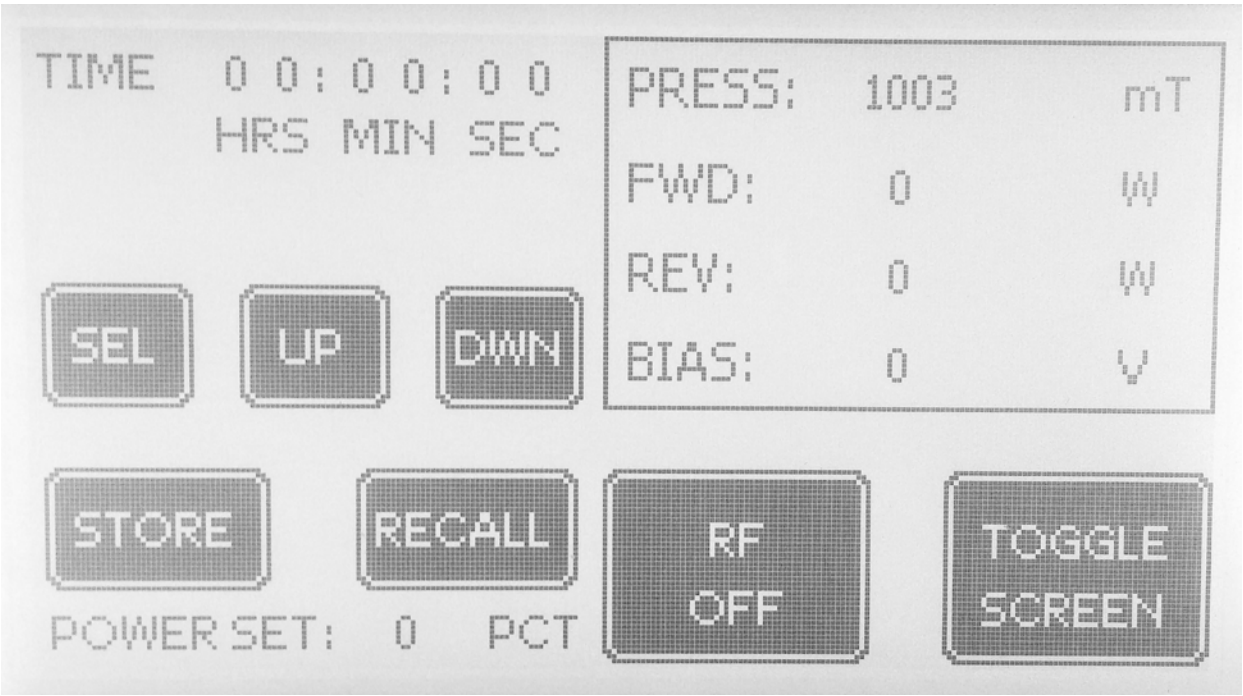

Fig 3-1 SCREEN 1 (Timer Screen)

TIME: Display of the current time remaining for process. The timer only runs when the RF is ON.

SEL: Selection of hours, minutes or seconds input variable.
UP DWN: Advance or reduce the input within that range.
STORE: Stores the current time in memory. This will stay in memory even if the system is off, but not if the unit is unplugged from a power source.
RECALL: Loads the last stored time into the process time.

POWER SET: Displays the power level as a percentage of 200W or the maximum power in this system.

PRESS: Display of Pressure as measured in mT. When the system is at atmosphere the value will read approximately 1000mT.

FWD: Display Forward power in Watts
REV: Display of Reverse (reflected) power in Watts.
BIAS: Display of Bias as voltage.

RF OFF/ON: Turns on and off the RF Power. Note: Certain conditions must be achieved before this button is active.

TOGGLE SCREEN: Switches to the Process Screen

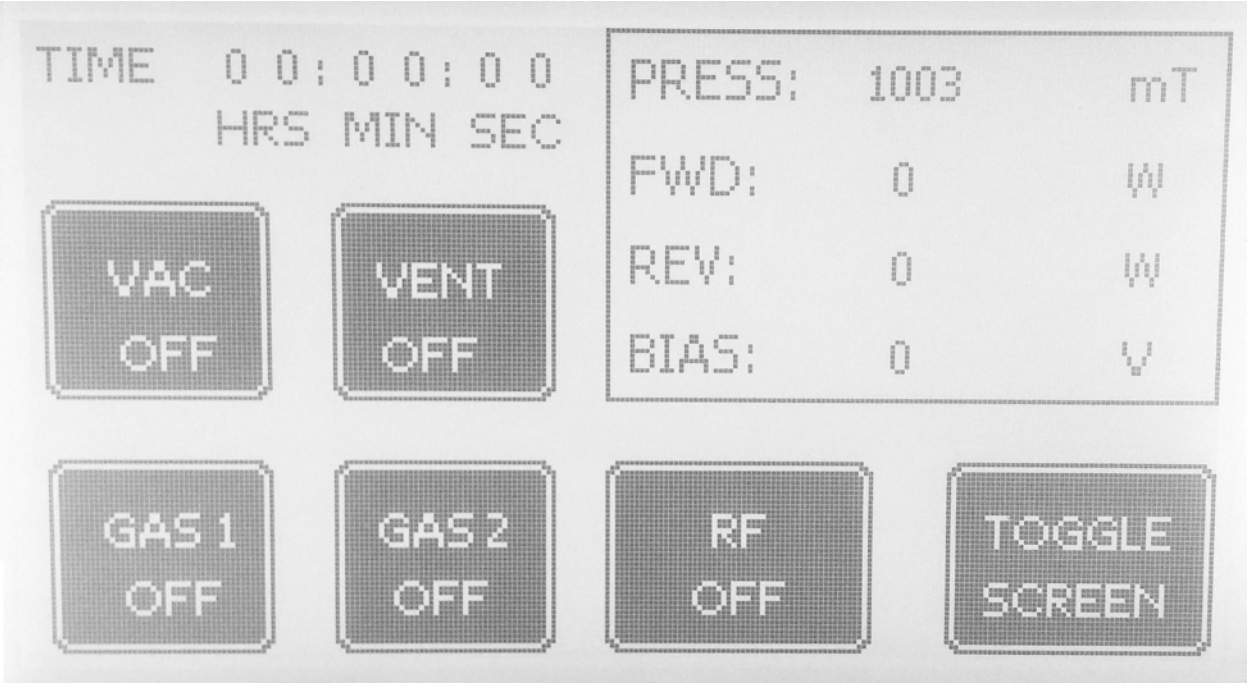

Fig 3-2 SCREEN 2 (Process Screen)

VAC OFF/ON: Turns on/off the vacuum pump to begin or halt the vacuum operation of the chamber.

VENT OFF/ON: Opens of closes the vent value to allow venting of the chamber. Note that the VAC and VENT cannot both be ON at the same time.

GAS 1 OFF/ON: Opens/closes the flow of gas through Gas line 1.
GAS 2 OFF/ON: Opens/closes the flow of gas through Gas line 2. Note: Certain conditions must be achieved before these buttons are active.

RF OFF/ON: Turns on/off the RF Power. Note: Certain conditions must be achieved before this button can be activated.

TOGGLE SCREEN: Switches to the Process Screen

Note that the OFF/ON notation on the buttons indicate the current status of the system. For example GAS 1 OFF indicates that the valve to Gas inlet 1 is closed and no gas is flowing through this line. RF ON would indicate that the RF Power is running.

3-2 BASIC OPERATION

Once properly assembled and connected to power, the switch on the front of the system will power on the touch screen to enable use.

The water recirculator should be powered on once pump down of the chamber has begun, gases are selected, and the process time is entered. Operation of the Plasma Prep RIE without water cooling may cause damage to the system.

Chamber pump down should take place within a few minutes, once the vacuum is on. Note that until the pressure in the chamber reaches approximately 600 mT or less, the RF ON button cannot be activated.

The Plasma Prep RIE operates under a range of pressures and power levels. Ideal pressures range from 150 to 300 mT although higher pressures can be achieved. Pressures above or below this level can be run; however, there can be less RF stability, particularly over a long time period. If such pressures are desired, then lower power levels may provide better stability.

Use of the RF Level and Tuning dial along with the readings of Pressure, Forward and Reverse power, Bias and Percent Set, will enable the operator to maximize the process conditions. For instance at 200 watts, the reverse power is typically in the range of 15 to 20 watts with a pressure of 200 mT. The Percent Set feature allow the operator to know what the maximum potential forward power is at that level allowing for more efficient tuning.

3-3 PROCESS PROCEDURE FOR THE PLASMA PREP RIE

1. From Atmosphere:

a. Load material or sample to be processed into chamber on sample stage.

b. Ensure proper seal on top and bottom L-Gaskets on the vacuum chamber and the RF shield is in place.

c. On the touch-screen, press VAC ON/OFF button to power on vacuum pump – monitor system pressure on top-right of screen.

d. When the vacuum meter reaches its lowest threshold, on the touch-screen, press the GAS ON/OFF to coincide with the desired process gas.

e. Adjust needle valve on the process gas flow-meter to optimize the pressure based on the volume of the process gas.

i. If multiple gas sources are being used, determine the ratio of the gas mixture and the pressure at which the process should be run.

ii. Calculate the difference between the base-pressure of the machine and the desired pressure of the process, and apply the gas-ratio to the difference in pressure.

1. Example: If base pressure=50mTorr, desired operating pressure=150mTorr, gas-ratio=9:1 CF_4:O_2. Allow system to reach the base-level vacuum of 50mTorr, slowly open CF_4 flow until pressure stabilizes at 140mTorr, followed by slowly opening O_2 flow until pressure stabilizes at 150mTorr.

f. Press the TOGGLE SCREEN button to view the timer process screen.

i. Using the Select (SEL), UP and Down (DWN) buttons, input the time desired to run the process.

ii. To save the set time for fast reference, press the STORE button. On a later process, press RECALL to automatically set a stored time.

g. When process gas and timer are set, Press RF ON/OFF to begin the process. Use power level knob to adjust the potential forward power in the plasma while monitoring the power set percentage indicator on the touch-screen

i. 50% indicates potential power of 100W.

ii. 100% indicates potential power of 200W.

h. Once the power has been set, adjust the tuning knob while monitoring both the forward power reading and the brightness of the plasma.

NOTE: Maximum potential may not be able to be achieved immediately, and monitoring of tuning and power level may

be needed to maintain parameters early in a run.

2. From Process End:
   a. The timer begins automatically when then RF power is turned on. When the timer expires, the system automatically powers off the RF and the process ends.
      i. The process may be terminated at any time without the timer using the RF ON/OFF button
   b. On the vacuum screen, press ON/OFF button for any process gas being used to close the solenoid.
   c. Press the VAC ON/OFF button to power off the vacuum pump
   d. Press the VENT ON/OFF button to vent the system. Open the top plate, remove processed materials, and press VENT ON/OFF again to close the vent valve
   e. Refer to Step one in order to begin process on a new sample.

3. To Power Off:
   a. Ensure proper seal on top and bottom L-Gaskets on the vacuum chamber and that vent valve is closed
   b. On the touch-screen, press VAC ON/OFF button to power off vacuum pump
   c. Close any process gas valves on the system and appropriate cut-off and regulator valves to the process gas source(s).
   d. Use Power switch on front of the machine to power system off

NOTE: When the Plasma Prep RIE is turned on for its initial use, allow the unit to run for approximately ten minutes before a process run. This will eliminate any contamination, which might be present in the chamber. Either air or process gas (O^2) can be used for this purpose.

3-4 PROCESS GASES

Each gas produces a slightly different color for the resulting plasma:

a. oxygen	blue/white
b. argon	fuchsia
c. carbon tetrafluoride	blue/white
d. nitrogen	violet

Note that these colors are given as an overall guide. The color in the chamber may vary due to pressure, sample and process conditions. If the color of the plasma is red to violet, and the etch rate seems low, then air may be leaking into the chamber (the color is due to the presence of nitrogen).

The most likely sources of air leaks are:

a. Vacuum line to back of Plasma Prep RIE to mechanical pump.

b. L-Gasket seals on the chamber (check to make sure no extraneous particles are present that would interfere with the vacuum).

Sometimes mixtures of gases are required in order to accomplish specific ends. One very important case is the removal of epoxy or silicone thermosetting materials (such as the plastic package of an electronic device). Although basically "organic", they are oftentimes filled with various inorganic (most common SiO_2) fillers. The gas composition usually used is 10% CF_4, 90% O_2, with the CF_4 removing the filler and the O_2 taking away the polymer.

3-5 ETCH RATES AND OPERATING CONDITIONS

Etch times within the Plasma Prep RIE are highly dependent on several variables and parameters within the system. The best way to determine repeatable etch rates is to record and document operating parameters to coincide with measured etching results.

Conditions to monitor to determine a reliable etch-table include:

a. Vacuum level
b. Process gases and flow rates
c. Operating power level
d. Bias level
e. Process time
f. Sample dimensions both before and after etching
g. Outlying factors which may affect performance of a run

Typical etch times from our Plasma Prep line of etchers may be used as a reference to begin testing:

a. Removal of 1µm SiO_2: 25-30 minutes.
b. Removal of 1µm Si_3N_4: 30-35 minutes.
c. Cleaning of hybrid device: several minutes.
d. Package decapsulation of I.C.s with several mils of polymer remaining: In this case, the top portion of the package is ground or milled away so that what remains is only several mils. This can take place within a few hours or may take a day or more.
e. "Etching" or "ashing" away of a "Nuclepore" membrane filter: 45 minutes in an oxygen environment.
f. Gentle etching to reveal inorganic material in an organic polymer matrix, such as magnetic storage media, pigment plastics, etc.: several minutes.

3-6 FRONT AND REAR INSTRUMENT PANEL DISPLAY

Figure 3-3 Front View of Plasma Prep RIE Controls and Indicators

1) Gas 1 Flow Meter/Control
2) Gas 2 Flow Meter/Control
3) LCD Screen
4) RF Level Control
5) Tuning Control
6) Main Power ON/OFF

Figure 3-4 Rear View of Plasma Prep RIE

7) Chamber Vent Line Input
8) Gas 2 Line Input
9) Gas 1 Line Input
10) Pump outlet (220V)
11) AC Power In (220V)
12) Water Lines In/Out
13) NW40 Vacuum Outlet
14) RF Deck Cooling Fan
15) Hinge Bracket

SECTION 4

USER MAINTENANCE

4-1 GENERAL

Maintenance on the Plasma Prep RIE consists of cleaning and replacing such parts as the chamber and L-Gaskets. Any other repairs should be performed by SPI Supplies. L-Gaskets should be checked for tears and regreased periodically with a high vacuum grease.

4-2 CLEANING

Cleaning consists of a routine procedure, which should be performed periodically. This schedule will depend on frequency of use, type of materials processed and the environment in which the machine has to operate.

Routine Procedure: The sample stage and vacuum chamber will require cleaning as it is more likely to become contaminated. For more difficult contaminants, (inorganic films and residues), use standard laboratory cleaning procedures. Remove the chamber and wash the chamber with a test tube brush and a good laboratory detergent or with solvents and lint-free cotton wipers.

The lid and sample stage will also require cleaning, but may remain in place on the system for routine wipe-downs.

4-3 SUCCESSFUL FUNCTIONING OF YOUR EQUIPMENT

Successful functioning of your equipment depends upon a proper vacuum. Your vacuum pump should be serviced on a frequent and regular schedule. Pump fluid changes should be done on a regular schedule per the pump manufacturer recommendation.

4-4 SPARE PARTS LIST

SPI#	PART NUMBER DESCRIPTION
11036-AB	Quartz Vacuum Chamber 5.5x10 inch
11037-AB	L-Gaskets Quantity 2

SPI Supplies offers a complete line of consumables and microscopy supplies. Suggested consumables for the Plasma Prep RIE:

SPI#	PART NUMBER DESCRIPTION
05040-AB	Apiezon M Vacuum Grease
05151-SA	SPI-Wipes Lint-Free Cotton Wipers
0CFT4WFPE-XD	Style #4WF CarbonFiber Tweezers
01398-AB	SPI Supplies ESD Antistatic Gloves

For other components not listed contact SPI Supplies at www.2spi.com

4-5 CUSTOMER RETURN INFORMATION

If a Plasma Prep RIE is to be returned to SPI Supplies, for whatever reason, the following procedure should be followed:

1. From the USA or Canada, call SPI Supplies Customer Service Department, 1-800-2424-SPI or 1-610-436-5400 for a Return Authorization Number (RA#). If unit is not received with this RA number on the outside of the box, it will be rejected by the Receiving Department. For other countries, contact either your closest SPI Supplies agent or SPI Supplies in the USA by phone 1-610-436-5400, FAX: 1-610-436-5755 or e-mail support@2spi.com following the same instructions.

2. Repack the machine in its original shipping container. If this is no longer available, take special precautions to avoid damage to the glass chamber and other fragile components.

3. If the machine is still under warranty, the only charges are shipping cost except in the case of mis-use or negligence. If the machine is out of warranty, a purchase order will be required for approved accounts and customer can expect to be billed for all parts and service. All others will require some form of guaranteed prepayment such as a letter of credit.

4-6

SUBSTRATE TO BE ETCHED	**REACTIVE GAS OR GAS MIXTURE**
Stainless Steel	CF_4 CF_4/O_2 mixture (experiment for correct proportions) CCl_4-necessary if chromium present
Hydrocarbons, all organics, polymers, etc.	O_2
Metal oxides	Ar
SiO_2; Si_3N_4 (passivation layers)	CF_4 or other reactive fluorine gases
Plastic packages	Combination of O_2 and CF_4, O_2 to etch plastic, CF_4 to etch glass filler. Typical formula: % 10 O_2/% 90 CF_4
Aluminum and aluminum alloys	Cl_2; CCl_4; or mixtures of Cl_2 + CCl_4
Al_2O_3; all forms of anodized aluminum; oxide layers on electronic circuits	**NOTE:** Initially use small amount of Br_2 in mixture to remove surface skin of Al_2O_3. Also useful are CF_4 and CHF_3 for this purpose