ID: photo-11    Location: FabLab Photo Tunnel

The March Photoresist Stripper is used to remove photoresist residue. Plumbed with both CF4 and O2, the March is an aggressive etcher for any organic material.
Operating Instructions

EQUIPMENT ORIENTATION
This section includes a general description of the overall plasma system as well as a more detailed description of the controls and indicators on the front and rear panels.

GENERAL EQUIPMENT DESCRIPTION
The Jupiter III plasma system is a parallel plate reactive ion etcher designed to meet the needs of today's failure analysis and research and development applications. It offers fast, uniform, and selective anisotropic etching. It consists of a single module, which contains a vacuum control system, gas delivery system, and an RF generator.

Designed for maximum performance and flexibility, March Instrument's Jupiter III Reactive Ion Etching systems are tabletop etchers used primarily in failure analysis and small scale production plasma etching applications.

PROCESS CONTROL
The variable parameters of the plasma process, including chamber pressure, process duration and gas flow rates are monitored and regulated through the Process Control panel on the front of the unit. The Jupiter III houses two Flowrators for regulation of process gas flow, and the system is equipped with a Convectron convection device for pressure determination.

The unit can be operated in either an automatic or manual mode. In automatic mode built-in sequencing will:
- Vacuum down the chamber to the preset base pressure level.
- Turn on the selected gases to the preset flow rate.
- Turn on the RF power to the preset level when the gas flow has stabilized.
- Maintain these parameters until desired processing time has elapsed.

The Process Controller will then shut off the RF power and perform a complete evacuation of process gases. The chamber will vent to atmospheric pressure and the end-of-process alarm will sound. Manual mode provides the same control over process parameters but requires that each sequence step be initiated by the operator.

Process Control Elements
- Two rotary process gas flow meters (solenoid controller)
- Convectron pressure gauge with base pressure set point
- Automated process sequencing with manual override and process timer
- Tuning Mismatch Alarm
- Automatic RF tuning

RADIO FREQUENCY POWER GENERATOR AND MATCHING NETWORK
The Jupiter III is equipped with a solid state RF- (Radio Frequency) generator with a fixed frequency of 13.56 MHz and a maximum power output of 300 watts. Impedance matching is achieved through the employment of an Inductive-Capacitive tuning network. The tuning network functions by adjusting the forward to reflected power ratio during processing in order to achieve the best power transfer to the plasma. The forward power is the total power output from the generator at a given setting. Reflected power is undesirable and should be minimized during operation. It is the portion of the forward power that is lost from the plasma and reflected back towards the generator. When the tuning network is operated manually, reflected power must be continuously monitored in order to keep it at a minimum. In auto mode, the tuning is automated for hands-off operation and convenience.
The top-loading chamber is designed to ensure anisotropic etching and maximize selectivity, uniformity, and speed. A ceramic ring focuses the plasma on the bottom electrode where the sample is placed, thus optimizing power utilization to increase anisotropy and etch rate. Both electrodes are water cooled to maintain the chamber at a low temperature during processing. The size difference between the top and bottom electrodes produces a DC bias which enhances ion bombardment and anisotropy.

The chamber is equipped with a circular quartz viewing window for observation of the plasma process. The primary chamber material is anodized aluminum; other components are manufactured from ceramic and quartz. No plastic components are used in the construction of the chamber.

JUPITER III SPECIFICATIONS
The following are the specifications for the Jupiter III system:
Exterior Dimensions
- 18" (46 cm) D x 13" (33 cm) W x 16" (40.5 cm) H.
Weight
- 80 lbs. (36.4 kg)
Chamber Material
- Anodized Aluminum
Chamber Interior Dimensions
- 10" Diameter x 1.5" High
Installation Working Surface
- Designed for use on table top or counter.
RF Power Generator
- 0-300 watt RF Power Generator.
- 13.56 MHz operating frequency.
- Solid state circuitry.
- Automatic or Manual impedance matching.
CONTROLS AND INDICATORS

This section describes the controls and indicators on the Jupiter III system. Each control and indicator is numbered on Figures 7 and 8 for reference.

Front Panel Controls
1. AC. The AC power switch is a push-button lamp switch which activates and deactivates the main power. The button is lit when the power is on.
2. AUTOIMAN. Selection of Manual (user controlled) or Automatic (system controlled) Tuning Mode is accomplished by placing the switch in the AUTO or MAN position.
3. GAS 1/ GAS 2. A button that turns the process gas flow on and off. When the button is lit, gas flow is activated via a solenoid. During automated operation, the vacuum set point must be reached before gas will flow. In manual operation, gas flow begins when the button is pressed, regardless of chamber pressure.
4. Flowrators. Each flowrator consists of a gas flow meter and a knob for adjusting the gas flow rate.
5. Digital Timer. Consists of a digital time display and plunger switches for changing the process time setting. The timer can be set to any desired process time up to 99 minutes and 99 seconds. The timer begins counting at the moment the RF power is activated. When running in Auto mode, the elapsed time (following application of RF power) is indicated on the display and processing stops when the timer reaches zero. In Manual operation mode, the timer is inactive.
6. VACUUM. Push button lamp switch which opens and closes the vacuum valve between the pump and chamber, allowing the chamber to be evacuated or bled back to atmospheric pressure. In the “on” position the vacuum solenoid valve is open and the bleed solenoid valve is closed (chamber under vacuum). When the switch is “off”, the vacuum solenoid valve is closed and the bleed solenoid valve is open (chamber at atmospheric pressure).
7. RESET. When in automatic operation mode, pressing this button will reset the internal timers and RF relay so that the process sequence can be run automatically.
8. Vacuum Meter. Provides a digital display of chamber pressure in Torr. It has a logarithmic scale with a readable range from about 0.01 Torr to 50 Torr. The meter is equipped with a threshold pressure set point mechanism, consisting of a red needle that is positioned by rotating the dial centered on the face of the meter. This allows operator control of the pressure at which the process sequence begins. In automatic operation mode, when the chamber pressure reaches the set point, any gas flow solenoids that are
enabled will open to allow the process gas to pass through the flowmeters and into the chamber. Internal timing cycles also begin. During manual operation the threshold pressure set point is inactive.

9. RF. The RF power switch is a push-button lamp switch that lights when the RF power is on.
10. **LEVEL.** The level control knob is a potentiometer which controls the power level.

11. **FWD/REV.** Toggles the RF meter display to indicate either forward RF power (FWD) or reflected RF power (REV) in watts.

12. **C1 & C2.** If the Manual tuning mode has been selected, toggling these switches controls the positioning of the air capacitors of the impedance matching network. Used to minimize reflected power by matching the impedance of the RF generator and the chamber.

13. **RF Power Meter.** Indicates forward or reflected RF power in watts. The FWD/REV switch determines which parameter is monitored.
Rear Panel Controls

14. AUTO-MANUAL. Toggles the machine between automatic and manual operation modes.

15. ALARM SPEAKER. Audio alarm that sounds to indicate RF tuning mismatch.

16. ALARM ON/OFF. Switch used to activate/deactivate the tuning mismatch alarm. In the "ON" position, the alarm will sound when the RF power is out of tune. In the "OFF" position, the alarm is disabled.

FIGURE 8.- Rear Panel Controls and Indicators
THEORY OF OPERATION

This chapter gives an overview of plasma and plasma processes. It outlines the basic requirements to create a plasma and what variables are under operator control.

THE PLASMA PROCESS: AN OVERVIEW

A gas plasma consists of a collection of ions, free radicals, and electrons produced when a gas is transformed to a high energy, excited state by exposure to an energy source under the right physical conditions. Natural plasma examples include lightning, fire, and the Aurora.

Plasma treatment is a process by which the surface of a material is modified in some way through the actions of the dissociated molecular components of a gas. Because these components are in such a high energy state, they are very chemically reactive and can easily affect changes to the surface of materials. The changes that occur are complex and dependent on many variables including gas chemistry, process pressure, and the surface chemistry of the material being processed. A key advantage to plasma treatment is that only the surface (first several molecular layers) of the material is altered; the characteristics of the bulk material remain the same.

In etching and cleaning processes, unwanted material is removed from the surface of the substrate using a relatively high energy plasma. The process breaks the contaminant molecules into smaller pieces which volatilise and are then swept out of the chamber by the vacuum pump.

Surface activation processes work by altering the first several molecular layers of the bulk material through incorporation of chemical functional groups that increase the surface energy of the material. This leads to improvements in the adhesion and wettability of the treated material.
BASIC ELEMENTS OF PLASMA TREATMENT

To plasma treat a sample in the Jupiter III, the basic steps are:
1. Place the material to be treated into the chamber.
2. Seal the vacuum chamber by closing the lid.
3. Pump the vacuum chamber down to a low, preset pressure level.
4. Introduce a process gas or gases into the chamber.
5. Apply RF energy to the low pressure gas in the chamber to light the plasma.

To end the process:
1. Stop applying RF energy to the chamber.
2. Stop the flow of process gases.
3. Bleed the chamber back to atmospheric pressure.
4. Open the vacuum chamber.
5. Remove the treated material from the chamber.

These steps are flow charted on the next page.

CAUTION: THE CHAMBER CAN BECOME VERY HOT DURING SOME PROCESSES. EXERCISE CAUTION TO PREVENT BURNS.

In order to develop and optimize a plasma process for a given material, the operator has the ability to alter the following parameters:

- Process gas(es) selected for use.
- Flow rate/pressure of selected gas(es).
- Amount of RF energy applied to the vacuum chamber.
- Amount of time material is exposed to the plasma.
- Vacuum chamber threshold pressure (the pressure setting that must be achieved before the process can start).

Process pressure, RF power, and treatment time are the primary factors that affect the intensity of the treatment. For example, a high energy treatment would be run under conditions of relatively low pressure, high power, and long treatment time. Conversely, a low energy treatment would be run under conditions of relatively high pressure, low power, and a short treatment time.

Since every material has different treatment requirements and many factors need to be taken into account, it is difficult to say what type of treatment will give the desired results. A general rule would be that energetic processes are better for cleaning and etching applications; more moderate processes are better for surface activation applications.
SETUP

This section illustrates the proper use of various equipment and process options.

ADJUSTING GAS FLOW

The operator can control the flow rate of each individual gas and mix two gases entering the plasma chamber. The scaling on the flowmeter ranges from 0 to 65 ml/min and the gas flow is linear within mid-range. The standard flowmeters can each regulate up to 50 cc/min of air at standard temperature and pressure.

It is important to note that each type of process gas has a different flowrate at a given flowmter setting. The flowrates for the most common process gases at various flowmter settings are listed under Gas Flow Settings, page 50.

When running two process gases at once, the operator should know the ratio of the two gases flowing into the chamber for future reference. Simple chamber pressure ratios (rather than flowrate ratios) are sufficient for most applications:

Example:

You want to process the sample with 300 mTorr of process gas at a ratio of 90% CF₄ and 10% O₂. Oxygen is Gas 1 and CF₄ is Gas 2.

- 90% of the total process gas pressure is due to CF₄: \(0.90 \times 300 = 270\) mTorr
- 10% of total process gas pressure is due O₂: \(0.10 \times 300 = 30\) mTorr

1. Press the VACUUM button and allow the chamber to evacuate for five minutes to ultimate vacuum.
2. Adjust the flow of the gas contributing the most pressure first. In this case, turn on GAS 2 and adjust the flow until the pressure reads \(0.27\) Torr over the ultimate pressure from step 1.
3. Turn on GAS 1 and adjust the flow until the pressure reads \(0.03\) Torr above the pressure value determined from step 2.
4. The flow meters are now set and you are ready to begin processing samples.

TUNING THE RF MATCHING NETWORK

The Jupiter III Plasma System utilizes an L-C tuning network to ensure maximum transfer of energy into the chamber. The unit is equipped with a manual tuning system comprised of motor driven air capacitors which, when the system is operated in manual tuning mode, are positioned by the operator to achieve minimum reflected power during processing. This positioning is accomplished through front panel mounted switches (C1 and C2). When running in Auto tuning mode, circuitry automatically monitors the forward-to-reverse power ratio on a continuous basis during processing and positions the air capacitors for optimum power transfer to the chamber. This is the preferred mode of operation.
CAUTION: REFLECTED POWER LEVELS THAT BECOME EXCESSIVE CAN CAUSE DAMAGE TO, OR FAILURE OF, THE RF POWER GENERATOR. IT IS VITAL THAT REFLECTED POWER BE MONITORED AND KEPT TO A MINIMUM LEVEL DURING OPERATION.

Manual Tuning
- Toggle the AUTO/MAN tuning mode switch to MAN position.
- Toggle C1 and C2 switches to minimize reflected power.
- Reflected power value is displayed on the RF Power Meter.

Automatic Tuning
- Toggle the AUTO/MAN tuning mode switch to the AUTO position.
- Reflected power value is displayed on the RF Power Meter.
- Monitor reflected power during the plasma process to ensure proper operation and Auto tuning.
PROCESS PROGRAMMING

This section describes the programming steps necessary for running processes in both the Manual and Automatic operational modes. The procedure for shutting down the system is also included. Before turning on the system, refer to the Initial Start Up, page 13.

MANUAL OPERATION

When developing a process, the Manual mode is used to determine gas setting versus pressure relationships and to set the RF power level for future runs in Auto mode.

1. Close the chamber lid.

2. Toggle the AUTO/MANUAL switch on the rear of the system to enable manual operation.

3. Ensure that the AUTO/MAN button on the front panel is set to AUTO (for automatic RF tuning).

4. Press the VACUUM button on the front panel to begin evacuating the chamber.

5. When the Pressure Display on the front panel reads less than 200 mTorr, press the GAS button corresponding to the desired process gas.

6. Turn the gas flow rate knob on the flowrator until the desired chamber pressure is achieved.

7. Press the RF button on the front panel so that the button is lit.

8. Ensure that the FWD/REV button on the front panel is set to FWD, then turn the power level knob on the front panel until the desired power level is observed on the power meter. A plasma should be visible in the chamber.

9. Monitor the reflected power on the power meter by pressing the FWD/REV button so that REV is selected. Reflected power should not be any higher than 5% of the forward power setting.

10. Press the RF button to shut down the RF power.

11. Deactivate the GAS buttons.

12. Press the VACUUM button to bleed the chamber back to atmospheric pressure.
AUTOMATIC OPERATION
Now that the desired settings for gas flow and RF power have been established in manual mode, the operator can run the process in Automatic mode:

1. Enter the desired amount of process time into the process timer by pressing the plunger switches (labeled + and -).

2. Place sample of material to be treated into the chamber and close the lid.

3. Toggle the AUTO/MANUAL button on the rear of the system to enable Automatic operation.

4. Turn the red Threshold Pressure Setpoint needle on the Pressure Meter to the desired threshold pressure for beginning the process.

5. Press the GAS buttons to enable the desired gas channels.

6. Press the RF button to enable RF power.

7. Press the RESET button to reset the system internal timers.

8. Press VACUUM button. The system will now run through all the steps necessary to complete the process.

9. When the process is complete, press the VACUUM button again to vent the chamber to atmospheric pressure. The sample can now be removed from the chamber.

10. For future runs under the same conditions, press the RESET button followed by the VACUUM button.

SYSTEM SHUT DOWN
Procedure for complete system shutdown:
1. Press the RF button to shut off RF power.

2. Turn off the gases by pressing the GAS buttons.

3. Press the VACUUM button to vent the chamber.

4. Press the AC button to shut off the system main power.

5. Unplug vacuum pump.

6. Turn off the chiller.