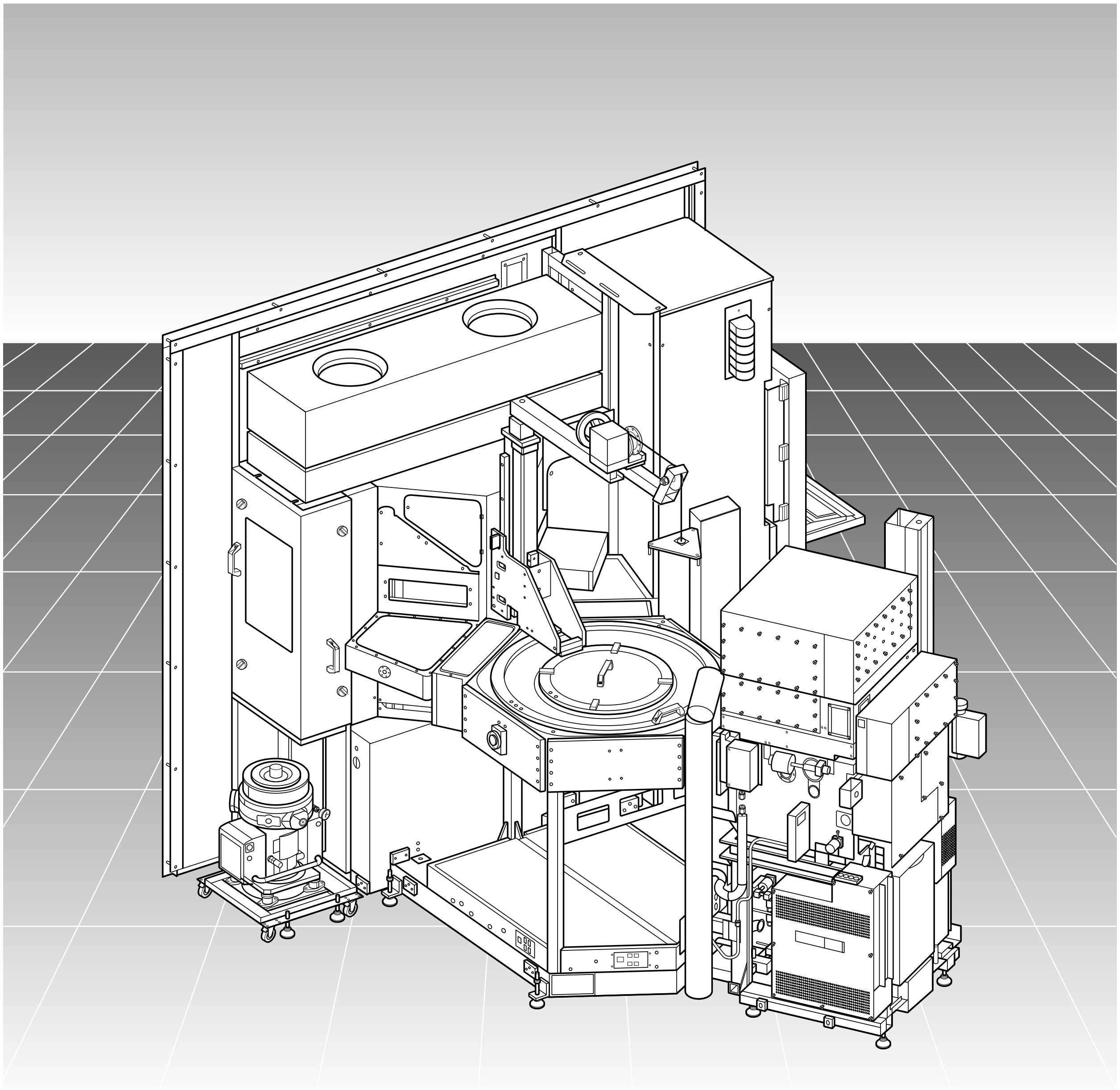
2300™ Etch Systems

Safety



Lam RESEARCH

Revision H

2300™ Etch Systems

Safety

BOM Version 571-810271-001

2300 Software Version 1.4

Revision H
March 2001

Revision A July 1998—First Printing (DCN Control)

Revision B September 1998—Second Printing

Revision C February 2000—Third Printing

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Revision E August 2000—Fifth Printing

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Part Number: 406-240390-002

Safety Preface

The safety guidelines for the equipment in this manual do not purport to address all the safety issues of the equipment. It is the responsibility of the user to establish appropriate safety, ergonomic, and health practices and determine the applicability of regulatory limitations prior to use. Potential safety hazards are identified in this manual through the use of words Danger, Warning, and Caution, the specific hazard type, and pictorial alert icons.

Hazard Levels

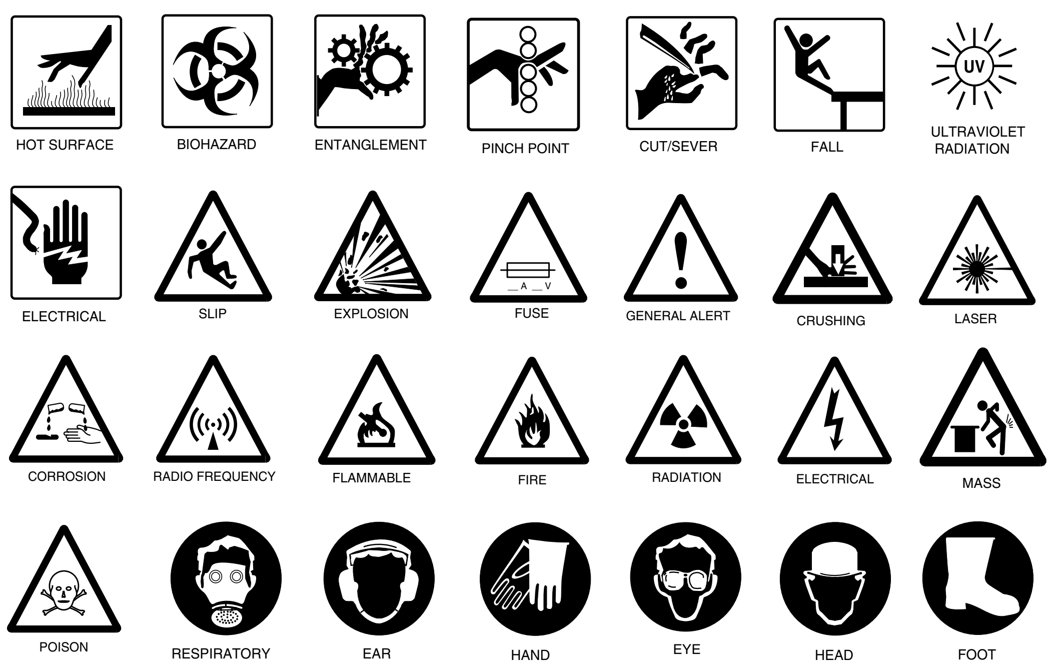
Danger: Indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This is limited to the most extreme situations.

Warning: Indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

Caution: Indicates a potentially hazardous situation which, if not avoided, could result in minor or moderate injury. It may also alert users against unsafe practices.

Notice: Indicates a statement of company policy (that is, a safety policy or protection of property).

Pictorial Alert Icons



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Cleanroom Version

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March 2001

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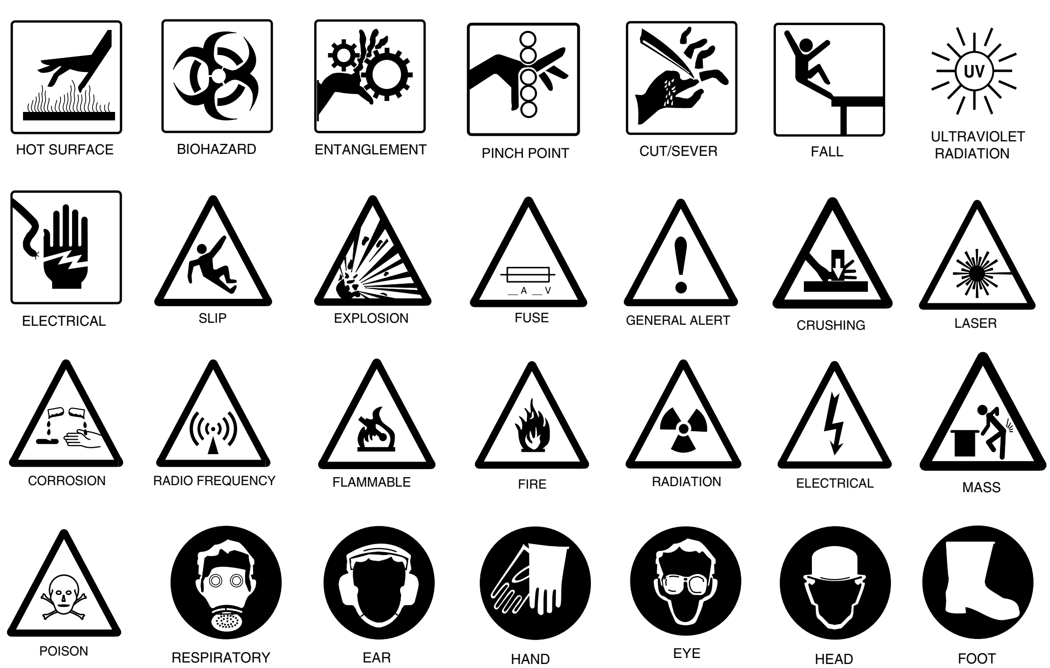

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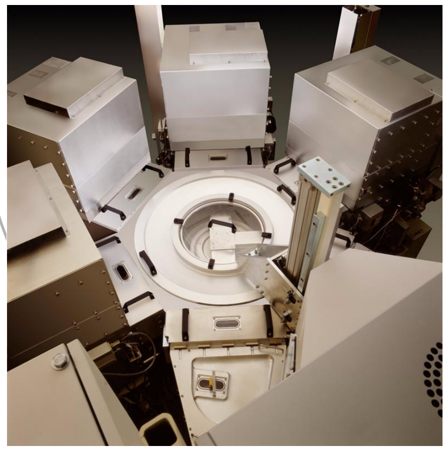
2300™ Etch Series



Lam's new 2300 etch series is the low-risk solution for sub-130 nm volume production on 300 mm substrates. The 2300 suite of products brings Lam's tradition of excellence in etch processing to 300 mm wafers with the Exelan™ 2300, the Versys™ Silicon 2300 and the Versys™ Metal 2300. The Versys conductor chambers have 200 and 300 mm capability, and all systems for conductor and dielectric films are available in a four chamber configuration. The compact 2300 series design reduces the floor space for high-volume production while still providing full service access.

The 2300 etch systems also enable wafer fabs to have one platform independent of their technology roadmap. Lam's 2300 etch series of products lowers the risk of transitioning from 200 to 300 mm wafers, of changing from metal etch to dual damascene, and of moving 300 mm volume production from 150 nm to sub-130 nm technology nodes.

Extensive use of modeling during system design has ensured that the best technology has been incorporated into all of the systems, optimizing chamber conductance, thermal characteristics, and plasma uniformity. The 2300 etch series also builds on the production experience of Lam's 200-mm Alliance™ etch systems, preserving the production benefits of repeatability, damage-free processing, and process flexibility.

Exelan 2300 leverages Lam's successful dual frequency confined (DFC) plasma technology currently used on Exelan, Lam's fastest ramping product to 300 mm processes and next-generation applications. Developed processes include both critical and noncritical etch. DFC technology has become the most successful production-proven technology for oxide copper-damascene applications, and customers are evaluating it for leading-edge, low k, dual damascene. Exelan 2300 provides leading edge solutions, with the industry's best damage performance and the lowest CoO.

Versys Metal and Versys Silicon rely on Lam's production-proven Transformer Coupled Plasma™ source to support in situ process solutions for leading edge device structures. Both conductor systems deliver superior performance, have large process windows, and process complex film stacks in situ with a single chamber configuration. Versys Silicon processes metal gate and STI with top corner rounding in situ. Versys Metal provides excellent process results with serial etch and strip on a single platform to control corrosion. Both Versys etch systems drive CoO down, to compete with the lowest cost systems in the industry.

Lam's 2300 etch systems offer the lowest risk path to 300-mm production. The system allows conductor processes to be fully matured in 200 mm volume production before they are transferred in the same chamber to 300 mm substrates. With a production-proven technology, advanced process capability, low capital investment, and the flexibility that delivers high volume throughput, Lam's 2300 Etch Series is the low risk solution for all 200 and 300 mm production lines at sub-130 nm technology nodes.

Contents

Figures

Tables

1 Overview

This manual provides safety information on all 2300™ etch systems available from Lam Research.

The equipment designed and manufactured by Lam uses potentially hazardous energies and substances. Although these systems have been designed to limit the risks associated with these hazards, service and maintenance personnel must still exercise appropriate caution when performing their tasks. The purpose of this manual is to provide service and maintenance personnel with information to aid them in avoiding these hazards when interacting with the system.

While this manual is intended to cover the different hazards associated with the 2300 systems, not all scenarios may be addressed. When faced with a potentially hazardous situation that is not addressed by this manual, personnel should immediately contact their Lam representative.

Manual Conventions

The safety information is presented in more general terms in the forward chapters of the manual, and becomes more descriptive in the individual system chapters.

Changes Since Last Revision

Revision H includes the following changes:

- Updates the Reference Documentation section in Chapter 1, "Overview."
- Updates the PM Hardware Interlock table in Chapter 10, "Versys Metal Process Module."

- Updates the Processes Which Are Interlocked section in Chapter 10, "Versys Metal Process Module."
- Adds the RF Energy section in Chapter 10, "Versys Metal Process Module."
- Adds the Chemicals Used During Etch Process section in Chapter 10, "Versys Metal Process Module."

Reference Documentation

Table 1–1 lists the related manuals referenced in this manual.

Table 1–1. Reference Documentation

Part number	Manual
406-240311-002	*2300 Transport Module Operation*
406-240311-003	*2300 Transport Module Maintenance*
406-240332-002	*Exelan 2300 Process Module Operation*
406-240332-003	*Exelan 2300 Process Module Maintenance*
406-240340-202	*Versys Metal/Silicon 2300 Process Module Operation*
406-240340-203	*Versys Metal/Silicon 2300 Process Module Maintenance*
406-240350-002	*Strip Module 2300 Process Module Operation*
406-240350-003	*Strip Module 2300 Process Module Maintenance*

Note The part numbers for cleanroom versions of the listed manuals (except facility manuals) start with the prefix 409. Facility manuals are not available in cleanroom version.

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2
Safety Systems

Lam equipment is equipped with active features that enhance operator and service technician safety, and help to protect persons and property against human error and component failure.

Training

All personnel must have the appropriate safety training.

Emergency Off

All Lam systems include an emergency off (EMO) system to disconnect power when an emergency occurs.

On the 2300 system, large, red palm-sized buttons are positioned a maximum of 10 feet apart. **EMO** buttons are positioned on the user interface (UI), the front right side of the transport module (TM), and if process module (PM) 4 is not installed, a third button is on the PM 4 facie. When any of these **EMO** buttons is pushed, the system is turned off up to the load terminals of the main contactor.

The voltage for the EMO circuit is 24 volts alternating current (VAC) and limited to 1 ampere. The circuit is located in the power/control rack.

The global EMO distribution is located at the AC distribution rack. The remote power distribution box (RPDB) reports its EMO state to the global EMO distribution. The PM pump and TCU **EMO** buttons report to the RPDB. The EMO circuit in the AC distribution rack is 24 VAC and limited to 1 ampere. The EMO circuit transformer provides power to the EMO loop for all EMO contacts and all contactor pilot relays, exclusively.

Power to the EMO transformer and associated circuitry remains on after the EMO system is activated.

All EMO events require manual recovery, which means that personnel must go to the module that generated the EMO event to verify a safe condition.

Remote Power Distribution Box

The remote power distribution box (RPDB) assembly is a standard component of each system. It includes the main circuit breaker and circuit breakers for the temperature control units (TCUs) and PM dry pumps.

All electrical connections must comply with the requirements of the national electric code (NEC) and local standards.

Typically, certified journeymen electricians install power distribution systems.

The user is responsible for distributing power from the main power/ control rack to the RPDB.

EMO Limitations

Following are the limitations of the EMO system when it is activated:

- When AC power to the turbo pump controller is disconnected, the controller will continue to operate for a few minutes while the pump spins down.
- Power to the system computer is not immediately disconnected. The internal uninterruptible power supply (UPS) supplies power for several seconds then turns off.
- Power to the pressure controller valve of the process module continues (with internal batteries) until the valve is fully closed, then the power turns off.
- Power to the EMO transformer and associated circuitry remains on after an EMO event.

- CB0 (main power) must be open when you are working inside the AC enclosure.

Figure 2–1 shows the interconnections between the TM and PM, and RPDB EMOs. Figure 2–2 shows the electrical connections of the TM and PM EMOs.

Figure 2–1. EMO Interconnect Diagram

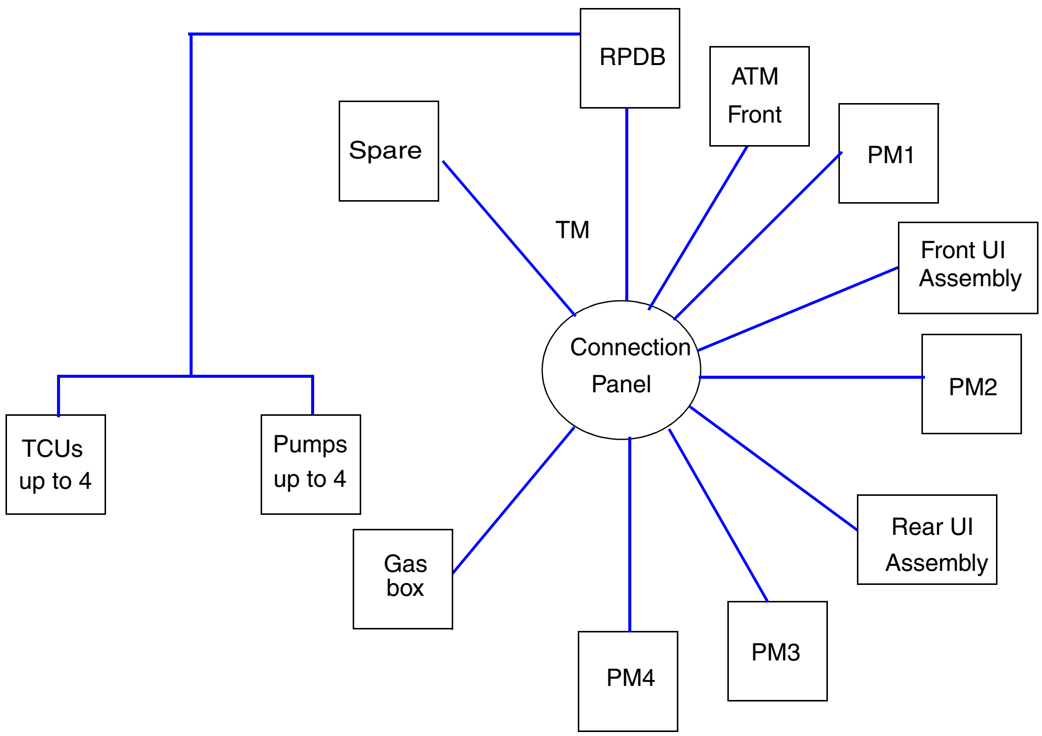
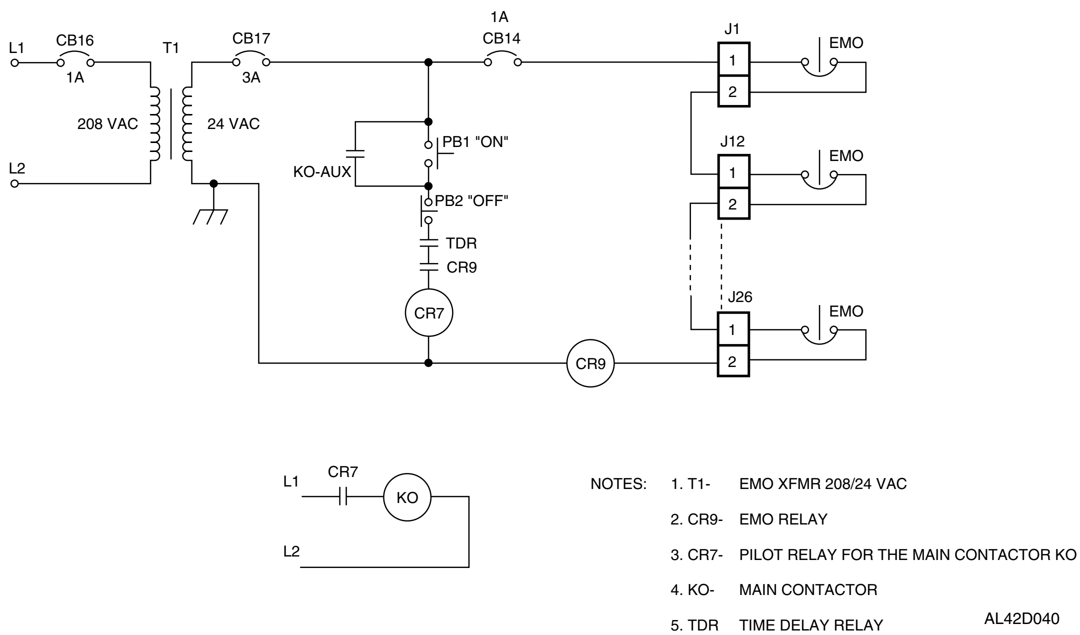


Figure 2–2. EMO Ladder Diagram



Lockout/Tagout for Main Circuit Breaker Disconnect Handle

A lockout is a method of keeping equipment from being energized and endangering workers.

Use standard lockout devices for main circuit breaker handle lockout and tagout. The main circuit breaker handle shall be placed in the safe position (OFF). A lock shall be attached to the handle (special opening are dedicated for that) so that the equipment cannot be energized.

In a tagout, a written warning shall be attached to the lockout device.

Lam recommends that you carefully follow the lockout and tagout procedures described in this manual before servicing the TM. These procedures must be performed only by authorized technicians.

The 2300 system provides signal “EMO circuit closed” to the remote control unit. This signal is generated by normal opened dry contacts of a relay which are connected to pins 1, 2 of the AC rack connector J28.

The 2300 system can connect your EMO device into the system's EMO daisy-chained circuit, using the AC rack connector J34.

Note The 2300 system is required to be bottom facilitated based on the industry standard. The main disconnect device is mounted with line terminals down and load terminals up.

You should obtain from a local jurisdiction, if necessary, a "code variance" in advance.

Environmental Regulations

Environmental regulations and requirements vary by the geographic location or governmental jurisdiction in which the product is installed.

Environmental requirements for process equipment include the following categories: air emissions (HAPs, PFCs, VOCs), water effluent, and solid or liquid hazardous wastes. In addition, semiconductor industry developed performance requirements are emerging in the areas of water and energy use efficiency. Lam participates in and tracks these developments.

Material Safety Data Sheets

Lam recommends that Material Safety Data Sheets (MSDS) be obtained from the chemical suppliers and maintained in the manual.

Point-of-Use Abatement

Point-of-use (POU) emission abatement systems treat air emissions from specific semiconductor processes. A typical POU system may serve one to four similar process modules. POUs remove compounds of interest before they enter the facility's main exhaust ducts. By contrast, facility-level abatement systems treat the collected exhaust of an entire facility or a large area within it.

Several types of POU systems treat specific classes of effluents such as HAPS. Currently, Lam is engaged in several research and development efforts for these systems.

The SEMATECH transfer document, *Point-of-Use Control Systems for Semiconductor Process Emissions*, provides guidance in the identification and selection of POU systems for particular process applications. In all cases where POU equipment is used with Lam products, it is essential that the user investigate and comply with all environmental regulations of the jurisdiction where the equipment is installed.

HAPs Regulation Management

Some qualitative and quantitative HAPs emissions data for the 2300 transport module exists.

Hazardous Waste

Some of the maintenance procedures for the 2300 system expend waste products. Treat all waste as toxic. If disposal is required, please observe the proper occupational safety and health administration (OSHA) approved or facility-approved disposal practices.

Table 2–1 shows the chemical by-products accumulated during regular maintenance of the process modules:

Table 2–1. Hazardous Materials Used for Preventive Maintenance

Material	Quantity per wet clean
6 percent H_2O_2 with DI H_2O on 40 each 9 x 9 lint-free polyester wipes	
Isopropyl alcohol on 20 each 9 x 9 lint-free polyester wipes	
Dry wipes (9 x 9 lint-free polyester)	20 each
Latex gloves	12 pairs
Nitrogen and inline gas filters (796-091775-001)	1 each

Recycling, Refurbishment and Reuse of Equipment

In accordance with SEMI S2-0200 Paragraph 9.65, which references also SEMI S-12, in the event of system reuse, recycling, or refurbishment, use the following guidelines:

- Treat any part of the etch system that comes in contact with hazardous gases the same way as you treat the hazardous gases and by-products generated by your process. Follow the same regional environmental and worker protection laws regarding the contact and disposal of hazardous materials.
- The major structural components for the 2300 system, including the frames, are 1020 cold rolled steel. Most parts of process modules have areas contact with hazardous gases. Consider these parts as hazardous materials, unless determined or decontaminated otherwise. Exercise caution when you contact these parts.

The hazardous materials in a Lam etch system are primarily caused by the following two factors:

- Providing high pressure hazardous gas, typically from 5 to 50 per square inch (psi), to the gas box for the reaction chamber and delivering low pressure hazardous gas to the reaction chamber from the gas box: The predominant material used to contain the gas is 316L stainless steel tubing. The hazardous gases at worst case may corrode the steel after a period of years, depending on the consistency of gas purity supplied to the gas box. No residual personnel hazards should remain after the hazardous gases are removed. Evaluate residual contamination consistent with gas used and facility steel re-use and recycling plan.
- Removing low pressure hazardous gas from the reaction chamber, typically at pressure under 10 torr: Process by-products will adhere to the materials in the vacuum flow from the reaction chamber to the facility backing pump. The typical materials of construction in the vacuum flow path are high purity ceramics (alumina), anodized 6061 aluminium, and 304 stainless steel. Process by-products are discussed elsewhere in this manual in more detail. At worst case, these process by-products may result in an airborne toxicity in the event of system reuse, recycling, or refurbishment. Use suitable personal protective

equipment (PPE) consistent with the process by-products and regional environmental and worker protection laws.

Ergonomics

Use proper lifting and handling techniques when working on the system. Improper ergonomic handling may result in injury. Some tasks outlined in this manual may require excess reach by personnel of shorter height. Lam recommends the use of a suitable foot stool, stepladder, or appropriate means when performing these tasks. You may obtain a step stool (PN 839-802663-001) from Lam to help you better perform these lifting and handling tasks.

Energized Electrical Work Types

The *Environmental, Health, and Safety Guidelines for Semiconductor Manufacturing Equipment* (SEMI S2-0200) defines four types of electrical work. The four types are as follows:

Type 1	Equipment is fully deenergized.
Type 2	Equipment is energized. Energized circuits are covered or insulated. Type 2 work includes tasks where the energized circuits are or can be measured by placing probes through suitable openings in the covers or insulators.
Type 3	Equipment is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are no greater than 30 volts alternating current (VAC) root mean square (RMS), 42.4 VAC peak, 60 volts direct current (VDC), or 240 volt-amperes in dry locations.
Type 4	Equipment is energized. Energized circuits are exposed and inadvertent contact with uninsulated energized parts is possible. Potential exposures are greater than 30 VAC RMS, 42.4 VAC peak, 60 VDC, 240 volt-amperes in dry locations. Potential exposures to radio-frequency currents, whether induced or via contact, exceed the limits in Table A5-1 of Appendix 5, SEMI S2-0200.

The applicable electrical work types are indicated in the Safety section at the beginning of each procedure.

Lockout/Tagout

Use a lockout to prevent energizing the equipment and endangering workers. When using lockouts the following conditions may exist.

- A disconnect switch, circuit breaker, valve, or other energy-isolating mechanism is put into the safe or off position.
- A device is often placed over the energy-isolating mechanism to hold it in the safe position.
- A lock is attached so that you cannot energize the equipment.

In a tagout, place the energy-isolating device into the safe position and attach a written warning to the device.

Lam recommends that you carefully follow the lockout and tagout procedures described in this chapter before servicing the unit. Only qualified and authorized technicians should perform these tasks.

Note Use standard lockout devices for pneumatic and liquid lockout/tagout.

Electrical Isolation

Shutting Down the System for Electrical Isolation

▶ **To shut down the system for electrical isolation,**

1. Before servicing, inform all affected personnel that the unit is to be shut down for servicing, and that all electrical power sources are to be locked out.
2. Shut down the unit using normal shutdown procedures.
3. Lock all the electrical power sources in the disconnect position with a padlock that you can only open with a key.

Note Power to the EMO transformer and associated circuitry remains on after an EMO event. Always lockout/tagout the main circuit breaker in the AC rack when working inside the AC or DC box.

4. Attach written warnings to the locking devices.

5 Verify that all electrical power has been disconnected by attempting to restart unit at the control panel, and by observing that the *power on* light is off.

Starting Up After Servicing

▶ **To start up after servicing,**

1. Ensure that you remove all hand tools and other foreign objects from the unit.
2. Restore all guards and enclosure panels to their normal operating positions.
3. Check the area around the unit to ensure that all personnel are at a safe distance.
4. Verify that all controls are in the off or neutral positions.
5. Remove the locks and tags that were placed on the electrical power sources.
6. Notify all area personnel that unit is to be energized.
7. Energize the unit.

Process Gas Isolation

You generally need to isolate the process gas when performing maintenance on a gas panel or when opening the gas delivery system.

Be sure to remove hazardous gases from gas panel (gas box) prior to servicing.

Shutting Down the Process Gas

▶ **To shut down the process gas,**

1. Close the manual gas supply valve(s) on the inlet side of the gas panel.
2. Apply a locking device over each gas supply valve handle and lock it with a padlock that you can only open with a key.

3 Attach written warnings to the locking devices.

Starting Up After Servicing

▶ **To start up after servicing,**

1 Unlock and remove the locks and tags on each gas supply valve handle.

2 Open the manual gas supply valve(s) on the inlet side of the gas panel.

Chemicals Used During Maintenance

The following chemicals are used in the maintenance of the process module:

- Isopropyl alcohol (IPA)
- Deionized (DI) water
- Hydrogen peroxide solution (for tungsten only)
- Fomblin® grease
- Hydrogen fluoride
- Krytox® grease

Note Not all chemicals listed are used for every process module.

Lam Recommendations

Use the following guidelines when performing routine maintenance on the reaction chamber:

- Wear appropriate protective gear, including arm guards, apron, goggles, and solvent-compatible gloves. This protective gear is essential to protect against human contact with toxic materials and vapors.
- Clear the surrounding area of all personnel not wearing appropriate protective gear.

- Prepare the chamber for pump and purge cycles by running the plasma clean recipes. These plasma clean recipes were developed to help neutralize chlorine-based by-products in the chamber prior to opening.
- Perform a nitrogen purge before beginning work on the process chamber or any chemistry-carrying parts. Perform a minimum 60 pump-and-purge cycles prior to opening a chamber configured for non-toxic gases, and 240 cycles for systems using hydrogen bromide. If you run a plasma clean just before opening the chamber, then 60 cycles is sufficient. Because fab operation procedures vary, industrial hygiene air sampling tests are advised and/or required when qualifying specific procedures to ensure compliance with TLV and PEL specifications. Consult the maintenance procedures for details. The pump-and-purge process is vital to reducing toxic chemical concentrations.
- Perform maintenance activities in a well ventilated area. Air circulation will help prevent excessive build-up of vapors due to the residual chemistry that may remain after the pump-and-purge cycles have been performed.

Potentially Hazardous Operations

Some procedures required for system maintenance involve potentially hazardous operations. Specific hazards are indicated by warning labels on the system and by prominent warnings and cautions in the system maintenance and operation manuals. Safety information, including the electrical state of the system during a given procedure, if applicable, is provided at the beginning of each procedure in the system maintenance manual. Operators and maintenance technicians need to be aware of potential hazards and applicable safety information, and take appropriate precautions.

All systems should be operated and maintained by qualified personnel only. Failure to observe this important restriction could result in death or injury to persons or damage to equipment. Lam offers extensive training courses to ensure that users have the training to perform their functions skillfully and safely. Lam strongly advises that operators and maintenance technicians working on a particular system only perform tasks that are consistent with their levels of training and experience.

Table 2–2 lists potentially hazardous operations and recommended procedures for minimizing dangers.

Table 2–2. Hazardous Operations

Operation	Danger	Recommended procedure(s)	Hazard alert
Chemical			
Opening the reaction chamber.	Residual gases may be present from recent processing of wafers and/or recent maintenance activities (such as gas calibrations). Reaction by-products could react with air to release hazardous gases.	Run chamber clean process, then perform the recommended number pump/purge cycles required. Ensure the plasma clean recipe is run. Turn off the 24 VDC actuators switch located on the main circuit breaker panel of the process module.	Failure to observe this precaution could result in exposure to toxic chemicals which could cause injury.
Inspecting or performing maintenance inside the chamber.	Residual gases may be present from recent processing of wafers and/or recent maintenance activities (such as gas calibrations). Reaction by-products could react with air to release hazardous gases.	Do not insert head into the reaction chamber.	Failure to observe this precaution could result in exposure to toxic chemicals which could cause injury.
Inspecting or performing maintenance inside the chamber.	Anodized surfaces could be scratched.	Take care to avoid scratching any anodized aluminum surfaces.	Failure to observe this precaution can result in premature wear of parts and/or shift in process results. It can also cause arching and burns, depending on the location of the scratches.
Handling of ceramic chamber parts.	All ceramic chamber parts are brittle and could break if dropped or bumped.	Take care when handling any ceramic parts not to drop or bump them.	Failure to observe this precaution could result in breakage of parts and the possible creation of sharp edges.
Cleaning ceramic chamber parts.	If the ceramic chamber parts are exposed to excessive moisture, a potential outgassing problem may exist.	Ensure the ceramic chamber parts have been thoroughly baked out.	Failure to observe this precaution could result in excessively high leakback rates.

Table 2–2. Hazardous Operations (continued)

Operation	Danger	Recommended procedure(s)	Hazard alert
Electrical			
Troubleshooting in AC/DC power distribution box.	Live terminals inside cover. Extreme hazard of electric shock if cover is removed with doors open and power on.	No regular maintenance is required. Troubleshoot only after lockout/tagout has been performed.	Failure to observe this precaution could result in serious injury or death.
Troubleshooting roughing pumps after performing an emergency off (EMO).	Electrical shock from hazardous voltage.	Lockout and tagout of power to the roughing pumps before servicing.	Failure to observe this precaution could result in serious injury or death.
Troubleshooting ESC power supply with the cover off and the interlock bypassed.	Electrical shock from hazardous voltage.	Performed by only qualified technicians informed of this precaution to work on ESC power supply with the cover removed.	Failure to observe this precaution could result in serious injury.
Calibration of components in RF system.	Exposure to non-ionizing radiation. Risk of electric shock and/or burn.	Turn off all generators from both the control screen and the circuit breakers prior to disconnecting any RF cables. Always securely connect RF cables prior to turning on power to the module and/or generators.	Failure to observe this precaution could result in serious injury or death.
Thermal			
Cleaning a hot reaction chamber.	Burns to personnel, potential fire if wrong cleaning chemicals are used.	Turn down chamber wall temperature prior to starting pump/purge. Use cleaning chemicals recommended by Lam only.	Failure to observe this precaution could result in burns caused by contact with hot chamber elements. Potential flash fire if acetone or other similar high pressure solvent is used.
Removing hot ESC cap with TCU running or lines not drained.	Burns to personnel, contamination to reaction chamber caused by TCU fluid.	Turn down electrode temperature. Turn off TCU and drain lines.	Failure to observe this precaution could result in burns caused by high pressure, high temperature TCU fluid spray. Chamber contamination caused by TCU fluid spraying around the chamber.

Table 2–2. Hazardous Operations (continued)

Operation	Danger	Recommended procedure(s)	Hazard alert
Removing gate valve when it is still hot.	Burns to personnel.	Turn down the reactor temperature. Allow to cool prior to removal.	Failure to observe this precaution could result in burns to hands and fingers unless unit is allowed to cool prior to removal.
Service/cleaning the gate valve while hot.	Burns to personnel.	Follow the pressure control procedures in this manual. Turn down temperature to ambient and allow to cool.	Failure to observe this precaution could result in burns to hands and fingers unless unit is allowed to cool prior to removal.
Servicing reactor cartridge heaters.	Burns to personnel.	Turn down all reactor temperature channels to ambient and allow to cool. Prior to removal, unplug heater(s) from power source.	Failure to comply could result in severe burns and a potential fire if the hot heater contacts a flammable surface.
Exposing the TCP coil.	The TCP coil and TCP window may be at a very high temperature.	Wait one half hour after operation of the upper RF.	Failure to observe this precaution could result in exposure to very hot parts.
Water Spill			
Replacing RF generators or turbo pump.	Water spill.	Turn off main power to the module and turn off water source to the process module. Disconnect the lowest line in the system and drain water into a catch pot. When disconnecting other lines, have wipes handy to soak up spills.	Failure to turn off water or drain lines could result in a water spill.
Mechanical			
Manually opening the gate valve.	The turbo pump could be running and the chamber at atmosphere. The gate valve should never open if the 3 torr switch is not mated.	Ensure that both the pump and chamber are at vacuum or that they are both at atmosphere.	Failure to observe this precaution could result in catastrophic failure of the turbo pump and damage to the pumping system.

Table 2–2. Hazardous Operations (continued)

Operation	Danger	Recommended procedure(s)	Hazard alert
Manually opening the gate valve.	The valve may close. A potential pinch point may exist during certain maintenance situations.	Do not insert hands in the valve while it is closing.	Failure to observe this precaution could result in a pinched hand by the valve while it closes.
Many maintenance operations require reaches which may be excessive for smaller operators.	The operator may sustain injury (such as a strained muscle), or lose their balance and fall.	Provide suitable step stools and ladders for the task at hand. Do not use the process module as a ladder or step stool.	Failure to observe this precaution could result in injury.

Manual Mode

Only factory-trained personnel should operate the system when it is in manual mode, because many of the software interlocks are bypassed when the system is placed in the manual mode. Operating personnel should use the system only when the system is in automatic mode.

Interlocks

The 2300 system is interlocked to protect against single fault hazards. These interlocks protect against human error or equipment failures that could allow exposure of personnel, facilities or community to hazards or directly result in injury, death or equipment loss. They are implemented in circuitry that is independent of the system controls. All of these interlocks will report alarms to the user interface if they are activated. They are also copied in the system control software.

Human Safety Interlocks

Human safety interlocks used to protect against injury of personnel rely only on electro-mechanical devices that are dual compliant. Microprocessors and integrated circuits are not used.

Equipment Interlocks

You can implement equipment interlocks to protect the wafers or subsystems from damage by using integrated circuits that comply with UL991. Only static logic circuits are acceptable. Microprocessor based circuitry or clocked circuits are not used.

Transport Module Interlocks

Slot Valve Close Signal to PM Interlocks

A maximum of four PMs can be connected to the TM, each with an independent interlock signal. TM interlock circuitry provides the slot valve close signal to each associated PM to interlock the chamber gas delivery valves.

Slot Valve Open Delta Pressure Interlock

To prevent opening a slot valve across a differential pressure, the “at atmosphere” and “at vacuum” pressure switches on both sides of the valve must match state with each pair at the opposite state (see Table 2–3).

Table 2–3. Slot Valve Open Delta Pressure Interlock

TM at ATM	PM at ATM	TM at VAC	PM at VAC	Valve State
0	0	0	0	No action
0	0	0	1	No action
0	0	1	0	No action
0	0	1	1	OPN
0	1	0	0	No action
0	1	0	1	No action
0	1	1	0	No action
0	1	1	1	No action
1	0	0	0	No action
1	0	0	1	No action
1	0	1	0	No action
1	0	1	1	No action
1	1	0	0	OPN
1	1	0	1	No action
1	1	1	0	No action
1	1	1	1	No action

Batch Transfer Arm Extension Interlock

Extension of the batch transfer arm is disabled unless all the following conditions are met:

- The loadlock outer door safety sensor is not blocked.
- The loadlock outer door is open.

You can only bypass this interlock by a command from a password-protected maintenance screen on the operator interface. Once the screen is exited, the interlock is automatically reactivated.

Loadlock Lasers

The lasers located in the loadlock are interlocked with the loadlock door so that the laser cannot be activated unless the loadlock door is closed and clamped shut. You can only bypass this interlock by using a command from a password-protected maintenance screen on the operator interface. Once the screen is exited, the interlock is automatically reactivated.

Loadlock Door Interlocks

The automated door motion is interlocked for both human safety and equipment safety.

Human Safety Interlock: The automated door-up motion is interlocked with a human safety interlock using safety certified sensor and relay. The sensor is located such that the operator is protected from all pinch points. The output of the sensor is sent to the load lock node, where it activates a normally open relay. In case the safety beam is interrupted, the relay will go to the default open position, disabling the door motion. This circuit is independent from equipment safety interlock.

Equipment Safety Interlock: The automated door up, down, in (clamp) and out (unclamp) motions are interlocked using programable logic device (PLD) and optoisolators. PLD has an internal latch, which overrides UI door movement commands and opens the door if during door up movement, the door safety beam is interrupted. To clear an internal latch, you must remove the door up command, and should not interrupt the door safety beam, the door up sensor shall be false and the door down sensor shall be true. The functionality of the equipment safety door interlocks is summarized in Table 2–4.

Table 2–4. Loadlock Door Interlock Conditions

Action	Door In	Door Out	Door Up	Door Down	Door Interrupt	Door Latch	ATM	Vac
Door Out							T	F
Door In			T	F				
Door Up	F	T			T	F		
Door Down	F	T						
Door Safety Latch Set			F	F	F			
Door Safety Latch Clear			F	T	T			

T=True condition, switch is actuated.

F = False condition, switch is not activated.

Gas Safety


GENERAL ALERT

Warning
Chemical Hazard: Consult the material safety data sheets or equivalent material safety information for chemical hazards. Hazardous gases may be used on the 2300 system.

The plasma clean recipes shown in the preparation steps outlined in the applicable PM operation and maintenance manual help neutralize chlorine-based by-products in the chamber prior to opening.

If the plasma clean recipes are run on the system, perform the pump-and -purge procedures a minimum 60 cycles prior to opening a chamber configured for non-toxic gases and 60 cycles for systems configured for corrosive gases, depending on process recipes and wafers between cleans. Because fab operation procedures and chemistry vary, industrial hygiene air sampling tests are advised and/or required when qualifying specific procedures to ensure compliance with threshold limit value (TLV) and permissible exposure limit (PEL) specifications. Lam also recommends that you run 240 pump-and-purge cycles for systems using hydrogen bromide, and 60 pump-and-purge cycles for non-toxic gases.

Gas Leak Detection Strategy

Containment of hazardous gases and detection of leaks are provided by a combination of on-board features and facilities infrastructure. The first priority is leak prevention, which is provided by physical containment, including back-up or double containment. The next priority is assuring proper evacuation of gases should containment systems fail or internal subatmospheric pressures fail to be maintained.

On-board safety systems continuously monitor chamber vacuum. Should this fall out of specification, a red alarm is signaled, the system returns to a safe, standby state, and the operator is notified through the user interface.

Additional gas containment features include:

- A differential-pressure switch interlock in the gas box that shuts off all gas being supplied to the system if the gas box exhaust is lost.
- Vacuum interlocks on the reaction chamber that cut off the flow of process gases and any RF power being supplied whenever vacuum integrity is lost.
- Gas panel provided with scrubbed exhaust connection.
- Upper chamber/upper match housing provided with scrubbed exhaust connection.

Lam recommends that you provide an additional level of protection by augmenting the containment features described above with leak detectors located in the breathing zone in work areas adjacent to the main reaction chambers and in the scrubbed exhaust from the on-board gas panel.

In the event that detection of hazardous production materials is required by regulations in place at the customer's site, Lam recommends that the sample point be located one foot downstream of the exhaust port.

Lam also recommends the following:

- The exhaust duct material is compatible with the exhaust gases and not subject to degradation with exposure to hazardous and/or corrosive materials.
- Each vacuum pump exhaust has overpressure protection in compliance with SEMI S2-0200 safety guidelines.
- Measure the exhaust performance close to the system end of the exhaust line (approximately 10 duct diameters optimum) using an anemometer to estimate volume flow based on linear flow measurements.
- Provide an audible and visual alarm on the chase side of the equipment to alert personnel of inadequate exhaust flow.

Gas Panel Safety

The gas panel of the 2300 etch system is designed for fail-safe operation under all reasonably foreseeable failure conditions. During failures, the gas panel prohibits gas flow and contains gases in a scrubbed enclosure to prevent the contamination of the environment and exposure to operating personnel.

Greenhouse Gases

At this printing, Lam is involved in a perfluorocarbon (PFC) leadership group with some of the leading semiconductor companies in an ongoing effort to meet future environmental regulations for wafer fabrication. This includes efforts to reduce and/or eliminate the use of global warming gases (PFCs) and ozone-depleting chemicals (CFCs). The technology today requires the end user to use some PFCs and CFCs for processing semiconductor devices, but whenever possible less hazardous process chemicals are replacing the more hazardous substances used in wafer fabrication.

The primary concern for the 2300 system is the use of sulfur hexafluoride (SF_6) used in the baseline process for tungsten etch. Trifluoromethane (CHF_3) is another PFC sometimes used in both aluminum and tungsten etch. If a fluorine-containing process gas is used in an etch reactor there is the possibility of the production of PFCs by the plasma process, since they are thermodynamically stable. Future restrictions of PFCs are possible and may require that the process be optimized or the effluent be treated to reduce the emission of PFCs.

Seismic Protection

The transport module complies to SEMI S2-0200, section 19, Seismic Protection when secured at the eight TM locations (as shown on 253-810068-001) and installed on the ground level of a building secured with ductile anchors with a length to diameter ratio greater than 8, in any seismic condition or region. When the TM is populated with the process modules, secure each PM at the seismic locations specified on the PM's facility drawing.

When the TM is installed on building levels other than at ground level, seismic analysis of the installation site is required to determine if the TM standard configuration will meet S2-0200. In cases where seismic loading is more severe, additional seismic bracing may be required. Contact Lam for availability of severe seismic bracing kits.

Servicing the MFCs

When performing the pump and purge cycles on the MFCs prior to servicing, it is important to make sure there is no trapped gas between the MFC primary and secondary valves. Use this procedure to ensure that the gas is removed and that you purge the gas and perform a proper pump-and-purge cycle to remove the nitrogen. The key to this procedure is to observe the pump/purge action on the operator or maintenance interface screen.

▸ **To service the MFCs,**

1. Turn off the hand valves on the gas inlet line and lock them out.
2. Flow the gas on the **Maintain\Chamber** window by giving the maximum set point value for each gas.

3. Check the monitored flow value for each gas and make sure the gas flows goes zero.
4. Make sure the chamber manometer goes to base pressure.
5. Change the set points of the MFCs to zero on the **Maintain\Chamber** window.
6. Activate the gas panel pump-and-purge cycle from the **Maintain\GasVac** window**.**
7. Check the MFC flow on the **Maintain\Chamber** window. The MFC should cycle from maximum flow to zero with every pump-and-purge cycle.
8. See the maintenance service manual to determine needed pump/ purges for the gas or gases that require servicing.
9. When the MFC service is complete, leak check the fittings that were opened.
10. Perform a pump-and-purge cycle on the MFC with nitrogen, using the number recommended in the maintenance manual.
11. Perform a purge cycle of the MFCs of the nitrogen gas by setting the MFC setpoints to the maximum flow.
12. When the MFC monitored flow goes to zero, set the MFC setpoints to zero.
13. Unlock and open the hand valves on the gas inlet line and charge the gas lines.

Lifting Safety

Many of the components of the 2300 system are heavy. When performing maintenance operations, use proper lifting techniques, lifting aids and multiple personnel. Most heavy objects are identified with labels.

RF Shields

The 2300 process modules are designed with several RF shields. Install the RF shields properly onto the system prior to engaging RF power. Do not activate the generator(s) if the covers on the upper or lower match are removed. The cover ensures safety, shielding operating personnel from the effects of RF Power. All operating personnel must use caution when working in the vicinity of RF power.

3
Hazard Labels

Lam Research systems include safety hazard labels to alert end-user personnel to the hazards present. Service and maintenance personnel should read this manual, along with the maintenance and operation manuals for detailed information on how to avoid or minimize these hazards.

Hazard Classifications

DANGER indicates an imminently hazardous situation which, if not avoided, will result in death or serious injury. This is limited to the most extreme situations.

WARNING indicates a potentially hazardous situation which, if not avoided, could result in death or serious injury.

CAUTION indicates a potentially hazardous situation which, if not avoided, could result in moderate or minor injury. It may also be used to alert against unsafe practices or equipment damage.

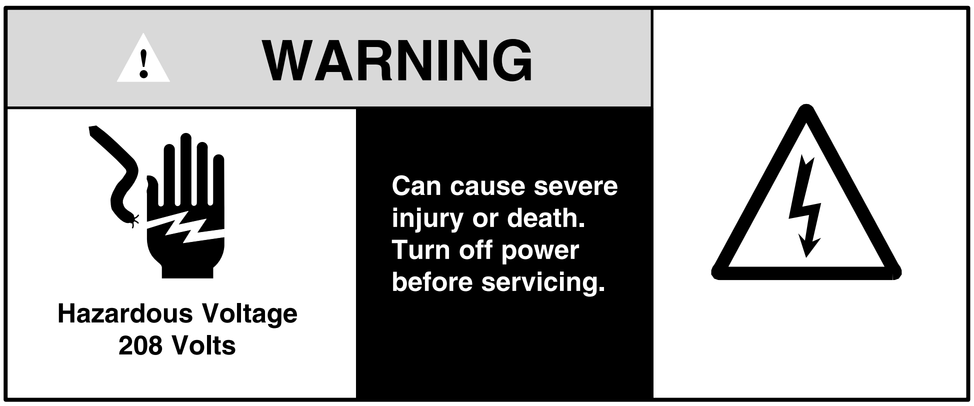
These designations help users identify the level of hazard present. This system is also used in the maintenance manuals.

NOTICE indicates a statement of company policy (for example, safety policy or protection of property) or identifying areas where additional safety-related information is provided.

Specific Hazard Labels

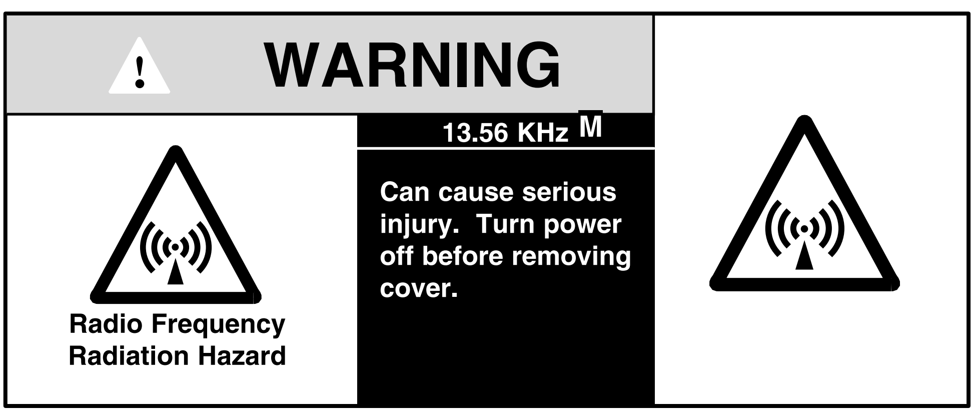
Hazardous Voltage

Warning labels fixed to external barriers that protect against contact with hazardous voltages inform personnel of the voltage hazard.



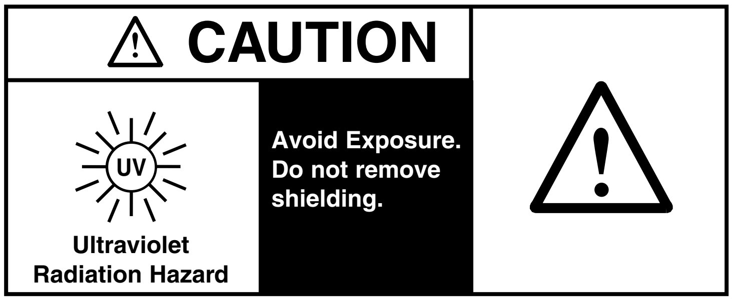
Hazardous RF Energy

Warning labels fixed to external barriers that protect against contact with hazardous RF energy inform personnel of the RF hazard.



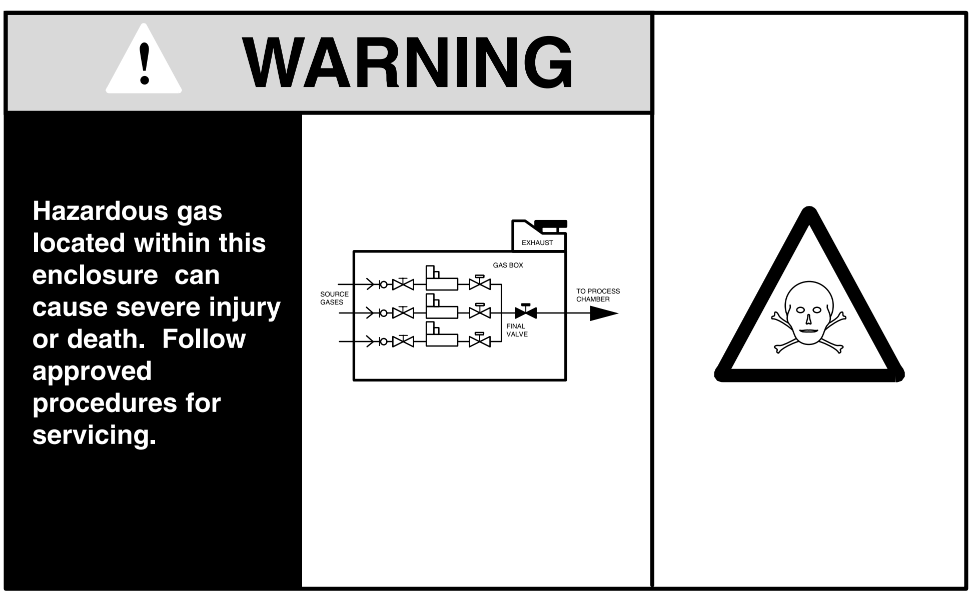
Hazardous UV Energy

Warning labels fixed to external barriers that protect against exposure to UV radiation.



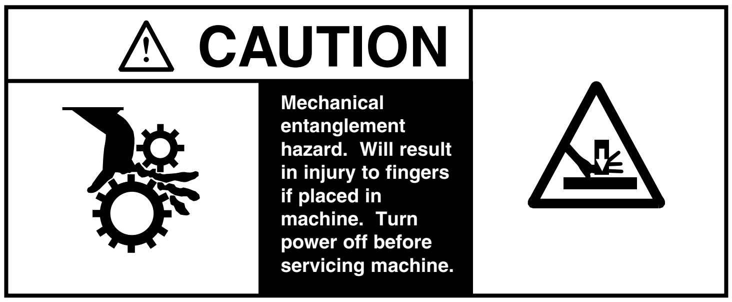
Hazardous Chemistry

Warning labels fixed to external barriers that protect against contact with hazardous chemicals inform personnel of the hazard.



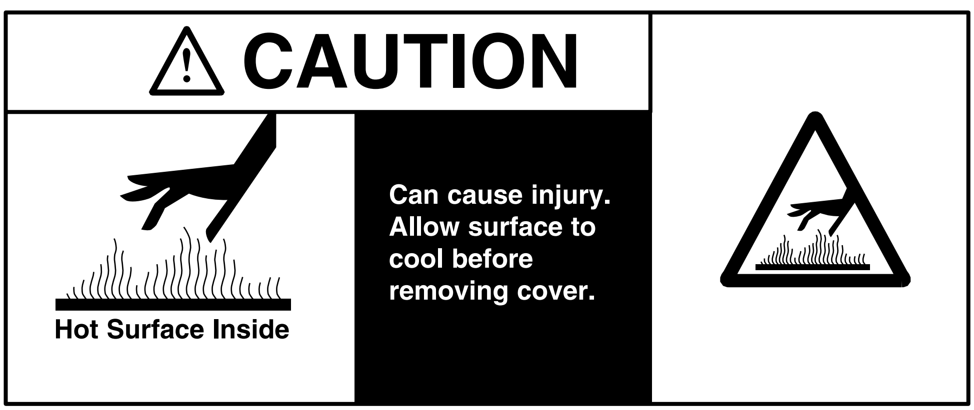
Hazardous Pinch Points

Warning labels fixed to the system where hazardous pinch points exist inform personnel of the need to keep hands and fingers away from potentially hazardous moving parts.



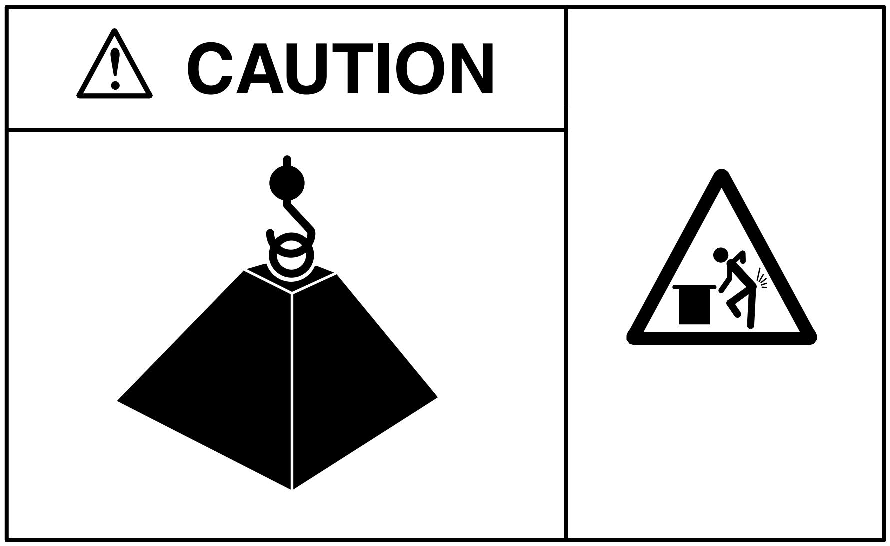
Hot Surface Hazard

Warning labels fixed to hot surfaces inform personnel of the need to keep hands and fingers away.



Heavy Lift Hazard

Warning labels fixed to the system where potentially hazardous heavy lifts are present inform personnel to use caution when lifting the object in question.



Fuse Replacement Warning

Warning labels fixed adjacent to fuse blocks inform personnel of potential fire hazard if a fuse is replaced with another fuse of the wrong rating or type.

Showing the Locations of the Safety Labels on the PM

Figure 3–1 through Figure 3–5 show the location of the safety labels on the Versys Silicon process module (PM). Table 3–1 describes the part numbers for the safety labels.

Figure 3–1. Label Locations on the Front of the PM

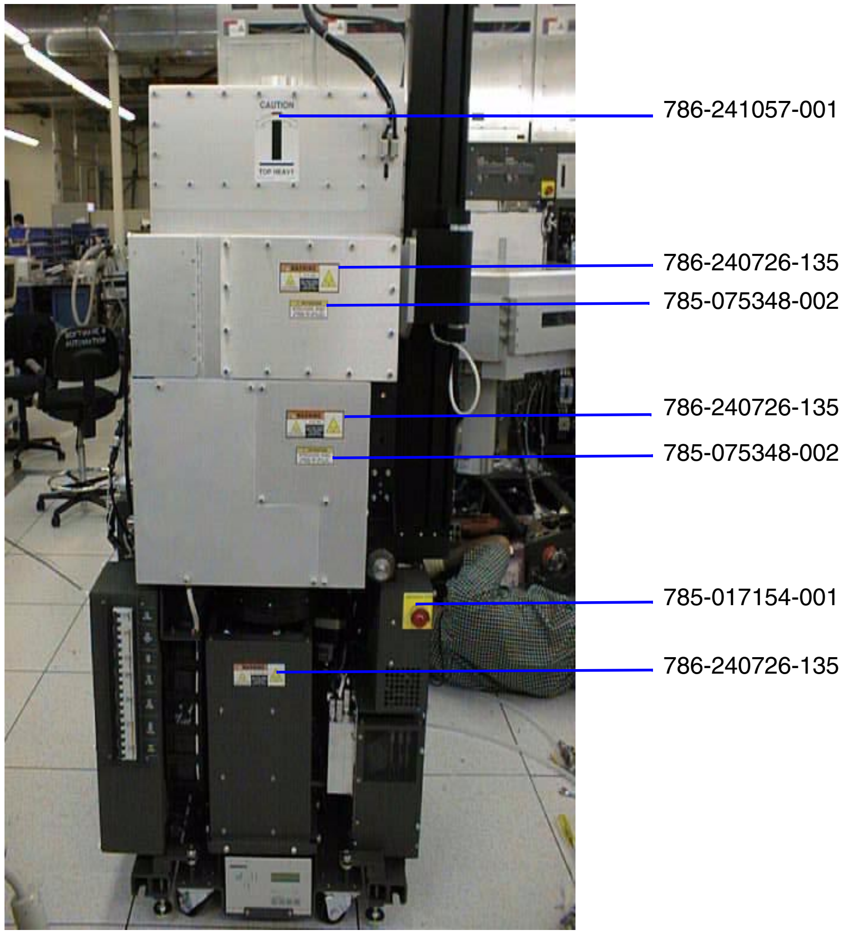


Figure 3–2. Label Locations on the Right of the PM

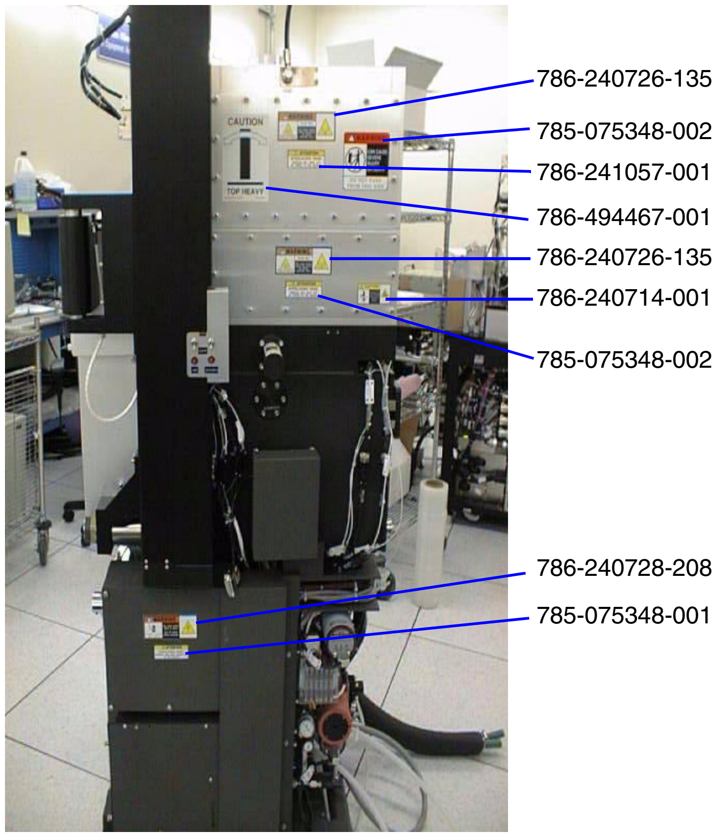


Figure 3–3. Label Locations on the Top Left of the PM

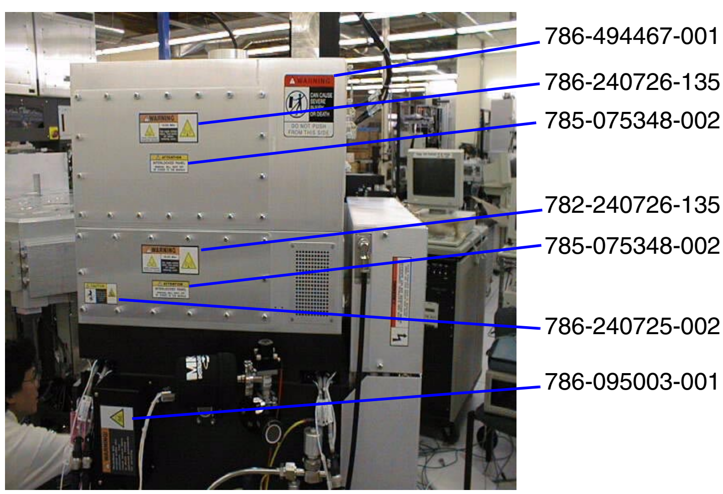


Figure 3–4. Label Locations on the Lower Left of the PM

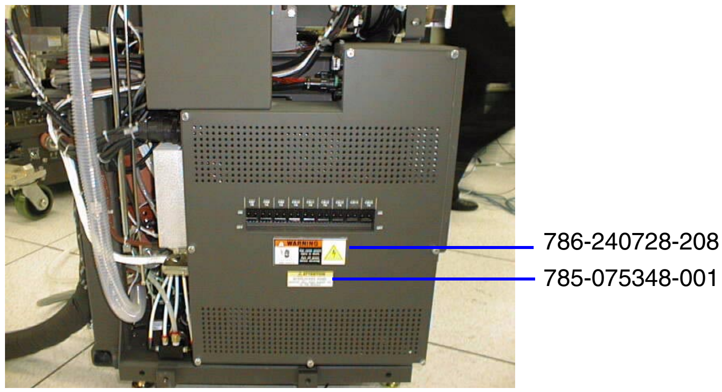


Figure 3–5. Label Locations on the Top of the PM

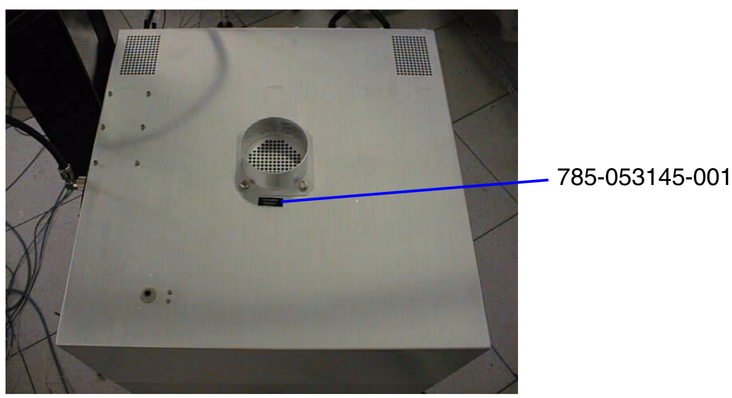


Table 3–1. Safety Label Descriptions

Part number	Title	Quantity
786-240728-208	Label, ANSI-CIS, Hi Volt, 208 VAC	2
786-494467-001	Label, Don't Push	2
786-241057-001	Label, Top Heavy	2
786-095003-001	Label, Warning, Toxic, Gas	1
785-017154-001	Label, Emergency Stop	1
786-240714-001	Label, ANSI-CIS UV	1
786-240726-135	Label, ANSI-CIS, RF	7
785-075348-002	Label, Attn, Intlk, Pnl, RF Pwr	6

Table 3–1. Safety Label Descriptions (continued)

Part number	Title	Quantity
785-075350-001	Label, Warning, Wtr & Elec Cmpnt	1
785-053145-001	Label, Scrubber Exhaust	1
786-240725-002	Label, ANSI-CIS, Pinch	2
785-075348-001	Label, Warning, Interlocked Pnl	2

4 Laser Safety Information

The lasers used in the loadlock and wafer aligner are FDA certified for Class 1 for the operator. The lasers themselves, however, are Class 2. The interlock methodology allows them to be certified as a Class 1 product.

Although the lasers are classified as human safety by the FDA, the FDA does not mandate relay logic for the interlock. This is because Class 2 lasers or laser systems emit a visible laser beam and because of its brightness, Class 2 laser light is too dazzling to stare into for extended periods. Momentary viewing is not considered hazardous since the upper radiant power limit on this type of device is less than the maximum permissible exposure (MPE) for momentary exposure of 0.25 seconds or less. Intentional extended viewing, however, is considered hazardous.

5
Chemical Safety

This chapter discusses current and potential future environmental restrictions on the use of PFCs (perfluorinated compounds) with the 2300 system. It is important to distinguish PFCs from chlorofluorocarbons (CFCs). Since the production of CFCs has been restricted by the 1990 Montreal Protocol International Agreement, CFCs are not used in the 2300 system.

The need for PFC control and its technology are under study and evaluation by the semiconductor industry since their use is not regulated. The primary concern for the 2300 system is the use of sulfur hexafluoride (SF_6) and trifluoromethane (CHF_3). If a fluorine-containing process gas is used in an etch reactor, there is the possibility of the production of PFCs by the plasma process since these chemicals are thermodynamically stable. Future restrictions of PFCs are possible, and may require that the process be optimized, or the effluent be treated to reduce the emission of PFCs.

Precautions

Maintenance

When performing maintenance on the reaction chamber or the chemical delivery system,

- Wear protective, cleanroom-approved clothing and gloves, safety glasses, and a full breathing apparatus whenever appropriate.
- Clear the surrounding area of all personnel not wearing appropriate protective gear.
- Perform a nitrogen purge before beginning work on the reaction chamber or any chemistry-carrying parts, unless specified otherwise. The main reaction chamber requires 120 pump-and-purge cycles of 30-second duration if no hydrogen bromide (HBr) is used in the process and 240 cycles of 30-second duration if HBr is present. The

type and duration of nitrogen purge needed with other parts of the gas delivery system will vary. Consult the maintenance procedures for details. The pump-and-purge process is vital to reducing toxic chemical concentrations.

- Perform maintenance activities in a well-ventilated area. Air circulation helps to prevent excessive buildup of vapors due to the residual chemistry that may remain after the pump-and-purge process has been performed.

Unwanted Chemical Releases

Lam etchers are equipped with active features that enhance operator and service technician safety, and help to protect the environment and property against human error and component failure. The following features are used as protection against any unwanted chemical releases:

- 2300 process modules have secondary containment on inlet gases.
- Gases are supplied at sub-atmospheric conditions, and the vacuum switch activates if the line pressure rises above 75 torr. A vacuum pressure interlock is triggered when vacuum is not present in the reaction chamber and cuts off flow of process gases and the RF supplied to the chamber.
- If the main reaction chamber is open, the tilt switch interlock inhibits process gas from being supplied to the chamber. This interlock effectively backs up the vacuum interlock in most process modules.
- A differential pressure switch interlock shuts off all gases being supplied to the system if the gas box exhaust flow is lost.
- A vacuum switch shuts off the supply of process gas to the reaction chamber if the integrity of the line supply gases from the gas box to the reaction chamber is broken.

Lam also recommends that the facility scrubber system remain operational in the event of a power failure.

Each process module has an independent exhaust port. Lam recommends that you have a dedicated vacuum pump for each process module. This will prevent cross-contamination of waste products from the process modules.

It is the responsibility of the customer to ensure that potentially hazardous mixtures of waste exhaust gases cannot occur in the exhaust handling system.

Lam recommends that you mount an area hazardous gas monitoring device in the vicinity of the system. The gas box interlock circuit has provisions for a dry contact interlock switch input from such a device allowing it to shut off all gas flow into the gas boxes.

It is the responsibility of the customer to provide exhaust systems which are compatible with exhaust chemistries noted in this manual.

Obtaining Environmental Effluent Information

For information on environment effluents from the baseline process, see your designated Lam contact person.

Obtaining Environmental Permit Information

For information on environmental permits for your system, see your designated Lam contact person.

Chemicals Used

Table 5–1 lists process chemicals commonly used in various Lam products.

Table 5–2 describes physical properties and health effects for humans if they are exposed for the various chemical used for process and maintenance in Lam products. Material safety data sheets are available from the suppliers of these chemicals and should be kept on hand.

GENERAL ALERT

Caution

Chemical Hazard: Obtain, refer to and keep on hand the material safety data sheets (MSDS) for alternate chemistries if they are used to support user processes,

Table 5–1. Chemical Uses

Process Modules	He	O_2	Ar	CF_4	CHF_3	C_2F_6	C_4F_8	CO	NF_3	N_2	HBr	HCl	Cl_2	BCl_3	SF_6	H_2O	C_3F_6	CH_2F_2
HDD etch	X	X	X	X	X	X	X	X		X					X			
Poly etch	X	X	X	X		X			X	X	X	X	X	X	X			
Metal etch	X	X	X							X			X	X	X			
Photoresist strip		X								X						X		
Dielectric etch	X	X	X	X	X		X	X		X							X	X

Table 5–2. Chemical-Specific Hazard Summary

Chemical	CAS No.	Description	Health effects	ACGIH TLV[a] (ppm)	OSHA PEL[b] (ppm)
Acetone	67-64-1	Colorless, highly volatile, flammable liquid. Sweet/fruity odor	Irritant of the eyes and mucous membranes and at high concentrations a central nervous system depressant. Acetone is considered to be of low risk to health because few adverse effects have been reported despite widespread use for many years.[c] In animal studies, acetone has been found to increase the toxicity of other solvents. Contact can cause skin and eye irritation.	TWA: 750[d] STEL: 1000[e] C: N/A[f]	TWA: 1000 STEL: N/A C: N/A

Table 5–2. Chemical-Specific Hazard Summary (continued)

Chemical	CAS No.	Description	Health effects	ACGIH TLV[a] (ppm)	OSHA PEL[b] (ppm)
Argon (Ar)	7440-37-1	Colorless, odorless, inert compressed gas	Inhalation of extremely high concentrations can cause headache and dizziness. Acts as a simple asphyxiant by displacing oxygen in air.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A
Boron Trichloride (BCl_3)	10294-34-5	Colorless, fuming liquid. Reacts with water and moist air to form hydrochloric and boric acids	Strong irritant of the eyes, mucous membranes, and skin as a result of its hydrolysis to hydrogen chloride.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A
Chlorine (Cl_2)	7782-50-5	Greenish-yellow gas with irritating, suffocating/sharp pungent (bleach) odor	Strong irritant of the eyes, mucous membranes, skin, and pulmonary tract. Mild mucous membranes irritation may occur at 0.2 to 16 ppm. Eye irritation occurs at 7 to 8 ppm, throat irritation at 15 ppm, and cough at 30 ppm. Other studies have shown that at least some subjects develop eye irritation, headache, and cough at concentrations as low as 1 to 2 ppm. In high concentrations, chlorine gas may irritate the skin, causing burning sensation, inflammation, blisters, or burns.[c]	TWA: 0.5 STEL: 1 C: N/A	TWA: N/A STEL: N/A C: 1

Table 5–2. Chemical-Specific Hazard Summary (continued)

Chemical	CAS No.	Description	Health effects	ACGIH TLV[a] (ppm)	OSHA PEL[b] (ppm)
Difluoromethane (CH_2F_2)	75-10-5	Faint, ehter-like order. Flammable liquid and gas under pressure. Can form explosive mixtures with air.	May cause frostbite. May cause dizziness and drowsiness. Self-contained breathing apparatus may be required by rescue workers.	None currently established	None currently established
Fluorides (as F)	7782-41-4	Odorless white to dark crystal or other solid, varies by fluoride compound	Fluoride causes irritation of the eyes and respiratory tract. Absorption of excess amounts of fluoride over a long period of time results in increased radiographic density of bone.	TWA: 2.5 (mg/m^3) STEL: N/A C: N/A	TWA: 2.5 (mg/m^3) STEL: N/A C: N/A
Helium (He)	7440-59-7	Colorless, odorless, tasteless gas	Acts as a simple asphyxiant by displacing oxygen in air. Inhalation of extremely high concentrations can cause headache and dizziness.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A
Hexafluoroethane	76-16-4	Colorless, slight ethereal, tasteless gas	Inhalation of high concentrations can cause dizziness, disorientation, incoordination, or narcosis. May cause asphyxiation due to oxygen displacement.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A
Hexafluoropropylene (C_3F_6)	116-15-4	Colorless gas	Causes frostbite when it contacts the skin and eyes. Also causes central nervous system depression and simple asphyxiation, including headache, dizziness, drowsiness, incoordination, slowed reaction time, slurred speech, giddiness, unconsciousness, rapid heart beat, a feeling of suffocation and blue color.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A

Table 5–2. Chemical-Specific Hazard Summary (continued)

Chemical	CAS No.	Description	Health effects	ACGIH TLV[a] (ppm)	OSHA PEL[b] (ppm)
Hydrogen Bromide (HBr)	10035-10-6	Colorless, corrosive, nonflammable gas with sharp, acrid odor	Irritant of the eyes, mucous membranes, and skin. There are no systemic effects reported from industrial exposure.[c]	TWA: N/A STEL: N/A C: 3	TWA: 3 STEL: N/A C: N/A
Hydrogen Chloride (HCl)	7647-01-0	Colorless fuming gas with sharp, irritating odor. Extremely corrosive	Strong irritant of the eyes, mucous membranes, and skin. The major effects of acute exposure are limited to the upper respiratory tract and are sufficiently severe to encourage a prompt withdrawal from a contaminated environment. Exposure of the gas to the skin can cause burns.	TWA: N/A STEL: N/A C: 5	TWA: N/A STEL: N/A C: 5
Hydrogen Fluoride (HF)	7664-39-3	Clear colorless vapor above boiling point (19.5° C), fuming liquid at lower temperatures. Corrosive, with sharp, irritating odor	Severe respiratory irritant. In solution it causes severe and painful burns of the skin and eyes. Fluorosis may be caused at levels significantly higher than the OSHA PEL.[g]	TWA: N/A STEL: N/A C: 3	TWA: 3 STEL: N/A C: N/A
Isopropyl Alcohol	67-63-0	Clear, colorless, flammable liquid/vapor	Irritant of the eyes and mucous membranes. Isopropyl alcohol is of low toxicity by any route, and the TLV is set to prevent eye, nose, and throat irritation.[g]	TWA: 983 STEL: 1230 C: N/A	TWA: 980 C: N/A
Nitrogen (N_2)	7727-37-0	Colorless, odorless, tasteless gas	Inhalation of extremely high concentrations can cause headache and dizziness. Acts as a simple asphyxiant by displacing oxygen in air.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A

Table 5–2. Chemical-Specific Hazard Summary (continued)

Chemical	CAS No.	Description	Health effects	ACGIH TLV[a] (ppm)	OSHA PEL[b] (ppm)
Nitrogen Trifluoride (NF_3)	7783-54-2	Odorless at potentially dangerous levels.	Causes anoxia in animals due to the formation of methemoglobin and a potential fluorosis hazard may be associated with prolonged inhalation at the TLV. There are no reports of human intoxication. Nitrogen trifluoride provides odor warning properties at potentially dangerous levels.	TWA: 10 STEL: N/A C: N/A	TWA: 10 STEL: N/A C: N/A
Oxygen (O_2)	7782-44-7	Colorless, odorless, tasteless gas	Low oxygen levels (less than 16%) can lead to asphyxiation. Industrial exposures to high oxygen pressures are rare.[h] All cells can be damaged by high oxygen levels, particularly the respiratory and central nervous systems.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A
Sulfur Hexafluoride (SF_6)	2551-62-4	Colorless, odorless gas	Acts as a simple asphyxiant by displacement of oxygen. At extremely high levels it may mildly affect the nervous system.[c]	TWA: 1000 STEL: N/A C: N/A	TWA: 1000 STEL: N/A C: N/A
Tetrafluoro-methane (CF_4)	75-73-0	Colorless, odorless, tasteless gas	Inhalation of high concentrations can cause dizziness, disorientation, incoordination, narcosis, or vomiting. May cause asphyxiation due to oxygen displacement.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A

Table 5–2. Chemical-Specific Hazard Summary (continued)

Chemical	CAS No.	Description	Health effects	ACGIH TLV[a] (ppm)	OSHA PEL[b] (ppm)
Trifluoro-methane (CHF_3)	75-46-7	Colorless, odorless, tasteless gas	Inhalation of high concentrations can cause dizziness, disorientation, incoordination, narcosis, or vomiting. May cause asphyxiation due to oxygen displacement.	TWA: N/A STEL: N/A C: N/A	TWA: N/A STEL: N/A C: N/A
Octafluoro-cyclobutane (C_4F_8)	115-25-3	Colorless, odorless gas	Acts as simple asphyxiant displacing air necessary for life. Causes rapid respiration, muscular incoordination, fatigue, dizziness, nausea, vomiting, unconsciousness and death.	TWA:S/A STEL: S/A C: N/A S/A= simple asphyxiant	TWA: S/A STEL: S/A C: N/A
Carbon Monoxide (CO)	630-08-0	Colorless, odorless gas	Causes headache, palpitations, dizziness, weakness, confusion and nausea. Continued exposure causes loss of consciousness and death.	TWA: 50 STEL: 400 C: N/A	TWA: 35 STEL: 400 C: N/A

a. ACGIH-TLVs are from 1994-95 ACHIH TLV Booklet

b. OSHA-PELs are Federal OSHA 29CFR 1910.1000, July 1, 1994

c. N.H. Proctor, J.P. Hughes: *Chemical Hazards of the Workplace*, 3rd edition, Lippincott, 1991.

d. TWA = 8-hour time-weighted average

e. STEL = 15-minute short-term exposure limit

f. C = Ceiling concentration

g. *Documentation of the Threshold Limit Values and Biological Exposure Indices*, 6th edition, Cincinnati, Ohio, ACGIH, 1991

h. G.D. Clayton, F.E. Clayton: *Patty's Industrial Hygiene and Toxicology*, 4th edition, Wiley and Sons, 1994

6
Water Containment

Lam equipment uses water for cooling and in some applications for processing. No means of water leak detection or leak containment are provided as standard equipment. It is your responsibility to detect any leakage in the water supply and shut off the water being supplied to the system.

7
Ultraviolet Radiation

The 2300 process modules produce a gas plasma in the reaction chamber which emits ultraviolet (UV) light. Prolonged exposure can cause skin burns or eye damage. All the view and instrument ports on the chamber are equipped with either plastic filters or metal enclosures which will block the UV light. Lam recommends the following:

- You should not operate the process module without the protective filters and enclosures installed.
- If, for maintenance purposes, you must operate the chamber with the protective filters or enclosures removed, wear protective eye wear and avoid prolonged exposure.

8
Versys Silicon Process Module

This chapter provides safety information specific to the Versys™ Silicon Process Module.

For system safety information or for safety information on any other process module for the system, see the remainder of this manual.

2300 process modules are operated from the transport module operator interface. For general system operating instructions, see the *2300 Transport Module Operation* manuals.

For transport module maintenance information, see the *2300 Transport Module Maintenance* manual.

Interlocks

Process Module Interlocks

The hazardous functions of the process module are interlocked as shown in Table 8–1.

Table 8–1. Process Module Interlocks

Table functions	Top RF power on	Lower RF power on	ESC power on	Chamber gas delivery valve on	Pendulum valve open	TMP not inhibited	Turbo exhaust valve on
Chamber pressure sw true	H	H	H	H	F		
Foreline pressure sw true		H			F	F	F
Chamber vacuum sw true	H		H	H			
Gas ring sw closed				H			

Table 8–1. Process Module Interlocks (continued)

Table functions	Top RF power on	Lower RF power on	ESC power on	Chamber gas delivery valve on	Pendulum valve open	TMP not inhibited	Turbo exhaust valve on
HE/RF enclosure cover sw closed		H					
Helium maximum flow sw true		F					
Station X slot valve closed				H			
Coil enclosure down sw closed	H	H		H			
TCP RF connector sw closed	H						
TCP match scrubber sw closed	H			H			
TCP Match cover sw closed	H			H			
Lower match cover sw closed		H	H				
Lower match connector sw closed		H					
Roughing pump on				H			
Precharge manifold at vacuum				H			
No customer gas detect				H			
No customer interlock				H			

H = hardware human safety interlock

F = firmware equipment safety interlock

Describing the Interlocks

Enclosure Hardware Interlocks

The PM AC power distribution enclosure and PM DC power distribution enclosure are equipped with interlocks that disconnect AC power to the PM if they are activated. These interlocks are all in series in the 24 VAC interlock circuit.

- The cover of the AC power distribution enclosure
- The cover of the DC power distribution enclosure

Process Module Hardware and Firmware Interlocks

All hardware and firmware interlocks on the PM have redundant software interlocks also. The following table lists the various PM interlocks implemented in hardware and firmware (as well as software) and the process that they interlock.

Table 8–2. PM Hardware Interlocks

		Chamber pressure sw true	Foreline pressure sw true	Chamber vacuum sw true	Chamber switch closed true	Water leak sensor true	He/RF enclosure cover sw closed	Station X slot valve closed	Coil enclosure down sw closed	TCP RF connector sw closed	Chamber scrubber sw closed	TCP match cover sw closed	Bias match cover sw close	Bias match RF connector sw closed	Precharge manifold at vacuum	No Customer gas detect	No Customer Interlock	Hardware itlk bypass DO activated
		Interlock switches/ DI ID no./ conditions																
P&ID designation		CM2S 1	CM3S 1	PS1						PS4								
		node1	node1	node1	node1	node1	node2	node2	VIOP	VIOP	VIOP	VIOP	VIOP	VIOP	node3	node3	node3	
		DI0	DI2	DI3	DI6	DIC	DI2	DIA	DI3	DI4	DI5	DI2	DI17	DI18	DI2	DI6	D17	
	LED on board	CR1-A	CR1-B	CR1-C	CR1-D	CR2-C	CR2-B	CR6-B		CR3-C								
Enable the following functions when the PM is in process mode																		
TCP RF power on	(CR5-D)			H	H				H	H	H	H						
Bias RF power on	(CR5-A)			H	H		H		H				H					
ESC power on	(CR5-B)			H		H									H	H	H	

Table 8–2. PM Hardware Interlocks (continued)

		Interlock switches/ DI ID no./ conditions																
		Chamber pressure sw true	Foreline pressure sw true	Chamber vacuum sw true	Chamber switch closed true	Water leak sensor true	He/RF enclosure cover sw closed	Station X slot valve closed	Coil enclosure down sw closed	TCP RF connector sw closed	Chamber scrubber sw closed	TCP match cover sw closed	Bias match cover sw close	Bias match RF connector sw closed	Precharge manifold at vacuum	No Customer gas detect	No Customer Interlock	Hardware itlk bypass DO activated
Chamber gas delivery valve on	(CR6-A)			H	H			H	H		H	H			H	H	H	
Pendulum valve open	(CR4-D)	F	F															
Turbo exhaust valve on			F															
Main water control valve						H												
Enable the following functions when the PM is in maintenance mode																		
Pendulum valve open		F																F
Turbo exhaust valve on		F																F

Note: H =Hardware interlock, relay used on the board. K = Firmware interlock, opto-couples used on the board

LEDs Location (top of the board)

TM Slot Valve	He Max Flow Switch	He/RF Enclosure Cover Switch	Chamber ATM switch	Gas Ring Down Switch	Chamber Vacuum Switch	Foreline Vacuum Switch	Chamber Pressure Switch
CR2-D	CR2-C	CR2-B	CR2-A	CR1-D	CR1-C	CR1-B	CR1-A
TMP Exh Valve Open	Hardware Bypass ON	Bias RF Connector Switch	Bias Match Covers Switches	TCP Match Covers Switches	TCP Match Scrubber Switch	TCP RF Connector Switch	Coil Enclosure Down Switch
CR4-D	CR4-C	CR4-B	CR4-A	CR3-D	CR3-C	CR3-B	CR3-A
Not used	Not used	Not used	Pendulum Valve Open	Bias RF Interlocks OK	TCP RF Interlocks OK	Chamber Gas Delivery OK	ESC High Voltage On
			CR6-A	CR5-D	CR5-C	CR5-B	CR5-A

DI Lights

Green=Switch is true

No light=Switch is not true

Node 3 (Gas Box) DS3	Node 1 (Chamber) DS1
Node 5 (VME) DS4	Node 2 (Lower Electrode) DS2

Node Connection Lights

Green=connected correctly

Red=not connected or connected wrong

Processes Which Are Interlocked

TCP RF Power On

Table 8–3 shows the hardware interlocks that disable TCP RF power unless they are satisfied.

Table 8–3. TCP RF Power

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
Coil Enclosure Down sw closed	VIOP_DI03
TCP RF connector sw closed	VIOP_DI04
TCP Match scrubber sw closed	VIOP_DI05
TCP Match cover sw closed	VIOP_DI02

Ensure that the PM chamber is at vacuum, which means the pressure is lower than 75 Torr. Make sure that the coil enclosure is in the down position so that RF cannot be generated and expose personnel to dangerous RF. Ensure that the TCP RF generator is connected to the TCP Matching Network and the house supplied scrubber is operational so that the pressure differential between inside the coil enclosure and ambient pressure is met. Make sure that all of the covers are in place on the TCP enclosure.

Additionally, the RF generator has an internal temperature interlock. Make sure that this interlock is not tripped due to excessive heat.

Bias RF Power On

Table 8–4 shows the hardware interlocks that disable Bias RF power unless they are satisfied.

Table 8–4. Bias RF Power On

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
He/RF enclosure cover sw closed	node2_DI2

Table 8–4. Bias RF Power On (continued)

Interlock state	Hardware
Helium maximum flow sw true	node2_DI3
Coil Enclosure Down sw closed	VIOP_DI03
Bias Match cover sw closed	VIOP_DI17
Bias Match RF Connector sw closed	VIOP_DI18

ESC Power On

Table 8–5 shows the hardware interlocks that disable ESC power unless they are satisfied:

Table 8–5. ESC Power On

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
He/RF enclosure cover sw closed	node2_DI2
Bias Match cover sw closed	VIOP_DI17

The vacuum switch prevents you from operating the ESC when the chamber is at atmosphere and opened, exposing personnel to dangerous voltages. The covers on the He/RF enclosure and the bias match prevent exposure to RF radiation.

Chamber Gas Delivery

Table 8–6 shows the hardware interlocks that disable delivery of process gas from the gas box to the reaction chamber unless they are satisfied:

Table 8–6. Chamber Gas Delivery

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
Gas Ring sw closed	node1_DI6
Station X slot valve closed	node2_DIA
Coil Enclosure Down sw closed	VIOP_DI03

Table 8–6. Chamber Gas Delivery (continued)

Interlock state	Hardware
TCP Match scrubber sw closed	VIOP_DI05
TCP Match cover sw closed	VIOP_DI02
Precharge manifold at vacuum	node3_DI2
No Customer gas detect	node3_DI6
No Customer interlock	node3_DI7

The precharge manifold vacuum switch is located inside of the gas box. The two customer specific I/Os are available for you to connect external switches to the process modules to act as interlocks.

Pendulum Valve Open

Table 8–7 shows the firmware interlocks that do not allow the pendulum valve to open unless they are satisfied:

Table 8–7. Pendulum Valve Open

Interlock state	Hardware
Chamber pressure sw true	node1_DI0
Foreline pressure sw true	node1_DI2

The chamber pressure switch prevents the pendulum valve from opening if the chamber pressure is greater than 500 mtorr. This prevents damage to the turbo pump. The pendulum valve is additionally interlocked to the foreline pressure switch which monitors pressure in the foreline and is a measure of how well the roughing pump is pumping.

Turbo Exhaust Valve Open

Table 8–8 shows the firmware interlock that does not allow the turbo exhaust valve to open unless it is satisfied:

Table 8–8. Turbo Exhaust Open

Interlock state	Hardware
Foreline pressure sw true	node1_DI2

Opening the foreline exhaust valve at a pressure above 750 mtorr could damage the turbo pump. The foreline pressure switch measures pressure in the foreline and prevents this from happening.

PM Heater Power Interlock

The AC/DC power distribution enclosure provides contactor K1 to interrupt AC power to the system heaters. This contactor is enabled by a combination RTD over-temperature sensors, the temperature monitor board (TMB) of the Anafaze™ temperature controller, and ground fault interrupter (GFI) T1. All over-temperature sensors for all controlled heaters, and the GFI sensor must be safe to enable AC power to heaters.

Thermal Interlock

The foreline manifold heaters are temperature regulated 208 VAC heaters, which employ bi-metallic over-temperature switches set at 100 degrees Celsius to disconnect heater power in the event of a thermal runaway.

Wafer Transfer Slot Valve Interlock

The wafer transfer slot valve is interlocked. This interlock helps to isolate gases in the reaction chamber. Signals are sent from the PM to the TM, so that the TM does not open the slot valve when the PM is at atmosphere and the TM is at vacuum.

Gas Box Hardware Interlocks

To protect personnel from exposing to toxic gases, the interlock circuitry must rely only on the dual compliant electro-mechanical devices.

Table 8–9 shows the gas panel functional interlocks.

Table 8–9. Gas Box Hardware Interlocks

		Inputs							
		Chamber delivery valve ok contact closure from PM interlock board	Roughing Pump ok contact Closure from PM interlock board	Precharge Manifold at VAC	Chamber Delivery at VAC	Differential pressure SW ok	N2 Purge Supply	Customer Gas Detect	Customer Interlock SW ok
				PSH2	PSH3	PSH8	PSH9	IS20	IS21
				DI2	DI3	DI4	DI5	DI6	DI7
SOVNo.	*Enable following function*								
SOV1	N2 Primary valve on						X	X	X
SOV2	Vacuum Primary valve on		X	X				X	X
SOV3	Gas Manifold Purge valve on						X	X	X
SOV4	Gas Manifold Precharge valve on		X	X				X	X
SOV5	Chamber gas delivery valve on	X	X	X				X	X
SOV7	Chamber slow vent						X	X	X
SOV8	Chamber wafer transfer						X	X	X
SOV9	Chamber N2 valve on						X	X	X
SOV10-80	All gas primary valve on				X	X		X	X
SOV12-82	All gas secondary valve on				X	X		X	X

SOVx refers to the shutoff valve in the gas box.

SOV1 Nitrogen Primary Valve On

Table 8–10 shows the following interlocks that prevent the opening of the nitrogen primary valve unless they are true.

Table 8–10. SOV1

Interlock	Number	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	S20
Customer Interlock SW ok	DI7	IS21

Interlocked unless opening by the pressure switch for the nitrogen purge supply (PSH9). Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered short.

SOV2 Vacuum Primary Valve On

Table 8–11 shows the following interlocks that prevent the opening of the vacuum primary valve unless they are true.

Table 8–11. SOV2

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold @ VAC	DI2	PSH2
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV3 Gas Manifold Purge valve on

Table 8–12 shows the following interlocks that prevent the opening of the gas manifold purge valve unless they are true.

Table 8–12. SOV3

Interlocks	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

Interlocked unless opening by the pressure switch for the nitrogen purge supply (PSH9). Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered "short".

SOV4 Gas Manifold Precharge Valve On

Table 8–13 shows the following interlocks that prevent the opening of the gas manifold precharge valve unless they are true.

Table 8–13. SOV4

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board	-	-
Precharge Manifold @ VAC	DI2	PSH2
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV5 Chamber Gas Delivery Valve On X

Table 8–14 shows the following interlocks that prevent the opening of the chamber gas delivery valve unless they are true.

Table 8–14. SOV5

Interlock	Hardware	Switch
Chamber delivery valve ok contact closure from PM interlock board.		
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold @ VAC	DI2	PSH2
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV7 Chamber Slow Vent

Table 8–15 shows the following interlocks that prevent the opening of the chamber slow vent valve unless they are true.

Table 8–15. SOV7

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV8 Chamber Wafer Transfer

Table 8–16 shows the following interlocks that prevent the opening of the chamber wafer transfer valve unless they are true.

Table 8–16. SOV8

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV9 Chamber N2 Valve On

Table 8–17 shows the following interlocks that prevent the opening of the chamber N2 valve unless they are true.

Table 8–17. SOV9

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV10-80 All Gas Primary Valve On

Table 8–18 shows the following interlocks that prevent the opening of the all gas primary valve unless they are true.

Table 8–18. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

Gas is prevented from going to the PM from the gas box if the chamber is not vacuum as read through vacuum switch (PSH3) and if the differential pressure switch (PSH8) in the coil enclosure is not true.

SOV12-82 All Gas Secondary Valve On

Table 8–19 shows the following interlocks that prevent the opening of the all gas secondary valve unless they are true.

Table 8–19. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

RF Energy

RF energy is produced by the Versys Silicon process module. Table 8–20 shows the power requirements for various applications of the Versys Silicon process module.

Table 8–20. Polysilicon Etch Power Requirements

Process	Process gas	Generator frequency (upper/lower)	Generator power (typical)
Polysilicon Oxide Breakthrough Step	CF_4 or Cl_2	13.56 MHz 13.56 MHz	250-350 50-250
Polysilicon Main Etch Step	Cl_2, HBr, O_2	13.56 MHz 13.56 MHz	150-450 100-250
Polysilicon Overetch Step	HBR, He, O_2	13.56 MHz 13.56 MHz	150-350 100-250
Tungsten Silicide Main and Overetch Steps	Cl_2, O_2	13.56 MHz 13.56 MHz	200-300 100-200
Nitride Bulk Etch Step	CF_4, HBr	13.56 MHz 13.56 MHz	500-700 50-200
Nitride Endpoint and Overetch Steps	SF_6, HBr	13.56 MHz 13.56 MHz	500-700 0-100
Plasma Clean Step 1	SF_6, Cl_2	13.56 MHz	600-800 0

Table 8–20. Polysilicon Etch Power Requirements

Process	Process gas	Generator frequency (upper/lower)	Generator power (typical)
Plasma Clean Step 2	SF_6, O_2	13.56 MHz	600-800 0

Chemicals

Chemicals Used During Maintenance

The following chemicals are used during each wet clean of the Versys Silicon process module:

- Isopropyl alcohol (IPA) (3 to 6 ounces)
- Hydrogen peroxide solution (6 percent H_2O_2 with DI H_2O) (30 ounces)

Chemicals Used During the Etch Process

The Versys Silicon process module is capable of three types of plasma etch processes: polysilicon, tungsten silicide and nitride. All the three etch processes produce different exhaust effluents.

Polysilicon Etch

Etching polysilicon is based upon the following chemical reaction:

$$Si + 2\ Cl_2 \rightarrow SiCl_4$$

Actual plasma etch processes, however, are more complex than this, because there are more chemical species involved in the etch. For example, other gases such as hydrogen bromide (HBr) are routinely added to the process and wafers contain other compounds including nitrogen (N), silicon (Si), oxygen (O), and photoresist. It is difficult to exactly calculate or even measure the effluent of a plasma reactor, but the major products can be readily predicted from a calculation of the thermodynamically most stable products.

For polysilicon etch using a baseline chlorine (Cl_2) and HBr, the most common effluent component is hyrocloric acid (HCl). Chlorine (Cl_2) utilization is complete, and not detected in the effluent. HBr and bromine (Br_2) were also detected in the effluent in smaller concentrations.

For the baseline carbon tetrafluoride (CF_4) oxide breakthrough step on polysilicon, CF_4 utilization is very low, at about 10 percent. Emissions are primarily perfluorocarbons (PFCs), with small quantities of silicon tetrafluoride (SiF_4) and carbon difluoride (COF_2). For the baseline process, the utilization efficiency of the CF_4 was 13.6 percent, while the production efficiency of the Trifluoromethane (CFH_3) and hexafluoroethane (C_2F_6) were 16.3 percent and 5.4 percent, respectively.

For the baseline nitride bulk etch step using CF_4 and HBr chemistry, the utilization efficiency of the CF_4 is 34.2 percent, while the production efficiency of the CFH_3 is 12.7 percent and the C_2F_6 is 1.6 percent.

For the baseline nitride endpoint and overetch steps using SF_6 and HBr chemistry, the utilization efficiency of the SF_6 is 83.6 percent.

For the baseline chlorine/sulfur hexafluoride (Cl_2/SF_6) plasma clean, Cl_2 utilization is low, and is thus detected in the effluent. SF_6 utilization is 53.0 percent. There is evidence of sulfuryl fluoride (SO_2F_2) and thionyl fluoride (SOF_2) detected in the effluent as well.

For the baseline sulfur hexafluoride/oxygen (SF_6/O_2) plasma clean, there is low fluorine consumption, and thus high emission levels of SOF_2 and SO_2F_2, and possibly SOF_2. SF_6 utilization efficiency is 68.3 percent.

The baseline process for polysilicon, oxide breakthrough step main, and overetch steps is:

BT step: 15mtorr, 200 sccm CF_4 for 10 seconds
ME step: 10mtorr, 100 sccm CL_2 300 sccm HBr
OE step: 60mtorr, 400 sccm He, 200 sccm HBr, 4 sccm O_2

Baseline process for tungsten silicide main and overetch steps is:

4mtorr, 180 sccm CL_2, 4 sccm O_2

Baseline process for nitride bulk, endpoint and overetch steps is:

BE step: 20mtorr, 150 sccm CF_4 50 sccm HBr
EP step: 15mtorr, 50 sccm SF_6 100 sccm HBr
OE step: 30mtorr, 50 sccm SF_6 100 sccm HBr

9 Versys Silicon PM Industrial Hygiene Report

This chapter lists the industrial hygiene (IH) test results of the Versys Silicon process module on the 2300 platform.

Test Parameters and Procedures

The following test equipment and test criteria were employed during testing of the Versys Silicon process module on the 2300 platform.

Table 9–1. Test Equipment and Test Criteria

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
RF Induced electric and Magnetic Fields	Narda Industrial Compliance Meter for Electromagnetic Energy Model 8511	4.89 mW/cm_2 electric 54.3 mW/cm_2 magnetic. (Instantaneous) Calculated from ACGIH Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)
UV Radiation	International Light Direct Reading Meter Model No. IL1400A Meter	10 µW/cm_2 for five minute exposure period From Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)
Bromine (Br_2)	NIOSH method 6011, iron chromatography silver membrane filter	Ppm Time Weighed Average TWA) for 8 hour exposure period From Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)

Table 9–1. Test Equipment and Test Criteria (continued)

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Carbon Monoxide (CO)	Direct Reading Monitor	25 ppm TWA for 8 hour exposure period From Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)
Carbon Tetrachloride (CCl_4)	OSHA method 7, GC/FID charcoal tube	5 ppm for 8 hour exposure period From Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)
Chlorine (Cl_2)	Direct Reading Monitor And NIOSH method 6011, ION chromatography silver membrane filter	0.5 ppm TWA for 8 hour exposure period 1 ppm (STEL) for instantaneous exposure period. From Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)
Hydrochloric Acid (HCl)	NIOSH method 7903, ION chromatography silica gel tubes for acids	5 ppm Ceiling for instantaneous exposure period.
Hydrofluoric Acid (HF)	NIOSH method 7903, ION chromatography silica gel tubes for acids	3 ppm Ceiling for instantaneous exposure period
Hydrogen Bromide (HBr)	MDA TLD-1 Toxic Gas Meter And NIOSH method 7903, ION chromatography silica gel tubes for acids	3 ppm Ceiling for instantaneous exposure period
Hydrogen Peroxide (H_2O_2)	OSHA method ID126SG differential pulse polarography	1 ppm TWA for 8 hour exposure period

Table 9–1. Test Equipment and Test Criteria (continued)

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Isopropyl Alcohol (IPA)	OSHA method 7, GC/FID charcoal tube	500 ppm STEL for 15 minute exposure period From Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)
Argon (Ar)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 0
Octafluorocyclobutane (C4F8)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 0
Hexafluoropropylene (C3F6)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 0
Oxygen (gaseous)(O2)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 0
Hexafluoroethane (C2F6)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 2
Carbon Tetrafluoride(CF4)	)Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 1
Trifluoromethane (CHF3)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 1
Sulfur Hexafluoride (SF6)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 1
Octafluorocyclobutane (C4F8)	(Inert gas) Non-toxic gas Do not need to sample	NFPA Code Health = 1
Nitrogen (N2) (Inert gas)	Non-toxic gas Do not need to sample	NFPA Code Health = 0
Noise (Sound Level Readings)	OSHA Quest Sound Level Meter	80 dBA

Test Results

Chemical Exposure

The process recipe used during engineering evaluation of the Versys Silicon process module was:

- Nitride: 10 mtorr/800Wt/70Wb/8 O_2/50 HBr/100CF_4/8T He/30
- Silicon: 10mtorr/900Wt/120Wb/35 Cl_2/8 O_2/150 HBr/8T He/30

The SEMI S2-0200 evaluation of the 2300 process module includes the industrial hygiene assessment of the potential for exposure to process chemistries including Cl_2, Br_2, HCl, HBr, HF, CCl_4; and the maintenance chemicals used during a chamber clean: IPA, and H_2O_2. Industrial hygiene data was recorded during the initial opening (post process) and subsequent opening and cleaning of the reaction chamber performed by an equipment technician. All equipment panels and protective covers were in place during the industrial hygiene measurements unless otherwise noted. Local exhaust at the process module was not utilized during the monitoring.

The process module that was sampled had processed 4,200 wafers for an engineering evaluation. The *Versys Silicon 2300 Process Module Maintenance* manual recommends a chamber clean each quarter. Prior to opening the chamber, a standard clean recipe consisting of 125 sccm of SF_6 for 135 seconds, then O_2 for 200 seconds. Then 30 pump/purge cycles were performed. At the time of evaluation, no recommended number of pump/purge cycles had been established. The *Versys Silicon 2300 Process Module Maintenance* manual recommends 50 to 100 pump/purge cycles if Cl_2 or HBr is in use.

Three real-time industrial hygiene air-sampling instruments were used to measure the identified analyses. Carbon monoxide was measured using an Interscan 1000 series, Model 1146 (SN 28257). The lower sensitivity for CO of the detector was 2 ppm. An Interscan Model 1340 (SN 215041) was used to measure Cl_2. The lower sensitivity was 0.1 ppm for $C1_2$. A Zellweger Analytics MDA TLD-1 (SN 104781) was utilized to detect HBr. The lower limit of detection for HBr using the MDA is 0.3 ppm. The TLD was operated with a freshly opened, freezer stored Chemcassete QC cartridge (Part No. 705505-0, SN900474), appropriate for HBr.

Industrial hygiene air samples were collected using SKC constant-flow air sampling pumps with inline collection media (see references to specific analyses). The pumps are UL-listed as intrinsically safe apparatus for use in Class I, II, and II, Division 1 Hazardous Locations. Start and end times were measured for each sample to determine the duration of sampling. Sample pump train flow rates were determined from pump calibration data. Sample pumps were calibrated using a BIOS Dry Cell Calibrator (Model DC-1B, Rev. 2.06E, SN B2951) equipped with a BIOS standard calibration cell (Model DC-1SC, Rev. E, SN S2854). The standard calibration cell is rated for sample pump flows of 10 to 9,999 milliliters per minute. The BIOS Dry Cell is an NIST-traceable primary standard.

The pumps were operated for at least five minutes to allow them to come to operating temperature, and for flow to stabilize. The flow rate for each pump was adjusted and set, and then calibrated using a representative sampling train (for example, sorbent tube, impinger with fluid, Tygon tubing, needle valve, and so forth.) that remains with the pump from pre-test calibration through testing and post-test calibration. During pre-test calibration, the flow through each sample pump/sample train is measured three times. At post-test calibration, the flow through each sample pump/sample train is again measured three times. Each pump is checked to verify that the average flow rate for pre-test and post-test calibrations differed by no more than 5 percent. For purposes of sample analysis, the flow rate was determined as the arithmetic average of the six calibration measurements (that is, three pre-test and three post-test calibrations). A *Sample Pump Calibration Log* is completed in the field to document the calibration.

Samples for H_2O_2 analysis were sent to Wisconsin Occupational Health Laboratory of Madison, Wisconsin. All other sample media were to submit to AT Labs of Boardman, Ohio for analysis. Both labs are American Industrial Hygiene Association (AIHA)-accredited industrial hygiene laboratories.

The following health hazard data was obtained for the Versys Silicon process module. Table 9–2 presents real time monitoring data.

Table 9–2. Industrial Hygiene Direct Reading Survey Results

Area / Sample description (sampling period 10:05 – 10:20 am)	Result ppm		Reference standards ACGIH TLV/ 25% Ppm	Reference standards OSHA PEL/25% Ppm
1. At edge of chamber during chamber crack.	HBr	<0.3	C 3/C0.75	3/0.75
	Cl_2	0.2	0.5/0.125	C1/C0.25
	CO	< 2	25/6.25	50/12.5
2. At edge of open chamber.	HBr	<0.3	C 3 C/0.75	3/0.75
	Cl_2	0.15	0.5/0.125	C1/C0.25
	CO	< 2	25/6.25	50/12.5
3. Technician breathing zone upon chamber open.	HBr	<0.3	C 3/0.75	3/0.75
	Cl_2	0.1	0.5/0.125	C1/C0.25
	CO	< 2	25/6.25	50/125
4. Technician breathing zone during removal of upper focus ring and hot ring.	HBr	Not measured	C 3/0.75	3/0.75
	Cl_2	0.1	0.5/0.125	C1/C0.25
	CO	< 2	25/6.25	50/125
5. Technician breathing zone during measurement of deposits on chamber.	HBr	<0.3	C 3/0.75	3/0.75
	Cl_2	0.1	0.5/0.125	C1/C0.25
	CO	< 2	25/6.25	50/1.25
6. Near chamber as cleaning begun.	HBr	<0.3	C 3/0.75	3/0.75
	Cl_2	<0.1	0.5/0.125	C1/C0.25
	CO	< 2	25/6.25	50/1.25
7. Technician breathing zone, during removal of liner.	HBr	<0.3	C 3/0.75	3/0.75
	Cl_2	<0.1	0.5/0.125	C1/C0.25
	CO	4	25/6.25	50/1.25
8. Technician breathing zone, as cleaning continued.	HBr	<0.3	C 3/0.75	3/0.75
	Cl_2	Not measured	0.5/0.125	C1/C0.25
	CO	< 2	25/6.25	50/1.25

Table 9–2. Industrial Hygiene Direct Reading Survey Results (continued)

Area / Sample description (sampling period 10:05 – 10:20 am)	Result ppm		Reference standards ACGIH TLV/ 25% Ppm	Reference standards OSHA PEL/25% Ppm
9. Near chamber lip while cleaning with IPA.	CO	Not measured	25/6.25	50/1.25

Notes:

ACGIH – American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL – Permissible Exposure Limit

ppm – parts per million

C – ceiling value

< denotes "less than" the detection limit indicated.

Ultra-Violet Radiation

The SEMI S2-0200 evaluation of the Versys Silicon process module on the 2300 platform includes the industrial hygiene evaluation of the potential for exposure to UV light. Measurements were recorded during normal operation of the process module under the SP1 recipe.

UV was measured using an International Light 1400A Radiometer survey meter (SN 3034) with a SEL 240 probe (SN 4438). Measurements were recorded throughout the normal recipe or cycling of wafers (see Table 9–3). Readings in microwatts per centimeter cubed (mW/cm^3) were recorded at a two-inch distance from the quartz glass viewport.

Table 9–3. UV Light Survey Results

Area/Description	Reading (mW/cm^2)	ACGIH effective i rradiance 5 min. exposure limit mW/cm^2
Left viewport, at face.	0.02	ACGIH = 10
Left viewport, at 2 inches distance.	< 0.01	ACGIH = 10
Right viewport, at face.	0.02	ACGIH = 10
Right viewport, at 2 inches distance.	< 0.01	ACGIH = 10

Note ACGIH – American Conference of Governmental Industrial Hygienists.

< Denotes "less than" the detection limit indicated.

Radio Frequency

The SEMI S2-0200 evaluation of the Versys Silicon process module on the 2300 platform includes the industrial hygiene evaluation of the potential for exposure to non-ionizing RF radiation. Measurements were recorded during normal operation of the process module (see Table 9–4). All panels, mesh screens, and protective covers were in place during the measurements.

RF was measured using a Narda Industrial Compliance Meter for Electromagnetic Energy, Model 8511. The Narda meter was set for a range that included the 13.56 MHz frequency being generated by the system. Maximum process recipe operation is 900 watts under the SP1 recipe for the 13.56 MHz power supply. Power levels are directly related to the desired process and specific recipe. Measurements were taken continuously throughout the process cycle two inches from the measurement area and included cables, power source, viewport and lower / upper match areas.

Table 9–4. Non-Ionizing RF Survey Results, 13.56 MHz, 900W

Area/description	Field (mW/cm^2)	Readings	ACGIH / OSHA[a] reference standards (6 min. exposure = mW/cm^2)	
TCP: At generator top At cable exit Along cable At connection to match	E Field	<0.01	4.89 mW/cm^2	**OSHA** = 10 mW/cm^2
	H Field	<0.01	54.3 mW/cm^2	
Bias: At generator top At cable exit Along cable At coil on floor Along cable left side At connection to match	E Field	<0.01	4.89 mW/cm^2	**OSHA** = 10 mW/cm^2
	H Field	<0.01	54.3 mW/cm^2	
At power source top and cable connection	E Field	<0.01	4.98 mW/cm^2	**OSHA** = 10 mW/cm^2
	H Field	<0.01	54.3 mW/cm^2	
TCP and Bias Match: Left side, Right side, Front and Back	E Field	<0.01	4.89 mW/cm^2	**OSHA** = 10 mW/cm^2
	H Field	<0.01	54.3 mW/cm^2	

a. These values also meet the SEMATECH Application Guide guidance limits for uncontrolled environments, specifically 0.98 mW/cm^2 for electric field strength

Sound Pressure Level

The following health hazard data was obtained for the Versys Silicon process module, measuring noise (using a Quest Sound Level Meter): Model 2400, Serial Number JN7110028.

The SEMI S2-0200 evaluation of the Versys Silicon process module includes the industrial hygiene review for potential exposure to elevated noise levels during operation of the system. No additional engineering controls such as noise reduction materials were utilized. The survey (see Table 9–5) was performed by initially recording background noise levels followed by measurements recorded adjacent to the equipment in both the operator and technician work areas during normal system operation under recipe SPC_Ox_ER Cl_2 50. The transporter side of the system was considered the backside of the system.

Table 9–5. Industrial Hygiene Noise Measurement Results

Location/Description	Result DBA	ACGIH TLV DBA
General Area Background, about 15-20 feet from system.	76 – 78	80
Left side, one foot from system, about 50 inches above floor level.	78	80
Front, 6 inches from system, about 60 inches above floor level.	76	80
Right side, 6 inches from system, about 60 inches above floor level.	76	80
Backside, 3 inches from system, about 60 inches above floor level.	76	80

10
Versys Metal Process Module

This chapter provides safety information specific to the Versys metal process module.

For system safety information or for safety information on any other process module for the system, refer to the remainder of this manual.

2300 process modules are operated from the transport module operator interface. For general system operating instructions, see the *2300 Transport Module Operation* manual.

For transport module maintenance information, see the *2300 Transport Module Maintenance* manual.

Interlocks

Process Module Interlocks

The hazardous functions of the Versys Metal process module are interlocked as shown in Table 10–1.

Table 10–1. Process Module Interlocks

Table functions	Top RF power on	Lower RF power on	ESC power on	Chamber gas delivery valve on	Pendulum valve open	TMP Not inhibited	Turbo exhaust valve on
Chamber pressure sw true	H	H	H	H	F		
Foreline pressure sw true		H			F	F	F
Chamber vacuum sw true	H		H	H			
Gas ring sw closed				H			

Table 10–1. Process Module Interlocks (continued)

Table functions	Top RF power on	Lower RF power on	ESC power on	Chamber gas delivery valve on	Pendulum valve open	TMP Not inhibited	Turbo exhaust valve on
HE/RF enclosure cover sw closed		H					
Helium maximum flow sw true		F					
Station X slot valve closed				H			
Coil enclosure down sw closed	H	H		H			
TCP RF connector sw closed	H						
TCP match scrubber sw closed	H			H			
TCP Match cover sw closed	H			H			
Lower match cover sw closed		H	H				
Lower match connector sw closed		H					
Roughing pump on				H			
Precharge manifold at vacuum				H			
No customer gas detect				H			
No customer interlock				H			

H = hardware human safety interlock

F = firmware equipment safety interlock

Describing the Interlocks

Enclosure Hardware Interlocks

The following enclosures are equipped with interlocks that disconnect AC power to the PM if activated. These interlocks are all in series in the 24 VAC interlock circuit.

- The cover for the AC power distribution enclosure
- The cover for the DC power distribution enclosure

Process Module Hardware and Firmware Interlocks

All hardware and firmware interlocks on the PM have redundant software interlocks also. The following table lists the various PM interlocks implemented in hardware and firmware (as well as software) and the process that they interlock.

Table 10–2. PM Hardware Interlocks

Interlock switches/ DI ID no./ conditions	Chamber pressure sw true	Foreline pressure sw true	Chamber vacuum sw true	Chamber switch closed true	Water leak sensor true	He/RF enclosure cover sw closed	Station X slot valve closed	Coil enclosure down sw closed	TCP RF connector sw closed	Chamber scrubber sw closed	TCP match cover sw closed	Bias match cover sw close	Bias match RF connector sw closed	Precharge manifold at vacuum	No Customer gas detect	No Customer Interlock	Hardware itlk bypass DO activated
P&ID designation	CM2S1	CM3S1	PS1	SW1					PS4								
	node1	node1	node1	node1	node1	node2	node2	VIOP	VIOP	VIOP	VIOP	VIOP	VIOP	node3	node3	node3	
	DI0	DI2	DI3	DI6	DIC	DI2	DIA	DI3	DI4	DI5	DI2	DI17	DI18	DI2	DI6	D17	
Enable the following functions when the PM is in process mode																	
TCP RF power on			H	H				H	H	H	H						
Bias RF power on			H	H		H		H				H					
ESC power on			H		H									H	H	H	
Chamber gas delivery valve on			H	H			H	H		H	H			H	H	H	

Table 10–2. PM Hardware Interlocks (continued)

	Interlock switches/ DI ID no./ conditions: Chamber pressure sw true	Foreline pressure sw true	Chamber vacuum sw true	Chamber switch closed true	Water leak sensor true	He/RF enclosure cover sw closed	Station X slot valve closed	Coil enclosure down sw closed	TCP RF connector sw closed	Chamber scrubber sw closed	TCP match cover sw closed	Bias match cover sw close	Bias match RF connector sw closed	Precharge manifold at vacuum	No Customer gas detect	No Customer Interlock	Hardware itlk bypass DO activated
Pendulum valve open	F	F															
Turbo exhaust valve on		F															
Main water control valve					H												
Enable the following functions when the PM is in maintenance mode																	
Pendulum valve open																	F
Turbo exhaust valve on																	F

Note: H =Hardware interlock, relay used on the board. F = Firmware interlock, opto-couples used on the board

LEDs Location (top of the board)

TM Slot Valve	He Max Flow Switch	He/RF Enclosure Cover Switch	Chamber ATM switch	Gas Ring Down Switch	Chamber Vacuum Switch	Foreline Vacuum Switch	Chamber Pressure Switch
CR2-D	CR2-C	CR2-B	CR2-A	CR1-D	CR1-C	CR1-B	CR1-A
TMP Exh Valve Open	Hardware Bypass ON	Bias RF Connector Switch	Bias Match Covers Switches	TCP Match Covers Switches	TCP Match Scrubber Switch	TCP RF Connector Switch	Coil Enclosure Down Switch
CR4-D	CR4-C	CR4-B	CR4-A	CR3-D	CR3-C	CR3-B	CR3-A
Not used	Not used	Not used	Pendulum Valve Open	Bias RF Interlocks OK	TCP RF Interlocks OK	Chamber Gas Delivery OK	ESC High Voltage On
			CR6-A	CR5-D	CR5-C	CR5-B	CR5-A

DI Lights

Green=Switch is true

No light=Switch is not true

Node 3 (Gas Box) DS3	Node 1 (Chamber) DS1
Node 5 (VME) DS4	Node 2 (Lower Electrode) DS2

Node Connection Lights

Green=connected correctly

Red=not connected or connected wrong

Processes Which Are Interlocked

TCP RF Power On

Table 10–3 shows the hardware interlocks that disable TCP RF power unless they are satisfied.

Table 10–3. TCP RF Power

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
Coil Enclosure Down sw closed	VIOP_DI03
TCP RF connector sw closed	VIOP_DI04
TCP Match scrubber sw closed	VIOP_DI05
TCP Match cover sw closed	VIOP_DI02
Chamber Switch Closed	Node 1_DI6

Ensure that the PM chamber is at vacuum, which means the pressure is lower than 75 Torr. Make sure that the coil enclosure is in the down position so that RF cannot be generated and expose personnel to dangerous RF. Ensure that the TCP RF generator is connected to the TCP Matching Network and the house supplied scrubber is operational so that the pressure differential between inside the coil enclosure and ambient pressure is met. Make sure that all of the covers are in place on the TCP enclosure.

Additionally, the RF generator has an internal temperature interlock. Ensure that the interlock does not trip due to excessive heat.

Bias RF Power On

Table 10–4 shows the hardware interlocks that disable Bias RF power unless they are satisfied.

Table 10–4. Bias RF Power On

Interlock state	Hardware
Chamber vacuum switch True	node1_DI3
He/RF enclosure cover switch closed	node2_DI2
Coil Enclosure Down switch closed	VIOP_DI03
Bias Match cover switch closed	VIOP_DI17
Bias Match RF connector switch closed	VIOP_DI18
Chamber switch closed	Node 1_DI6

ESC Power On

Table 10–5 shows the hardware interlocks that disable ESC power unless they are satisfied:

Table 10–5. ESC Power On

Interlock state	Hardware
Chamber vacuum switch true	node1_DI3
He/RF enclosure cover switch closed	node2_DI2
Bias match cover switch closed	VIOP_DI17

The vacuum switch prevents you from operating the ESC when the chamber is at atmosphere, opened, and exposes personnel to dangerous voltages. The covers on the He/RF enclosure and the bias match prevent exposure to RF radiation.

Chamber Gas Delivery

Table 10–6 shows the hardware interlocks that disable delivery of process gas from the gas box to the reacion chamber unless they are satisfied.

Table 10–6. Chamber Gas Delivery

Interlock state	Hardware
Chamber vacuum switch true	node1_DI3
Chamber switch closed	node1_DI6
Station X slot valve closed	node2_DIA
Coil Enclosure Down sw closed	VIOP_DI03
TCP Match scrubber sw closed	VIOP_DI05
TCP Match cover sw closed	VIOP_DI02
Precharge manifold at vacuum	node3_DI2
No Customer gas detect	node3_DI6
No Customer interlock	node3_DI7

The precharge manifold vacuum switch is located inside of the gas box. The two customer specific I/Os are available for the customer's use to connect external switches to the process modules to act as interlocks.

Pendulum Valve Open

Table 10–7 shows the firmware interlocks that do not allow the pendulum valve to open unless they are satisfied:

Table 10–7. Pendulum Valve Open

Interlock state	Hardware
Chamber pressure sw true	node1_DI0
Foreline pressure sw true	node1_DI2

The chamber pressure switch prevents you from opening the pendulum valve if the chamber pressure is greater than 500 mtorr. This prevents damage to the turbo pump. The pendulum valve is additionally interlocked to the foreline pressure switch which monitors pressure in the foreline and is a measure of how well the roughing pump is pumping.

Turbo Exhaust Valve Open

Table 10–8 shows the firmware interlock that does not allow the turbo exhaust valve to open unless it is satisfied:

Table 10–8. Turbo Exhaust Open

Interlock state	Hardware
Foreline pressure sw true	node1_DI2

Opening the foreline exhaust valve at a pressure above 750 mtorr could damage the turbo pump. The foreline pressure switch measures pressure in the foreline and prevents this from happening.

PM Heater Power Interlock

The AC/DC power distribution enclosure provides contactor K1 to interrupt AC power to the system heaters. This contactor is enabled by a combination RTD over-temperature sensors, the temperature monitor board (TMB) of the Anafaze temperature controller, and ground fault interrupter (GFI) T1. All over-temperature sensors for all controlled heaters, and GFI sensor must be safe to enable AC power to heaters.

Thermal Interlock

The foreline manifold heaters are temperature regulated 208 VAC heaters, which employ bi-metallic over-temperature switches set at 100 degrees Celsius to disconnect heater power in the event of a thermal runaway.

Wafer Transfer Slot Valve Interlock

The wafer transfer slot valve is interlocked. This interlock helps to isolate gases in the reaction chamber. Signals are sent from the PM to the TM, so that the TM does not open the slot valve when the PM is at atmosphere and the TM is at vacuum.

Gas Box Hardware Interlocks

To protect personnel from exposing to toxic gases, the interlock circuitry must rely only on the dual compliant electro-mechanical devices.

Table 10–9 shows the gas panel functional interlocks.

Table 10–9. Gas Box Hardware Interlocks

		Inputs							
		Chamber delivery valve ok contact closure from PM interlock board	Roughing Pump ok contact Closure from PM interlock board	Precharge Manifold at VAC	Chamber Delivery at VAC	Differential pressure SW ok	N2 Purge Supply	Customer Gas Detect	Customer Interlock SW ok
				PSH2	PSH3	PSH8	PSH9	IS20	IS21
				DI2	DI3	DI4	DI5	DI6	DI7
SOVNo.	*Enable following function*								
SOV1	N2 Primary valve on						X	X	X
SOV2	Vacuum Primary valve on		X	X				X	X
SOV3	Gas Manifold Purge valve on						X	X	X
SOV4	Gas Manifold Precharge valve on		X	X				X	X
SOV5	Chamber gas delivery valve on	X	X	X				X	X
SOV7	Chamber slow vent						X	X	X
SOV8	Chamber wafer transfer						X	X	X
SOV9	Chamber N2 valve on						X	X	X
SOV10-80	All gas primary valve on				X	X		X	X
SOV12-82	All gas secondary valve on				X	X		X	X

SOVx refers to the shutoff valve in the gas box.

SOV1 Nitrogen Primary Valve On

Table 10–10 shows the following interlocks that prevent the opening of the nitrogen primary valve unless they are true.

Table 10–10. SOV1

Interlock	Number	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	S20
Customer Interlock SW ok	DI7	IS21

Interlocked unless opening by the pressure switch nitrogen purge supply (PSH9). Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered short.

SOV2 Vacuum Primary Valve On

Table 10–11 shows the following interlocks that prevent the opening of the vacuum primary valve unless they are true.

Table 10–11. SOV2

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold @ VAC	DI2	PSH2
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV3 Gas Manifold Purge valve on

Table 10–12 shows the following interlocks that prevent the opening of the gas manifold purge primary valve unless they are true.

Table 10–12. SOV3

Interlocks	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

These valves are interlocked unless opening by the pressure switch for the nitrogen purge supply (PSH9). Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered “short”.

SOV4 Gas Manifold Precharge Valve On

Table 10–13 shows the following interlocks that prevent the opening of the gas manifold precharge valve unless they are true.

Table 10–13. SOV4

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board	-	-
Precharge Manifold @ VAC	DI2	PSH2
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV5 Chamber Gas Delivery Valve On X

Table 10–14 shows the following interlocks that prevent the opening of the chamber gas delivery valve unless they are true.

Table 10–14. SOV5

Interlock	Hardware	Switch
Chamber delivery valve ok contact closure from PM interlock board.		
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold @ VAC	DI2	PSH2
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV7 Chamber Slow Vent

Table 10–15 shows the following interlocks that prevent the opening of the chamber slow vent valve unless they are true.

Table 10–15. SOV7

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV8 Chamber Wafer Transfer

Table 10–16 shows the following interlocks that prevent the opening of the chamber wafer transfer valve unless they are true.

Table 10–16. SOV8

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV9 Chamber N2 Valve On

Table 10–17 shows the following interlocks that prevent the opening of the chamber N2 valve unless they are true.

Table 10–17. SOV9

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV10-80 All Gas Primary Valve On

Table 10–18 shows the following interlocks that prevent the opening of the all gas primary valve unless they are true.

Table 10–18. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

Gas is prevented from going to the PM from the gas box if the chamber is not vacuum as read through vacuum switch (PSH3) and if the differential pressure switch (PSH8) in the coil enclosure is not true.

SOV12-82 All Gas Secondary Valve On

Table 10–19 shows the following interlocks that prevent the opening of the all gas secondary valve unless they are true.

Table 10–19. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

RF Energy

The Versys Metal process module produces RF energy. Table 10–20 describes the RF frequencies and power requirements for various applications of the Versys Metal process module.

Table 10–20. RF Frequencies and Power for Versys Metal Systems

Process	Process gas	Generator type (upper/ lower)	Generator frequency (upper/ lower)	Generator power (maxi.)	Generator power (typical)
Non-toxic test recipe	Ar, N_2	APEX RFDS	13.56 MHz 13.56 MHz	1.50 kW 1.25 kW	125 - 250W 75 - 125W
Aluminum main etch step	Cl_2, BCl_3	APEX RFDS	13.56 MHz 13.56 MHz	1.50 kW 1.25 kW	500 - 1100W 100 - 500W
Aluminum overetch step	Cl_2, BCl_3, N_2	APEX RFDS	13.56 MHz 13.56 MHz	1.50kW 1.25 kW	250 - 500W 100 - 500W
Tungsten etch	SF_6, N_2	APEX RFDS	13.56 MHz 13.56 MHz	1.50kW 1.25 kW	600 - 900W 50 - 100W
TiN barrier	Cl_2, BCl_3	APEX RFDS	13.56 MHz 13.56 MHz	1.50 kW 1.25 kW	150 - 400W 150 - 350W

APEX – Selectable regulation on delivered or forward power

RFDS – Regulates on delivered power (forward power – reflected power)

Chemicals

Chemicals Used During Maintenance

The following chemicals are used in the maintenance of the Versys Metal process module:

- Isopropyl alcohol (IPA)
- Deionized (DI) water
- Hydrogen peroxide solution (for tungsten only)
- Fomblin® grease
- Krytox® grease

Chemicals Used During the Etch Process

The Versys Metal system is capable of two types of plasma etch processes: aluminum and tungsten. Both produce different exhaust effluents.

Aluminum Etch

Etching aluminum is based upon the following chemical reaction:

$2\ Al + 3\ Cl_2 \rightarrow Al_2Cl_6$

Actual plasma etch processes involve other chemicals. For example, other gases such as boron trichloride (BCl_3) are routinely added to the process and wafers contain other compounds including copper (Cu), titanium (Ti), nitrogen (N), silicon (Si), oxygen (O), and photoresist. The major effluent products can be readily predicted from a calculation of the thermodynamically most stable products. The results shown in Table 10–21 indicate that unreacted BCl_3 and chlorine (Cl_2) and the product aluminum hexachloride (Al_2Cl_6) are the major components of the effluent.

Table 10–21. Aluminum Etch Effluent Components

Products	Per wafer units	Per year units
BCl_3	1.022 g	154 Kg
Cl_2	0.600 g	85.9 Kg
Al_2Cl_6	0.125 g	18.8 Kg
HCi	0.020 g	3.0 Kg
$TiCl_4$	0.020 g	3.0 Kg
N_2	0.014 g	2.1 Kg
CCl_4	0.016 g	2.4 Kg
$SiCl_4$	0.005 g	0.7 Kg
CO_2	0.001 g	0.1 Kg
Cu_3Cl_3	0.001 g	0.1 Kg

Note This calculation is for a baseline aluminum etch process of a 200-millimeter diameter wafer, and assumes a two-step etch, with a main etch step at 8 mtorr using 250 standard cubic centimeter per minute (sccm) Cl_2 and 150 sccm BCl_3 for 33 seconds, and an overetch step at 8 mtorr using 150 sccm Cl_2, 150 sccm boron trichloride (BCl_3), and 20 sccm nitrogen (N_2) for 45 seconds. The wafer is assumed to consist of 8000 angstrom (Å) SiO_2, 500 Å Ti, 6000 Å aluminum (Al) (with 0.5 percent Cu), 250 Å TiN, and 1.1 micron of photoresist and has 50 percent open area. The estimated effluent per year assumes 150,000 wafers are processed in a year.

Tungsten Etch

Etching of tungsten is based upon the formation of volatile tungsten hexafluoride (WF_6) from fluorine atoms generated in a plasma from a feed gas with sulfur hexafluoride (SF_6). Actual plasma etch processes, however, are more complex than this. You can readily predict the major products from a calculation of the thermodynamically most stable products. The results shown in Table 10–22 indicate that unreacted sulfur hexafluoride (SF_6), Chlorine (Cl_2), boron trichloride (BCl_3), and the product tungsten hexafluoride (WF_6) are the major components of the effluent.

Table 10–22. Tungsten Etch Effluent Components

Products	Per wafer units	Per year units
SF_6	0.623 g	93.5 Kg
WF_6	0.246 g	36.8 Kg
Cl_2	0.176 g	26.4 Kg
BCl_3	0.349 g	52.6 Kg
S	0.035 g	5.2 Kg
N_2	0.030 g	4.6 Kg
CF_4	0.025 g	3.8 Kg
$TiCl_4$	0.013 g	2.0 Kg
HF	0.009 g	1.3 Kg
CO_2	0.001 g	0.1 Kg

This calculation is for a baseline tungsten etch process of a 200-millimeter diameter wafer, and assumes a three-step etch, with a main etch step at 12 mtorr using 100 sccm SF_6 and 20 sccm N_2 for 60 seconds, an overetch step with the same recipe for 12 seconds, and a TiN barrier layer etch of 6 mtorr using 100 sccm Cl_2 and 115 sccm BCl_3 for 35 seconds. The wafer is assumed to consist of 8000 Å SiO2, 250 Å Ti, 250 Å TiN, 5000 Å Tungsten, and 1.2 micron of photoresist and has 50 percent open area. The estimated effluent per year assumes 150,000 wafers are processed in a year.

11
Versys Metal PM Industrial Hygiene Report

This chapter lists the industrial hygiene test results of the Versys metal process module on the 2300 platform.

Test Parameters and Procedures

The following test equipment and test criteria were employed during testing of the Versys metal process module.

Table 11–1. Test Equipment and Test Criteria

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Infra-Red (IR) radiation	International Light 1400A Radiometer	ACGIH TLV Effective Irradiance (exposure > 1000 seconds = 10 mW/cm^2 SEMI S2–0200 Operator-Accessible and Maintenance/Service - Accessible Limit (20% of ACGIH limit) = 2.0 mW/cm^2
Ultra-Violet (UV) Light	International Light 1400A Radiometer	ACGIH TLV Effective Irradiance, 5 minutes Exposure = 10 μW/cm^2) SEMI S2–0200 Operator-Accessible and Maintenance/Service - Accessible Limit = 0.02μW/ cm^2

Table 11–1. Test Equipment and Test Criteria (continued)

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Radio-Frequency (RF) Induced Electric and Magnetic Fields	Narda, Model 8511 Electric and Magnetic Field Probes	ACGIH TLV 6 Minutes Exposure Limit = 4.89 and 54.47 mW/cm^2 for Electric and Magnetic Fields respectively. OSHA PEL 6 Minute Exposure Limit = 10 mW/cm^2 for both Electric and Magnetic Fields. SEMI S2-0200 Operator-Accessible Limit (20% of IEEE/ANSI C95.1-1999 Uncontrolled Limit) = 0.20 and 10.88 mW/cm^2 for Electric and Magnetic Fields respectively. SEMI S2-0200 Maintenance/Service-Accessible Limit (20% of IEEE/ANSI C95.1-1999 Controlled Limit) = 0.98 and 10.88 mW/cm^2 for Electric and Magnetic Fields respectively.
Sound Pressure Level	OSHA Quest Q2400 Sound Level Meter Direct Reading Meter	80 dBA SEMI S2–0200 Section 27.1

Notes:

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL – Permissible Exposure Limit

ANSI –American National Standards Institute

IEEE –Institute of Electrical and Electronics Engineers

mW/cm^2 – milliwatts per square centimeter

$\mu W/cm^2$ – microwatts per square centimeter

dB(A) – decibels (Audio), A scale

Test Results

Chemical Exposure

Chemical exposure sampling and analysis was not conducted as part of this evaluation.

Ultra-Violet Radiation

UV light was measured using an International Light 1400A Radiometer survey meter (SN 3034) with a SEL 240 detector (SN 4438). Measurements were recorded throughout the normal recipe for cycling of wafers. Levels were recorded in microwatts per centimeter squared (µW/cm2) for UV at various distances from the outside skin that shields the quartz glass viewport (with protective mesh). The non-ionizing radiation monitoring results and the relevant reference standards for UV radiation are presented in Table 11–2.

Table 11–2. UV Light Survey Results

Area/Description	UV Reading (mW/cm^2)	ACGIH TLV Effective Irradiance 5 min. exposure limit (mW/cm^2)	Operator-Accessible and Maintenance /Service-Accessible SEMI S2-0200 Limit (mW/cm^2)	Result
Left Side, 0.8 inch from Main Viewport	0.02	ACGIH = 10	0.02	PASS
Left Side, 2.0 inches from Main Viewport	0.00	ACGIH = 10	0.02	PASS

Table 11–2. UV Light Survey Results (continued)

Area/Description	UV Reading (mW/cm^2)	ACGIH TLV Effective Irradiance 5 min. exposure limit (mW/cm^2)	Operator-Accessible and Maintenance /Service-Accessible SEMI S2-0200 Limit (mW/cm^2)	Result
Left Side, 6.0 inches from Main Viewport	0.00	ACGIH = 10	0.02	PASS
Right Side, 0.8 inch from Secondary Viewport	0.01	ACGIH = 10	0.02	PASS
Right Side, 2.0 inches from Secondary Viewport	0.01	ACGIH = 10	0.02	PASS
Right Side, 6.0 inches from Secondary Viewport	0.00	ACGIH = 10	0.02	PASS

Notes:

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

$\mu W/cm^2$ – microwatts per square centimeter

Exposure limits not applicable to background sample

For the recipe described earlier, UV measurements taken at a distance of 0.8 inches from the viewport were reported to be at the maximum allowable limit of 0.02 $\mu W/cm^2$, as shown in Table 11–2. This distance is the closest approach for the Versys Metal 2300 process module under normal operating conditions, and therefore this measurement indicates compliance with SEMI S2–0200. Limits for operator–accessible areas and maintenance and service areas do not differ. The distance of 0.8 inches should be specified in the equipment manuals as the minimum distance at which an operator or service technician may view the chamber during plasma generation.

All monitoring results were less than 25 percent of the ACGIH TLV for a five minute exposure to UV light.

Infra-Red Radiation

To ensure adherence to SEMI S2–0200 Section 25, the evaluation of the LAM Versys Metal 2300 process module includes an industrial hygiene evaluation of the potential for exposure to infra–red (IR) light. Measurements were recorded during normal operation of the process module. Non-ionizing radiation in the IR wavelength range is produced during process plasma generation.

IR was measured using an International Light 1400A Radiometer survey meter (SN 3034) with a SEL 623 detector (SN 462). Measurements were recorded during use of the recipe described above. Readings in milliwatts per square centimeter (mW/cm^2) were recorded at various distances from the outside skin that shields the quartz glass viewport (with protective mesh). IR radiation monitoring results and the relevant reference standards are presented in Table 11–3.

Monitoring results presented in Table 11–3 are below the SEMI S2-0200 limits.

Table 11–3. Infra-Red Light Survey Results

Area/description	IR reading (mW/cm^2)	ACGIH TLV effective irradiance exposure > 1000 seconds (mW/cm^2)	Operator-accessible and maintenance/ service-accessible SEMI S2-0200 Limit (mW/cm^2)	Result
Left Side, 0.8 inch from Main Viewport	0.155	ACGIH = 10	2.0	PASS
Left Side, 2.0 inches from Main Viewport	0.135	ACGIH = 10	2.0	PASS
Left Side, 6.0 inches from Main Viewport	0.047	ACGIH = 10	2.0	PASS
Right Side, 0.8 inch from Secondary Viewport	0.046	ACGIH = 10	2.0	PASS
Right Side, 2.0 inches from Secondary Viewport	0.036	ACGIH = 10	2.0	PASS

Table 11–3. Infra-Red Light Survey Results (continued)

Area/description	IR reading (mW/cm^2)	ACGIH TLV effective irradiance exposure > 1000 seconds (mW/cm^2)	Operator-accessible and maintenance/ service-accessible SEMI S2-0200 Limit (mW/cm^2)	Result
Right Side, 6.0 inches from Secondary Viewport	0.025	ACGIH = 10	2.0	PASS

Notes:

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

$mWcm^2$ – milliwatts per square centimeter

Radio Frequency Induced Fields

The evaluation of the LAM Versys Metal 2300 process module includes the industrial hygiene evaluation of the potential for exposure to non-ionizing radio frequency (RF) radiation. Measurements were recorded during normal operation of the process module. All panels, mesh screens and protective covers were in place while measurements were being taken.

RF energy was measured using a Narda Model 8511 Broadband survey meter and applicable electric and magnetic field probes for the TCP and BIAS RF generators. Both generators operate at a frequency of 13.56 MHz and were in use during data collection. Measurements were taken during the process cycle at a distance of approximately 2 inches from the measurement area and included cables, cable connections, power sources and match areas. Specific sampling locations, non-ionizing radiation monitoring data and the relevant reference standards are detailed in Table 11–4.

All of the monitoring results for electric and magnetic fields induced by each of the 13.56 MHz non-ionizing RF radiation matches were less than the OELs specified in the S2–0200 Operator and Maintenance/Service Accessible limits.

Table 11–4. Non-Ionizing RF 13.56 MHz Survey Results

Area/description	Result field	Readings (mW/cm^2)	ACGIH TLV plane wave power (S) 6 minute-exposure (mW/cm^2)	OSHA PEL (6 minutes) (mW/cm^2)	Operator-accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)	Maintenance/service-accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)
Front of TCP match	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Connector at TCP Match	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Along Length of TCP Cable	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Front of TCP Generator	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Front of BIAS Match	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Connector at BIAS Match	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Along Length of BIAS Cable	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Front of BIAS Generator	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Front Side of Process Module	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88

Table 11–4. Non-Ionizing RF 13.56 MHz Survey Results (continued)

Area/description	Result field	Readings (mW/cm^2)	ACGIH TLV plane wave power (S) 6 minute-exposure (mW/cm^2)	OSHA PEL (6 minutes) (mW/cm^2)	Operator-accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)	Maintenance/service-accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)
Right Side of Process Module	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Left Side of Process Module	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88

Notes:

ACGIH – American Conference of Governmental Industrial Hygienists

TLV - Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL - Permissible Exposure Limit

mW/cm^2 – milliwatts per square centimeter

ACGIH electric field TLV: Electric Field Strength (E) = 1842 / f = 1842 / 13.56 = 135.84 V/m. 13.56 MHz plane-wave power density (S) = $E^2 / 3770 = (135.84)^2 / 3770 = 4.89$ mW/cm^2

ACGIH magnetic field TLV: Magnetic Field Strength (H) = 16.3 / f = 16.3 / 13.567 = 1.202 A/m. 13.56 MHz plane-wave power density (S) = $37.7(H)^2 = 37.7 (1.202)^2 = 54.47$ mW/cm^2

IEEE C95.1 - Table 1 Maintenance and Service Accessible (controlled environments). Column #4 13.56MHz Power Density (S) = $180 / f^2 = 900 / (13.56)^2 = 0.98$ mW/cm^2 E-field and
S = $10{,}000 / f^2 = 10{,}000 / (13.56)^2 = 54.39$ mW/cm^2 H-field. OEL = 20% (S) = 0.20 mW/cm^2 and
10.88 mW/cm^2 respectively

IEEE C95.1 - Table 2 Operator Accessible (uncontrolled environments). Column #4, 13.56 MHz Power Density (S) = $180 / f^2 = 180 / (13.56)^2 = 4.89$ mW/cm^2 E-field and 10,000 / f^2 = 10,000 / $(13.56)^2$ = 54.39 mW/cm^2 H-field. OEL = 20% (S) = 0.05 mW/cm^2 and 2.74 mW/cm^2 respectively

The measured values also pass the SEMATECH Application Guide guidance limits for uncontrolled environments, specifically 0.49 mW/cm^2 for induced electric fields.

Magnetic Field Strength

No magnets are used in the Versys Metal 2300 process module. Therefore, static magnetic measurements were not recorded.

Sound Pressure Level

The evaluation of the Versys Metal 2300 process module includes an industrial hygiene review for potential exposure to elevated sound pressure levels during operation of the tool. The process module was surveyed and no additional engineering controls such as noise reduction materials were utilized. The survey was performed by initially recording background noise levels followed by measurements recorded adjacent to the tool at the required distances. Sound pressure level was measured using a Quest Sound Level Meter: Model 2400, Serial Number JN7110028.

Table 11–5 presents the results of the sound pressure level survey. Unless otherwise noted, measurements were taken 1.5 meters above the ground and at a horizontal distance of 1 meter from the tool per SEMI S2–0200.

All recorded measurements were below the 80 dBA threshold in SEMI S2–0200 Section 27.1. The maximum expected duration of personnel exposure during normal maintenance activities is eight hours.

Table 11–5. Industrial Hygiene Sound Pressure Level Survey

Location/Description	Reading dBA	SEMI S2-0200 standard (continuous) (dBA)	Result
General Area Background.	68.8[1]	80	PASS[2]
Front Side of Tool	69.2	80	PASS
Right Side of Tool	69.7	80	PASS
Left Side of Tool	71.3	80	PASS
Back Side of Tool	70.3[2]	80	PASS

Note**:**

dBA – decibels, A-weighted scale

1 – Recorded approximately 4.6 meters from process module and approximately 1.2 meters above floor area.

2 – Area measured not directly subject to SEMI S2–0200 Standards. Sound Pressure Levels are not corrected for background noise.

12
Strip Process Module

This chapter provides safety information specific to the strip process module.

For system safety information or for safety information on any other process module for the system, refer to the remainder of this manual.

2300 process modules are operated from the transport module operator interface. For general system operating instructions, see the *2300 Transport Module Operation* manual.

For transport module maintenance information, see the *2300 Transport Module Maintenance* manual.

Interlocks

Process Module Interlocks

The hazardous functions of the strip process module are interlocked as shown in Table 12–1.

Table 12–1. Strip PM Interlocks

Table functions	Top RF power on	Bias RF power on	Chamber gas delivery valve on	Chamber isolation valve open
Foreline pressure sw true				F
Chamber vacuum sw true	H	H	H	
Station x slot valve closed				
TCP coil down sw closed	H	H	H	
TCP RF connector sw closed	H			
TCP match scrubber sw closed	H		H	

Table 12–1. Strip PM Interlocks (continued)

Table functions	Top RF power on	Bias RF power on	Chamber gas delivery valve on	Chamber isolation valve open
TCP match cover sw closed	H		H	
Bias match cover sw closed		H		
Bias match connector sw closed		H		
Bias match interface box closed		H		
Precharge manifold at vacuum			H	
No customer gas detect			H	
No customer interlock			H	

H = hardware human safety interlock

F = firmware equipment safety interlock

Describing the Interlocks

Enclosure Hardware Interlocks

The following enclosures are equipped with interlocks that disconnect AC power to the PM if activated. These interlocks are all in series in the 24 VAC interlock circuit.

- The cover for the AC power distribution enclosure
- The cover for the DC power distribution enclosure

Process Module Hardware and Firmware Interlocks

All hardware and firmware interlocks on the PM have redundant software interlocks also. The following table lists the various PM interlocks implemented in hardware and firmware (as well as software) and the process that they interlock.

Table 12–2. PM Hardware Interlocks

Interlock Switches/ DI ID no./ Conditions	Foreline vacuum sw true	Chamber vacuum sw true	Station X slot valve closed	Bias match interface box switch	Water leak sensor true	DI water leak sensor	TCP coil down switch closed	TCP RF connector sw closed	TCP match scrubber sw closed	TCP match cover sw closed	Bias match cover sw close	Bias match RF connector sw closed	Precharge manifold at vacuum	No Customer gas detect	No Customer Interlock
P&ID designation		CM2S 1						PS4							
	node1	node1	node1	node1	node1	node1	VIOP	VIOP	VIOP	VIOP	VIOP	VIOP	node3	node3	node3
	DI6	DI3	DID	DIE	DI10	DI11	DI3	DI4	DI5	DI2	DI17	DI18	DI2	DI6	D17
	CR1-B	CR1-A	CR6-B		CR2-C			CR3-C							
Enable the following functions when the PM is in process mode															
TCP RF power on		H					H	H	H	H					
Bias RF power on		H		H			H				H	H			
Chamber gas delivery valve on		H	H				H		H	H			H	H	H
Chamber Iso valve open	F														
Main water control valve					H										
VoDM primary shutoff valve						H									

Note: H =Hardware interlock, relay used on the board. F = Firmware interlock, opto-couples used on the board

LEDs Location (top of the board)

TM Slot Valve	He Max Flow Switch	He/RF Enclosure Cover Switch	Chamber ATM switch	Gas Ring Down Switch	Chamber Vacuum Switch	Foreline Vacuum Switch	Chamber Pressure Switch
CR2-D	CR2-C	CR2-B	CR2-A	CR1-D	CR1-C	CR1-B	CR1-A
TMP Exh Valve Open	Hardware Bypass ON	Bias RF Connector Switch	Bias Match Covers Switches	TCP Match Covers Switches	TCP Match Scrubber Switch	TCP RF Connector Switch	Coil Enclosure Down Switch
CR4-D	CR4-C	CR4-B	CR4-A	CR3-D	CR3-C	CR3-B	CR3-A
Not used	Not used	Not used	Pendulum Valve Open	Bias RF Interlocks OK	TCP RF Interlocks OK	Chamber Gas Delivery OK	ESC High Voltage On
			CR6-A	CR5-D	CR5-C	CR5-B	CR5-A

DI Lights

Green=Switch is true

No light=Switch is not true

Node 3 (Gas Box) DS3	Node 1 (Chamber) DS1
Node 5 (VME) DS4	Node 2 (Lower Electrode) DS2

Node Connection Lights

Green=connected correctly

Red=not connected or connected wrong

Processes Which Are Interlocked

TCP RF Power On

Table 12–3 shows the hardware interlocks that disable TCP RF power unless they are satisfied.

Table 12–3. TCP RF Power

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
Coil Enclosure Down sw closed	VIOP_DI03
TCP RF connector sw closed	VIOP_DI04
TCP Match scrubber sw closed	VIOP_DI05
TCP Match cover sw closed	VIOP_DI02

Ensure that the PM chamber is at vacuum, which means the pressure is lower than 75 Torr. Make sure that the coil enclosure is in the down position so that RF cannot be generated and expose personnel to dangerous RF. Ensure that the TCP RF generator is connected to the TCP Matching Network and the house supplied scrubber is operational so that the pressure differential between inside the coil enclosure and ambient pressure is met. Make sure that all of the covers are in place on the TCP enclosure.

Additionally, the RF generator has an internal temperature interlock. Ensure that the interlock does not trip due to excessive heat.

Bias RF Power On

Table 12–4 shows the hardware interlocks that disable Bias RF power unless they are satisfied.

Table 12–4. Bias RF Power On

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
He/RF enclosure cover sw closed	node2_DI2

Table 12–4. Bias RF Power On (continued)

Interlock state	Hardware
Helium maximum flow sw true	node2_DI3
Coil Enclosure Down sw closed	VIOP_DI03
Bias Match cover sw closed	VIOP_DI17
Bias Match RF Connector sw closed	VIOP_DI18

ESC Power On

Table 12–5 shows the hardware interlocks that disable ESC power unless they are satisfied:

Table 12–5. ESC Power On

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
He/RF enclosure cover sw closed	node2_DI2
Bias Match cover sw closed	VIOP_DI17

The vacuum switch prevents you from operating the ESC when the chamber is at atmosphere, opened, and exposes personnel to dangerous voltages. The covers on the He/RF enclosure and the bias match prevent exposure to RF radiation.

Chamber Gas Delivery

Table 12–6 shows the hardware interlocks that disable delivery of process gas from the gas box to the reaction chamber unless they are satisfied:

Table 12–6. Chamber Gas Delivery

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3
Gas Ring sw closed	node1_DI6
Station X slot valve closed	node2_DIA
Coil Enclosure Down sw closed	VIOP_DI03

Table 12–6. Chamber Gas Delivery (continued)

Interlock state	Hardware
TCP Match scrubber sw closed	VIOP_DI05
TCP Match cover sw closed	VIOP_DI02
Precharge manifold at vacuum	node3_DI2
No Customer gas detect	node3_DI6
No Customer interlock	node3_DI7

The precharge manifold vacuum switch is located inside of the gas box. The two customer specific I/Os are available for the customer's use to connect external switches to the process modules to act as interlocks.

Pendulum Valve Open

Table 12–7 shows the firmware interlocks that do not allow the pendulum valve to open unless they are satisfied:

Table 12–7. Pendulum Valve Open

Interlock state	Hardware
Chamber pressure sw true	node1_DI0
Foreline pressure sw true	node1_DI2

The chamber pressure switch prevents you from opening the pendulum valve if the chamber pressure is greater than 500 mtorr. This prevents damage to the turbo pump. The pendulum valve is additionally interlocked to the foreline pressure switch which monitors pressure in the foreline and is a measure of how well the roughing pump is pumping.

Turbo Exhaust Valve Open

Table 12–8 shows the firmware interlock that does not allow the turbo exhaust valve to open unless it is satisfied:

Table 12–8. Turbo Exhaust Open

Interlock state	Hardware
Foreline pressure sw true	node1_DI2

Opening the foreline exhaust valve at a pressure above 750 mtorr could damage the turbo pump. The foreline pressure switch measures pressure in the foreline and prevents this from happening.

PM Heater Power Interlock

The AC/DC power distribution enclosure provides contactor K1 to interrupt AC power to the system heaters. This contactor is enabled by a combination RTD over-temperature sensors, the temperature monitor board (TMB) of the Anafaze temperature controller, and ground fault interrupter (GFI) T1. All over-temperature sensors for all controlled heaters, and GFI sensor must be safe to enable AC power to heaters.

Thermal Interlock

The foreline manifold heaters are temperature regulated 208 VAC heaters, which employ bi-metallic over-temperature switches set at 100 degrees Celsius to disconnect heater power in the event of a thermal runaway.

Wafer Transfer Slot Valve Interlock

The wafer transfer slot valve is interlocked. This interlock helps to isolate gases in the reaction chamber. Signals are sent from the PM to the TM, so that the TM does not open the slot valve when the PM is at atmosphere and the TM is at vacuum.

Gas Box Hardware Interlocks

To protect personnel from exposing to toxic gases, the interlock circuitry must rely only on the dual compliant electro-mechanical devices.

Table 12–9 shows the gas panel functional interlocks.

Table 12–9. Gas Box Hardware Interlocks

		Inputs							
		Chamber delivery valve ok contact closure from PM interlock board	Roughing Pump ok contact Closure from PM interlock board	Precharge Manifold at VAC	Chamber Delivery at VAC	Differentia l pressure SW ok	N2 Purge Supply	Customer Gas Detect	Customer Interlock SW ok
				PSH2	PSH3	PSH8	PSH9	IS20	IS21
				DI2	DI3	DI4	DI5	DI6	DI7
SOVNo.	*Enable following function*								
SOV1	N2 Primary valve on						X	X	X
SOV2	Vacuum Primary valve on		X	X				X	X
SOV3	Gas Manifold Purge valve on						X	X	X
SOV4	Gas Manifold Precharge valve on		X	X				X	X
SOV5	Chamber gas delivery valve on	X	X	X				X	X
SOV7	Chamber slow vent						X	X	X
SOV8	Chamber wafer transfer						X	X	X
SOV9	Chamber N2 valve on						X	X	X
SOV10-80	All gas primary valve on				X	X		X	X
SOV12-82	All gas secondary valve on				X	X		X	X

SOVx refers to the shutoff valve in the gas box.

SOV1 Nitrogen Primary Valve On

Table 12–10 shows the following interlocks that prevent the opening of the nitrogen primary valve unless they are true.

Table 12–10. SOV1

Interlock	Number	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	S20
Customer Interlock SW ok	DI7	IS21

Interlocked unless opening by the pressure switch for the nitrogen purge supply (PSH9). Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered short.

SOV2 Vacuum Primary Valve On

Table 12–11 shows the following interlocks that prevent the opening of the vacuum primary valve unless they are true.

Table 12–11. SOV2

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold @ VAC	DI2	PSH2
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV3 Gas Manifold Purge valve on

Table 12–12 shows the following interlocks that prevent the opening of the gas manifold purge primary valve unless they are true.

Table 12–12. SOV3

Interlocks	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

These valves are interlocked unless opening by the pressure switch for the nitrogen purge supply (PSH9). Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered “short”.

SOV4 Gas Manifold Precharge Valve On

Table 12–13 shows the following interlocks that prevent the opening of the gas manifold precharge valve unless they are true.

Table 12–13. SOV4

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board	-	-
Precharge Manifold @ VAC	DI2	PSH2
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV5 Chamber Gas Delivery Valve On X

Table 12–14 shows the following interlocks that prevent the opening of the chamber gas delivery valve unless they are true.

Table 12–14. SOV5

Interlock	Hardware	Switch
Chamber delivery valve ok contact closure from PM interlock board.		
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold @ VAC	DI2	PSH2
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV7 Chamber Slow Vent

Table 12–15 shows the following interlocks that prevent the opening of the chamber slow vent valve unless they are true.

Table 12–15. SOV7

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV8 Chamber Wafer Transfer

Table 12–16 shows the following interlocks that prevent the opening of the chamber wafer transfer valve unless they are true.

Table 12–16. SOV8

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV9 Chamber N2 Valve On

Table 12–17 shows the following interlocks that prevent the opening of the chamber N2 valve unless they are true.

Table 12–17. SOV9

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

SOV10-80 All Gas Primary Valve On

Table 12–18 shows the following interlocks that prevent the opening of the all gas primary valve unless they are true.

Table 12–18. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

Gas is prevented from going to the PM from the gas box if the chamber is not vacuum as read through vacuum switch (PSH3) and if the differential pressure switch (PSH8) in the coil enclosure is not true.

SOV12-82 All Gas Secondary Valve On

Table 12–19 shows the following interlocks that prevent the opening of the all gas secondary valve unless they are true.

Table 12–19. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure SW ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock SW ok	DI7	IS21

RF Energy

To be supplied.

Chemicals

Chemicals Used During Maintenance

The following chemicals are used during each wet clean of the Strip Module 2300 system:

- Isopropyl alcohol (IPA) (3 to 6 ounces)
- Di water (H_2O) (30 ounces)
- Hydrogen peroxide solution (for tungsten only)
- Fomblin grease
- Hydrogen fluoride

Chemicals Used During the Etch Process

To be supplied.

13
Strip PM Industrial Hygiene Report

This chapter lists the industrial hygiene test results of the strip process module on the 2300 platform.

Test Parameters and Procedures

The following test equipment and test criteria were employed during testing of the Strip Module 2300 system.

Table 13–1. Test Equipment and Test Criteria

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Infra-Red (IR) radiation	International Light 1400A Radiometer	ACGIH TLV Effective Irradiance (exposure > 1000 seconds = 10 mW/cm^2 SEMI S2–0200 Operator-Accessible and Maintenance/Service - Accessible Limit (20% of ACGIH limit) = 2.0 mW/cm^2
Ultra-Violet (UV) Radiation	International Light 1400A Radiometer	ACGIH TLV Effective Irradiance, 5 minutes Exposure = 10 $\mu W/cm^2$) SEMI S2–0200 Operator-Accessible and Maintenance/Service - Accessible Limit = 0.02$\mu W/cm^2$

Table 13–1. Test Equipment and Test Criteria (continued)

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Radio-Frequency (RF) Induced Electric and Magnetic Fields	Narda, Model 8511 Electric and Magnetic Field Probes	ACGIH TLV 6 Minutes Exposure Limit = 4.89 and 54.47 mW/cm^2 for Electric and Magnetic Fields respectively. OSHA PEL 6 Minute Exposure Limit = 10 mW/cm^2 for both Electric and Magnetic Fields. SEMI S2-0200 Operator-Accessible Limit (20% of IEEE/ANSI C95.1-1999 Uncontrolled Limit) = 0.20 and 10.88 mW/cm^2 for Electric and Magnetic Fields respectively. SEMI S2-0200 Maintenance/Service-Accessible Limit (20% of IEEE/ANSI C95.1-1999 Controlled Limit) = 0.98 and 10.88 mW/cm^2 for Electric and Magnetic Fields respectively.
Sound Pressure Level	OSHA Quest Q2400 Sound Level Meter Direct Reading Meter	80 dBA SEMI S2–0200 Section 27.1

Notes:

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL – Permissible Exposure Limit

ANSI –American National Standards Institute

IEEE –Institute of Electrical and Electronics Engineers mW/cm^2 – milliwatts per square centimeter

μW/cm^2 – microwatts per square centimeter

dB(A) – decibels (Audio), A scale

Test Result

Chemical Exposure

Chemical exposure sampling and analysis was not conducted as part of this evaluation.

Ultra-Violet Radiation

UV light was measured using an International Light 1400A Radiometer survey meter (SN 3034) with a SEL 240 detector (SN 4438). Measurements were recorded throughout the normal recipe for cycling of wafers. The maximum power of 1250 watts for the clean recipe was in use during the testing. Levels were recorded in microwatts per centimeter squared (μW/cm2) for UV at various distances from the outside skin that shields the quartz glass viewport (with protective mesh). The non-ionizing radiation monitoring results and the relevant reference standards for UV radiation are presented in Table 13–2.

Table 13–2. UV Light Survey Results

Area/Description	UV Reading (mW/cm^2)	ACGIH TLV Effective Irradiance 5 min. exposure limit (mW/cm^2)	Operator-Accessible and Maintenance/Service-Accessible SEMI S2-0200 Limit (mW/cm^2)	Result
Ambient background in work area	NA	ACGIH = 10	0.02	PASS
Front side, 0.0 inch from upper fan	0.02	ACGIH = 10	0.02	PASS

Table 13–2. UV Light Survey Results (continued)

Area/Description	UV Reading (mW/cm^2)	ACGIH TLV Effective Irradiance 5 min. exposure limit (mW/cm^2)	Operator-Accessible and Maintenance/Service-Accessible SEMI S2-0200 Limit (mW/cm^2)	Result
Front side, 0.8 inch from upper fan	0.01	ACGIH = 10	0.02	PASS
Front side, 2.0 inches from upper fan	0.00	ACGIH = 10	0.02	PASS
Front side, 6.0 inches from upper fan	0.00	ACGIH = 10	0.02	PASS
Front side, 0.0 inch from lower fan	0.01	ACGIH = 10	0.02	PASS
Front side, 0.8 inch from lower fan	0.01	ACGIH = 10	0.02	PASS
Front side, 2.0 inches from lower fan	0.00	ACGIH = 10	0.02	PASS
Front side, 6.0 inches from lower fan	0.00	ACGIH = 10	0.02	PASS
Right side, 0.0 inch from TCP grill	0.01	ACGIH = 10	0.02	PASS
Right side, 0.8 inch from TCP grill	0.00	ACGIH = 10	0.02	PASS
Right side, 2.0 inches from TCP grill	0.00	ACGIH = 10	0.02	PASS
Right side, 6.0 inches from TCP grill	0.00	ACGIH = 10	0.02	PASS
Left side, 0.8 inch from viewport	0.00	ACGIH = 10	0.02	PASS
Left side, 2.0 inches from viewport	0.00	ACGIH = 10	0.02	PASS
Left side, 6.0 inches from viewport	0.00	ACGIH = 10	0.02	PASS

Notes:

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

μW/cm^2 – microwatts per square centimeter

Exposure limits not applicable to background sample

For the recipe described earlier, maximum UV measurements taken at a distance of 0.8 inch from the respective measurement location were reported to be 0.01 μW/cm^2, as shown in Table 13–2. This distance is judged to be that of the closest approach for the Strip Module 2300 system under normal operating conditions, and therefore this measurement indicates compliance with SEMI S2–0200. Limits for Operator–accessible areas and Maintenance and Service areas do not differ.

All monitoring results were found to be less than 25 percent of the ACGIH TLV for a five minute exposure to UV light.

Infra-Red Radiation

To ensure adherence to SEMI S2–0200 Section 25, the evaluation of the Strip Module 2300 system includes an industrial hygiene evaluation of the potential for exposure to Infra–Red (IR) light. Measurements were recorded during normal operation of the process module. Non-ionizing radiation in the IR wavelength range is produced during process plasma generation.

IR was measured using an International Light 1400A Radiometer survey meter (SN 3034) with a SEL 623 detector (SN 462). The maximum power of 1250 watts for the clean recipe was in use during the testing. Measurements were recorded during use of the recipe described above. Readings in milliwatts per square centimeter (mW/cm^2) were recorded at various distances from the outside skin that shields the quartz glass viewport (with protective mesh). IR radiation monitoring results and the relevant reference standards are presented in Table 13–3.

Monitoring results presented in Table 13–3 are below the SEMI S2-0200 limits.

Table 13–3. Infra-Red Light Survey Results

Area/Description	IR reading (mW/ cm^2)	ACGIH TLV effective irradiance exposure > 1000 seconds (mW/cm^2)	Operator-accessible and maintenance /service-accessible SEMI S2-0200 Limit (20% of ACGIH limit) (mW/cm^2)	Result
Ambient background in work area	NA	ACGIH = 10	2.0	PASS
Front side, 0.0 inch from upper fan	0.03	ACGIH = 10	2.0	PASS
Front side, 0.8 inch from upper fan	0.02	ACGIH = 10	2.0	PASS
Front side, 2.0 inches from upper fan	0.01	ACGIH = 10	2.0	PASS
Front side, 6.0 inches from upper fan	< 0.06	ACGIH = 10	2.0	PASS
Front side, 0.0 inch from lower fan	0.02	ACGIH = 10	2.0	PASS
Front side, 0.8 inch from lower fan	0.02	ACGIH = 10	2.0	PASS
Front side, 2.0 inches from lower fan	0.02	ACGIH = 10	2.0	PASS
Front side, 6.0 inches from lower fan	0.01	ACGIH = 10	2.0	PASS
Right side, 0.0 inch from TCP grill	0.41	ACGIH = 10	2.0	PASS
Right side, 0.8 inch from TCP grill	0.40	ACGIH = 10	2.0	PASS
Right side, 2.0 inches from TCP grill	0.02	ACGIH = 10	2.0	PASS

Table 13–3. Infra-Red Light Survey Results (continued)

Area/Description	IR reading (mW/ cm^2)	ACGIH TLV effective irradiance exposure > 1000 seconds (mW/cm^2)	Operator-accessible and maintenance /service-accessible SEMI S2-0200 Limit (20% of ACGIH limit) (mW/cm^2)	Result
Right side, 6.0 inches from TCP grill	0.01	ACGIH = 10	2.0	PASS
Left side, 0.8 inch from viewport	0.062	ACGIH = 10	2.0	PASS
Left side, 2.0 inches from viewport	0.060	ACGIH = 10	2.0	PASS
Left side, 6.0 inches from viewport	0.060	ACGIH = 10	2.0	PASS

Notes:

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

mWcm^2 – milliwatts per square centimeter

< – Not detected at or above limit stated. Detection limit is approximate. Exposure limits not applicable to background sample.

Radio Frequency

The evaluation of the Strip Module 2300 system includes the industrial hygiene evaluation of the potential for exposure to non-ionizing Radio Frequency (RF) radiation. Measurements were recorded during normal operation of the process module. All panels, mesh screens and protective covers were in place while measurements were being taken.

RF energy was measured using a Narda Model 8511 Broadband survey meter (SN02009) and applicable electric and magnetic field probes for the TCP RF generator. The generator operates at a frequency of 13.56

MHz and the maximum power of 1250 watts for the clean recipe was in use during the testing. Measurements were taken during the process cycle at a distance of approximately 2 inches from the measurement area and included cables, cable connections, power sources, and so on. Specific sampling locations, non-ionizing radiation monitoring data and the relevant reference standards are detailed in Table 13–4.

All of the monitoring results for electric and magnetic fields induced by the 13.56 MHz non-ionizing TCP RF radiation generator were less than the OELs specified in the S2–0200 Operator and Maintenance/Service Accessible limits.

Table 13–4. Non-Ionizing 13.56 MHz RF Survey Results

Area/description	Result Field	Readings (mW/ cm^2)	ACGIH TLV plane wave power (S) 6 minute-exposure (mW/ cm^2)	OSHA PEL (6 minutes) (mW/ cm^2)	Operator accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)	Maintenance/service-accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)
Front side of process module	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Back side of process module	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Right side of process module	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Left side of process module	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Front side, upper fan	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Front side, lower fan	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Right side, TCP grill	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88

Table 13–4. Non-Ionizing 13.56 MHz RF Survey Results (continued)

Area/description	Result Field	Readings (mW/cm^2)	ACGIH TLV plane wave power (S) 6 minute-exposure (mW/cm^2)	OSHA PEL (6 minutes) (mW/cm^2)	Operator accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)	Maintenance/service-accessible SEMI S2-0200 limit (20% of OEL) (mW/cm^2)
Connection to upper chamber	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
At cable connection to generator	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88
Along length of cable	E Field	<0.01	4.89	10	0.20	0.98
	H Field	<0.01	54.47	10	10.88	10.88

Notes:

ACGIH – American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL – Permissible Exposure Limit

OEL – Occupational Exposure Limit

mW/cm^2 – milliwatts per square centimeter

< – not detected at or above limit stated. All measurements were taken approximately 2 inches from indicated location.

ACGIH electric field TLV: Electric Field Strength (E) = 1842 / f = 1842 / 13.56 = 135.84 V/m. 13.56 MHz plane-wave power density (S) = E^2 / 3770 = $(135.84)^2$ / 3770 = 4.89 mW/cm^2

ACGIH magnetic field TLV: Magnetic Field Strength (H) = 16.3 / f = 16.3 / 13.567 = 1.202 A/m. 13.56 MHz plane-wave power density (S) = $37.7(H)^2$ = 37.7 $(1.202)^2$ = 54.47 mW/cm^2

IEEE C95.1 - Table 1 Maintenance and Service Accessible (controlled environments). Column #4 13.56MHz Power Density (S) = 180 / f^2 = 900 /

$(13.56)^2$ = 0.98 mW/cm^2 E-field and
S = 10,000 / f^2 = 10,000 / $(13.56)^2$ = 54.39 mW/cm^2 H-field. OEL = 20% (S) = 0.20 mW/cm^2 and
10.88 mW/cm^2 respectively

IEEE C95.1 - Table 2 Operator Accessible (uncontrolled environments). Column #4, 13.56 MHz Power Density (S) = 180 / f^2 = 180 / $(13.56)^2$ = 4.89 mW/cm^2 E-field and 10,000 / f^2 = 10,000 / $(13.56)^2$ = 54.39 mW/cm^2 H-field. OEL = 20% (S) = 0.05 mW/cm^2 and 2.74 mW/cm^2 respectively

Magnetic Field Strength

No magnets are used in the Strip Module 2300 system. Therefore, static magnetic measurements were not recorded.

Sound Pressure Level

The evaluation of the Strip Module 2300 system includes an industrial hygiene review for potential exposure to elevated sound pressure levels during operation of the tool. The process module was surveyed and no additional engineering controls such as noise reduction materials were utilized. The survey was performed by initially recording background noise levels followed by measurements recorded adjacent to the tool at the required distances. Sound pressure level was measured using a Quest Sound Level Meter: Model 2400, Serial Number JN7110028.

Table 13–5 presents the results of the sound pressure level survey. Unless otherwise noted, measurements were taken 1.5 meters above the ground and at a horizontal distance of 1 meter from the tool per SEMI S2–0200.

All recorded measurements were below the 80 dBA threshold in SEMI S2–0200 Section 27.1. The maximum expected duration of personnel exposure during normal maintenance activities is eight hours since the measured sound pressure levels exceeded 75 dBA, information should be provided in the equipment maintenance manual describing the sound pressure and locations.

Table 13–5. Industrial Hygiene Sound Pressure Level Survey

Location/Description	Reading dBA	SEMI S2-0200 standard (continuous) (dBA)	Result[2]
General Area Background[1]	79.0	80	PASS
Front Side of Tool	78.1	80	PASS
Right Side of Tool, 0.61 meter away	79.8	80	PASS
Left Side of Tool	79.8	80	PASS
Rear Side of Tool, 0.3 meter away	78.0	80	PASS

Note**:**

dBA – decibels, A-weighted scale

Recorded approximately 4.6 meters from process module.

1 – Area measured not directly subject to SEMI S2–0200 Standards.

2 – Sound Pressure Levels are not corrected for background noise.

14
Exelan 2300 Process Module

This chapter provides safety information specific to the Exelan 2300 process module.

For system safety information or for safety information on any other process module for the system, refer to the remainder of this manual.

2300 process modules are operated from the transport module operator interface. For general system operating instructions, see the *2300 Transport Module Operation* manual.

For transport module maintenance information, see the *2300 Transport Module Maintenance* manual.

Interlocks

Process Module AC Power Interlocks

The following enclosures are equipped with interlocks that disconnect AC power to the PM if activated. These interlocks are all in series in the 24 VAC interlock circuit.

- The cover for the AC power distribution enclosure
- The cover for the DC power distribution enclosure

Process Module Hardware and Firmware Safety Interlocks

All hardware and firmware interlocks on the PM also have redundant software interlocks. Table 14–1 lists the various PM interlocks implemented in hardware and firmware (as well as software) and the process that they interlock.

Table 14–1. PM Hardware Interlocks

		Interlock switches/ DI ID no./ conditions															
		Chamber pressure switch true (<500mT)	Foreline pressure switch true	Chamber vacuum switch true	Chamber closed switch true	Water leak sensor true	He/RF enclosure cover sw closed	Station X slot valve closed	Chamber scrubber sw closed	No Hydrogen detected	Precharge manifold at vacuum	No Customer gas detect	No Customer Interlock	Hardware itlk bypass DO activate	2 MHz RF generator cover switch	27 MHz RF generator cover switch	RF match cover switch
P&ID designation		CM2S 1	CM3S 1	PS1	SW1				PS4								
		node1	node1	node1	node1	node1	node2	node2	node3	node3	node3	node3	node3				
		DI0	DI2	DI3	DI6	DIC	DI2	DIA	DI5	DI8	DI2	DI6	D17				
	LED on board	CR1-A	CR1-B	CR1-C	CR1-D	CR6-B	CR2-B	CR2-D	CR3-C								
RF power on	(CR5-D)			H	H		H								H	H	H
ESC power on	(CR5-A)			H			H										
Chamber Gas delivery valve on	(CR5-B)			H	H			H	H	H	H	H	H				
*Pendulum valve open	(CR6-A)	F	F														

Table 14–1. PM Hardware Interlocks (continued)

		Interlock switches/ DI ID no./ conditions																
		Chamber pressure switch true (<500mT)	**Foreline pressure switch true**	**Chamber vacuum switch true**	**Chamber closed switch true**	**Water leak sensor true**	**He/RF enclosure cover sw closed**	**Station X slot valve closed**	**Chamber scrubber sw closed**	**No Hydrogen detected**	**Precharge manifold at vacuum**	**No Customer gas detect**	**No Customer Interlock**	**Hardware itlk bypass DO activate**	**2 MHz RF generator cover switch**	**27 MHz RF generator cover switch**	**RF match cover switch**
*Turbo exhaust valve on	(CR4-D)		F														
Main water control valve						H											

Note:

H =Hardware interlock, relay used on the board. F = Firmware interlock, opt-couples used on the board

* This interlock can be bypassed through software while in the maintenance mode.

The interlock board in mounted on the side of the reaction chamber of the process module. It is cabled to the node 1 and 2 boards, the DC control assembly, the VME assembly, the gas box, and the transport module. An array of LEDs along the top of the board provides the status of specific interlocks.

LEDs Location (top of the board)g

TM Slot Valve	Spare	He/RF Enclosure Cover Switch	Chamber ATM switch	Chamber Closed Switch	Chamber Vacuum Switch	Foreline Vacuum Switch	Chamber Pressure Switch (500mT)
CR2-D	CR2-C	CR2-B	CR2-A	CR1-D	CR1-C	CR1-B	CR1-A
TMP Exh Valve Open	Hardware Bypass ON	Spare	Spare	Spare	TCP Match Scrubber Switch	Spare	Spare
CR4-D	CR4-C	CR4-B	CR4-A	CR3-D	CR3-C	CR3-B	CR3-A
Spare	Spare	Main water valve	Pendulum Valve Open OK	RF Interlocks OK	Spare	Chamber Gas Delivery OK	ESC interlock OK
CR6-D	CR6-C	CR6-B	CR6-A	CR5-D	CR5-C	CR5-B	CR5-A

Note: This side up when looking at the LEDs location.

Describing the Process Module Interlock Switches

Chamber Pressure Switch

This switch's location is to be determined (TBD). It is part of the transfer chamber manometer. The switch monitors the pressure inside the chamber. The switch setting is set to trip at 500 mtorr.

Foreline Pressure Switch

This switch is located along the foreline leading to the roughing pump. The switch monitors the pressure in the foreline to ensure that the pump is operating correctly. The switch setting is set to trip at 1 torr.

Chamber Vacuum Switch

This switch's location is TBD. The switch monitors the pressure state inside the chamber. If the chamber is below 75 torr, the chamber is at vacuum and the switch is closed. The switch is in an open state if the pressure is greater than 75 torr.

Chamber Closed Switch

This switch is located on the hoist side of the process module along the top plate. The switch monitors whether or not the top plate is in the down position sealing the chamber. If the top plate is down, the switch is closed. The switch is open when the tip plate is lifted off the chamber.

Water Leak Sensor

This sensor is made up of a special cable used to detect water leaks. The sensor is terminated with a 1.5 kilo ohm resistor. The sensor cable originates a the Leak Detect printed circuit board (PCB) which is located above Node 1. The cable is routed from the Leak Detect PCB to the following locations:

- Top plate water tray to monitor leaks from the top plate water fittings. This tray is located along the top plate on the hoist side of the PM.
- Bottom water tray to monitor leaks from the 2 MHz generator fittings. This tray is located along underneath the 2 MHz generator towards the rear of the PM.
- Manifold water tray to monitor leaks from the water manifold assembly. This tray is located below the water manifold towards the rear of the PM.
- Top water tray to monitor leaks from the 27 MHz generator and turbo pump fittings. This tray is located on the top of the 2 MHz generator.

He/RF Enclosure Switch

This switch is located on the upper right corner of the He/RF main cover. This cover protects personnel from dangers associated with the RF match and the ESC power supply. When the cover is properly installed, the switch is in a closed position. The switch is open if the cover is removed or not installed properly.

Station X Slot Valve Switch

This switch is located at the slot valve opening between the PM and TM. This switch monitors the position of the slot valve. If the slot valve is in the closed or up position, isolating the PM from the TM, the switch is in the closed position. If the slot valve is down, the switch is open.

Chamber Scrubber Switch

This switch isolated on the top plate within the wafer area pressure (WAP) enclosure. The switch monitors the pressure within the WAP enclosure relative to the pressure outside the enclosure. The switch is used to verify that the scrubber exhaust has been properly installed. If the scrubber exhaust is working properly, the pressure within the WAP enclosure will be lower than the pressure outside the WAP enclosure and the switch will be closed. If the scrubber exhaust is not functioning properly, the switch will be open.

2 MHz Generator Cover Interlock

This interlock switch is located inside the 2 MHz generator and is used to verify that the 2 MHz cover is properly installed. If the cover is installed properly, the switch is closed. If the cover is missing or improperly installed, the switch will be open.

27 MHz Generator Cover Interlock

This interlock switch is located inside the 27 MHz generator and is used to verify that the 27 MHz cover is properly installed. If the cover is installed properly, the switch is closed. If the cover is missing or improperly installed, the switch will be open.

RF Match Cover Interlock

This interlock switch is located inside the RF match and is used to verify the match cover is properly installed. If the cover is installed properly, the switch is closed. If the cover is installed properly, the switch is closed. If the cover is missing or improperly installed, the switch will be open.

Processes Which Are Interlocked

RF Power On

Table 14–2 shows the hardware interlocks that disable RF power unless they are satisfied.

Table 14–2. RF Power On

Interlock state	Hardware
Chamber vacuum sw true	node1_DI3
He/RF enclosure cover sw closed	node2_DI2
Chamber closed sw true	node1_DI6

Ensure that the PM chamber is at vacuum, which means the pressure is lower than 75 Torr. Make sure that all of the covers are in place on the He/RF enclosure. Ensure that the chamber top plate is in the down position, activating the chamber closed switch.

Additionally, the RF generator has an internal temperature interlock. Ensure that the interlock does not trip due to excessive heat.

ESC Power On

Table 14–3 shows the hardware interlocks that disable ESC power unless they are satisfied:

Table 14–3. ESC Power On

Interlock state	Hardware
Chamber Vacuum sw True	node1_DI3

Table 14–3. ESC Power On (continued)

Interlock state	Hardware
He/RF enclosure cover sw closed	node2_DI2

The vacuum switch prevents you from operating the ESC when the chamber is at atmosphere to prevent exposing personnel to dangerous voltages in case the chamber is open. The cover on the He/RF enclosure prevents exposure to hazardous high voltage.

Chamber Gas Delivery

Table 14–4 shows the hardware interlocks that disable delivery of process gas from the gas box to the reaction chamber unless they are satisfied:

Table 14–4. Chamber Gas Delivery

Interlock state	Hardware
Chamber Vacuum sw true	node1_DI3
Chamber closed sw true	node1_DI6
Station X slot valve closed	node2_DIA
Chamber scrubber sw closed	VIOP_DI05
Precharge manifold at vacuum	node3_DI2
No Customer gas detect	node3_DI6
No Customer interlock	node3_DI7
Hydrogen interlock ok	node3_D18

The chamber must be at vacuum and closed to allow gas delivery and prevent personnel from being exposed to hazardous chemicals. The slot valve between the PM and TM must be closed to prevent contamination. The chamber scrubber switch, located in the wafer area pressure (WAP) enclosure, must be closed to ensure that the scrubber is operational so that the personnel are not exposed to hazardous chemicals.

The precharge manifold vacuum switch is located inside of the gas box. The two customer specific I/Os are available for the customer's use to connect external switches to the process modules to act as interlocks. A separate interlock is available for hydrogen equipment.

Pendulum Valve Open

Table 14–5 shows the firmware interlocks that do not allow the pendulum valve to open unless they are satisfied:

Table 14–5. Pendulum Valve Open

Interlock state	Hardware
Chamber pressure sw true	node1_DI0
Foreline pressure sw true	node1_DI2

The chamber pressure switch prevents you from opening the pendulum valve if the chamber pressure is greater than 500 mtorr. This prevents damage to the turbo pump. The pendulum valve is additionally interlocked to the foreline pressure switch which monitors pressure in the foreline is maintained below 750 mtorr and is a measure of how well the roughing pump is pumping.

Turbo Exhaust Valve Open

Table 14–6 shows the firmware interlock that does not allow the turbo exhaust valve to open unless it is satisfied:

Table 14–6. Turbo Exhaust Open

Interlock state	Hardware
Foreline pressure sw true	node1_DI2

Opening the foreline exhaust valve at a pressure above 750 mtorr could damage the turbo pump. The foreline pressure switch measures pressure in the foreline and prevents this from happening.

Wafer Transfer Slot Valve Interlock

The wafer transfer slot valve is interlocked. This interlock helps to isolate gases in the reaction chamber. Signals are sent from the PM to the TM, so that the TM does not open the slot valve when the PM is at atmosphere and the TM is at vacuum.

Main Water Control Valve

The main water control valve, which is controlled by SOV1-5B, is interlocked to the leak sensor. The leak sensor monitors the top plate water fittings, 27MHz generator water fittings, the TMP water fittings and the 2MHz water fittings for leaks. If a water leak is detected, the SOV1-5B is shut off, turning off all the water supply to the PM. The water will remain off until the alarm is acknowledged and the sensors become dry.

Gas Box Hardware Interlocks

To protect personnel from exposing to toxic gases, the interlock circuitry must rely only on the dual compliant electro-mechanical devices.

Table 14–7 shows the gas panel functional interlocks.

Table 14–7. Gas Box Hardware Interlocks

		Inputs							
		Chamber delivery valve ok contact closure from PM interlock board	Roughing Pump ok contact Closure from PM interlock board	Precharge Manifold at 400 Torr	Chamber Delivery at VAC	Differential pressure switch ok	N2 Purge Supply	Customer Gas Detect	Customer Interlock switch ok
				PSH2	PSH3	PSH8	PSH9	IS20	IS21
				DI2	DI3	DI4	DI5	DI6	DI7
SOVNo.	*Enable following function*								
SOV1	N2 Primary valve on						X	X	X
SOV2	Vacuum Primary valve on		X	X				X	X
SOV3	Gas Manifold Purge valve on						X	X	X
SOV4	Gas Manifold Precharge valve on		X	X				X	X
SOV5	Chamber gas delivery valve on	X	X	X				X	X
SOV7	Chamber slow vent						X	X	X
SOV8	Chamber wafer transfer						X	X	X
SOV9	Chamber N2 valve on						X	X	X
SOV10-80	All gas primary valve on				X	X		X	X
SOV12-82	All gas secondary valve on				X	X		X	X

Note: SOVx refers to the shutoff valve in the gas box.

SOV1 Nitrogen Primary Valve On

Table 14–8 shows the following interlocks that prevent the opening of the nitrogen primary valve unless they are true.

Table 14–8. SOV1

Interlock	Number	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	S20
Customer Interlock switch ok	DI7	IS21

The nitrogen primary valve is interlocked against opening unless the nitrogen purge supply pressure switch is true. Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered short.

SOV2 Vacuum Primary Valve On

Table 14–9 shows the following interlocks that prevent the opening of the vacuum primary valve unless they are true.

Table 14–9. SOV2

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold less than 400 mTorr switch true	DI2	PSH2
Differential pressure switch ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

SOV3 Gas Manifold Purge valve on

Table 14–10 shows the following interlocks that prevent the opening of the gas manifold purge primary valve unless they are true.

Table 14–10. SOV3

Interlocks	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

These valves are interlocked. Additionally, the customer has the option of adding up to two external interlocks of their choice. The system ships with these two I/Os jumpered “short”.

SOV4 Gas Manifold Precharge Valve On

Table 14–11 shows the following interlocks that prevent the opening of the gas manifold precharge valve unless they are true.

Table 14–11. SOV4

Interlock	Hardware	Switch
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold less than 400 mTorr	DI2	PSH2
Differential pressure switch ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

SOV5 Chamber Gas Delivery Valve On

Table 14–12 shows the following interlocks that prevent the opening of the chamber gas delivery valve unless they are true.

Table 14–12. SOV5

Interlock	Hardware	Switch
Chamber delivery valve ok contact closure from PM interlock board.		
Roughing Pump ok contact Closure from PM interlock board		
Precharge Manifold less than 400 mTorr	DI2	PSH2
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

SOV7 Chamber Slow Vent

Table 14–13 shows the following interlocks that prevent the opening of the chamber slow vent valve unless they are true.

Table 14–13. SOV7

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

SOV8 Chamber Wafer Transfer

Table 14–14 shows the following interlocks that prevent the opening of the chamber wafer transfer valve unless they are true.

Table 14–14. SOV8

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

SOV9 Chamber N2 Valve On

Table 14–15 shows the following interlocks that prevent the opening of the chamber N2 valve unless they are true.

Table 14–15. SOV9

Interlock	Hardware	Switch
N2 Purge Supply	DI5	PSH9
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

SOV10-80 All Gas Primary Valve On

Table 14–16 shows the following interlocks that prevent the opening of the all gas primary valve unless they are true.

Table 14–16. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure switch ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

Gas is prevented from going to the PM from the gas box if the chamber is not vacuum as read through vacuum switch (PSH3) and if the differential pressure switch (PSH8) within the upper chamber enclosure (near the scrubber exhaust) is true.

SOV12-82 All Gas Secondary Valve On

Table 14–17 shows the following interlocks that prevent the opening of the all gas secondary valve unless they are true.

Table 14–17. SOV12-82

Interlock	Hardware	Switch
Chamber Delivery @ VAC	DI3	PSH3
Differential pressure switch ok	DI3	PSH8
Customer Gas Detect	DI6	IS20
Customer Interlock switch ok	DI7	IS21

RF Energy

RF energy is produced by the Exelan 2300 process module. Table 14–18 shows the power requirements for various applications of the Exelan 2300 process module.

Table 14–18. Dielectric Etch Power Requirements

Process	Process gas	Generator frequency (upper/lower)	Generator power (typical)
BARC open	Ar, CF_4, O_2	27 MHz 2 MHz	800W 100W
SiO_2 Via main etch	Ar, C_4F_8, CH_2F_2, O_2, CF4, CHF3	27 MHz 2 MHz	1000-2500W 1000-3500W
SiN spacer etch	CF4, CHF3, O_2, Ar	27 MHz 2 MHz	1400W 100W
Plasma Clean Step 1	O_2	27 MHz 2 MHz	300-600W 0-300W

Table 14–18. Dielectric Etch Power Requirements (continued)

Process	Process gas	Generator frequency (upper/lower)	Generator power (typical)
Plasma Clean Step 2	O_2, N_2	27 MHz 2 MHz	300-600W 0-300W

Chemicals

Chemicals Used During Maintenance

The following chemicals are used during each wet clean of the Exelan 2300 process module.

- Isopropyl alcohol (IPA) (3 to 6 ounces)
- Deionized water
- Krytox grease

Chemicals Used During the Etch Process

The following chemicals are used during etch process of the Exelan 2300 process module.

- Carbon Tetrafluoride (CF_4)
- Argon (Ar)
- Oxygen (O_2)
- Helium (He)
- Trifluoromethane (CHF_3)
- Nitrogen (N_2)
- Carbon Monoxide (CO)

- Octafluorocyclobutane (C_4F_8)
- Hexafluoropropylene (C_3F_6)
- Difluoromethane (CH_2F_2)

15 Exelan 2300 PM Industrial Hygiene Report

This chapter lists the industrial hygiene test results of the Exelan 2300 process module (PM) on the 2300 platform.

Test Parameters and Procedures

The following test equipment and test criteria were employed during testing of the Exelan 2300 process module.

Table 15–1. Test Equipment and Test Criteria

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Carbon Monoxide (CO)	Interscan 1146 Direct Reading Monitor (Real TIme)	25 ppm TWA for 8 hour exposure period From Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices (1999)
Hydrogen Cyanide (HCN)	Laboratory Analysis, NIOSH 6010	4.7 ppm ceiling for 15 minute exposure period
Hydrogen Fluoride (HF)	MDA TLD-1 Toxic Gas Meter (Real Time) and Laboratory Analysis, NIOSH 7903	3 ppm ceiling
Ultra-Violet (UV) Light	International Light 1400A Radiometer	Operator-Accessible and Maintenance/Service - Accessible SEMI S2–0200 Limit = 0.02μW/cm^2 ACGIH TLV Effective Irradiance (5 min. exposure (μW/cm^2)

Table 15–1. Test Equipment and Test Criteria (continued)

Parameter/ chemical	Test procedure/analytical method	Exposure limit / (TLV)
Infra-Red (IR) radiation	International Light 1400A Radiometer	ACGIH TLV Effective Irradiance (exposure > 1000 sec. = 10 mW/cm^2 Operator-Accessible and Maintenance/Service -Accessible SEMI S2–0200 Limit (20% of ACGIH limit) = 2.0 mW/cm^2
RF Induced Electric and Magnetic Fields	Narda, Model 8511 Electric and Magnetic Field Probes	1.23 and 13.6 mW/cm^2 for electric and magnetic for instantaneous exposure, respectively at 27 MHz. 100 and 2504 mW/cm^2 for electric and magnetic for instantaneous exposure, respectively at 2 MHz. From IEEE/ANSI C95.1-1999 Standard for Uncontrolled Access Exposure Limits.
Sound Pressure Level	OSHA Quest Q2400 Sound Level Meter Direct Reading Meter	80 dBA SEMI S2–0200 Section 27.1

Notes:

RF - Radio Frequency

TWA - Time-weighted average

ppm - parts per million

mW/cm^2 - milliwatts per square centimeter

mT - millitesla

T - Tesla

dB(A) - decibels (Audio), A scale

Test Results

Chemical Exposure

The recipe used during the engineering evaluation of the Exelan 2300 reaction chamber was:

- BARC: Carbon Tetrafluoride (CF_4) (45 sccm)/Argon (Ar) (100 sccm)/Oxygen (O_2) (15 sccm)
- HARC: Argon (Ar) (300 sccm)/Oxygen (O_2) (19 sccm)/ Octafluorocyclobutane (C_4F_8) (18 sccm)

The Exelan 2300 process module that was sampled had processed 2025 wafers for an engineering evaluation with a cycle time of 225 seconds per wafer. The first 2000 wafers were run with RF energy, while the last 25 wafers were run without RF. Plasma (RF) was operated at 2 MHz and 3000 watts of power and at 27 MHz and 2000 watts for 150 seconds per wafer during the HARC process recipe. The 2 MHz generator was not used during the BARC recipe and the 27 MHz generator was operated at 800 watts of power. The Chamber was run for a total of 125 hours since the previous chamber opening. Prior to opening the chamber, five (5) standard cycle purges were performed. The recommended number of purge cycles before chamber opening is five. A standard cycle purge includes a chamber vent to atmospheric pressure and then a backfill with nitrogen.

Two real-time industrial hygiene air-sampling instruments were used to measure the identified analytes. A Zellweger Analytics MDA TLD-1 was utilized to detect hydrogen fluoride (HF). The lower limit of detection for HF using the MDA is 0.6 ppm. The TLD-1 meter was used to take samples either in the chamber (at the locations described in Table 1) or approximately 12 inches above the open chamber in the breathing zone of the technician while removing the process kit and during the wipe down. An Interscan 1146 was used to collect carbon monoxide (CO) samples. The lower limit of detection for CO using the Interscan 1146 is 0.5 ppm. The Interscan collected samples from just inside the chamber lip during and subsequent to the opening of the chamber.

The industrial hygiene integrated air samples were collected using SKC constant-flow air sampling pumps. Flow rates were calibrated both before and after each sampling period, using a BIOS DC-1 calibrator, a primary standard. The air samples for hydrogen fluoride (HF) were collected onto treated silica gel tubes and analyzed using the NIOSH 7903 method for ion chromatography. Hydrogen cyanide (HCN) samples were collected using soda lime tubes and analyzed by the NIOSH 6010 methodology. All samples were analyzed by Assay Technology, an American Industrial Hygiene Association-accredited laboratory.

The background sample for calibration was collected approximately 21 feet from the chamber. The collection point for the technician breathing zone sample was between chest and collar level. Samples were also collected at the lip of the chamber after it had been opened.

All equipment panels and protective covers were in place during the industrial hygiene measurements unless otherwise noted. Local exhaust at the process module was not utilized during the monitoring. The process module chamber inspection, disassembly, and clean required a total of 25 minutes to complete. The real-time chemical exposure results and relevant reference standards are presented in Table 15–2. Results of laboratory analyses are presented in Table 15–3.

The Earth Tech industrial hygiene strategy includes the collection of data for sample locations outside of the technician's breathing zone. Samples taken outside of the breathing zone provide useful hazard assessment information related to the effectiveness of existing process and safety controls. This additional data assists the end user in identifying and prioritizing equipment hazards at their site.

Table 15–2. Industrial Hygiene Chemical Exposure Survey Results

Area / Sample description	Result (ppm)		Reference standards ACGIH TLV/25% (ppm)	Reference standards OSHA PEL/25% (ppm)	Result
At chamber lip, chamber opened minimally (cracked)	HF	0.8	C3/0.75	3/0.75	NA
Just inside chamber lip	CO	0.0	25/6.25	35/8.75	NA
Inside chamber, 3” below lip	HF	1.0	C3/0.75	3/0.75	NA
Inside chamber, 12” below lip	HF	0.7	C3/0.75	3/0.75	NA
Inside chamber, 6” below lip	HF	0.0	C3/0.75	3/0.75	NA
Technician breathing zone during IPA clean	HF	0.0	C3/0.75	3/0.75	PASS
Removal of quartz ring, inside chamber, 3” above ESC	HF	0.0	C3/0.75	3/0.75	NA
Removal of ground ring, inside chamber, 3” below lip	HF	0.0	C3/0.75	3/0.75	NA

Notes:

ACGIH – American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL – Permissible Exposure Limit

ppm – parts per million

C – ceiling value

HP – hydrogen fluoride

CO – Carbon Monoxide

Exposure limits applicable only to measurements taken in breathing zone

Table 15–3. Chemical Exposure Sampling Laboratory Analytical Results

Sample description	Result (ppm)		Reference standards ACGIH TLV/25% (ppm)	Reference standards OSHA PEL/25% (ppm)	Result
Background, 21 feet from chamber	HF	<0.1	C 3/0.75	3/0.75	PASS
Background, 21 feet from chamber	HCN	<0.03	C 4.7/1.18	10/2.5	PASS
Background, 21 feet from chamber	IPA	<0.21	400/100	400/100	PASS
Technician, breathing zone	HF	<0.3	C 3/0.75	3/0.75	PASS
Technician, breathing zone	HCN	<0.06	C 4.7/1.18	10/2.5	PASS
Technician, breathing zone	IPA	74	400/100	400/100	PASS
Chamber lip, mainframe side	HF	<0.3	C 3/0.75	3/0.75	PASS
Chamber lip, mainframe side	HCN	<0.05	C 4.7/1.18	10/2.5	PASS

Notes:

HF – hydrogen fluoride, samples collected after processing 2025 wafers

HCN – hydrogen cyanide, samples collected after processing 2025 wafers

IPA – isopropyl alcohol, samples collected after processing 265 wafers

Exposure limits applicable only to measurements taken in breathing zone

< – not detected at or above limit stated

For the purposes of this report, the definition of the Occupational Exposure Limit (OEL) as the term is used in SEMI S2–0200, is the American Congress of Governmental Industrial Hygienists (ACGIH) Threshold Limit Value (TLV) or the Occupational Safety and Health Administration (OSHA) Personal Exposure Limit (PEL) unless otherwise stated. As can be seen in Table 1, a hydrogen Fluoride (HF) concentrations slightly greater than 25 percent of the Occupational Exposure Limit (OEL) of 0.75 ppm as defined in SEMI S2–0200 were measured during the real–time chemical exposure survey. A concentration of 0.8 ppm was found at the chamber lip just subsequent to "cracking" the chamber opening and a concentration of 1.0 ppm was found approximately three inches below the lip inside the chamber itself. However, these measurements were not recorded in the breathing zone and therefore the OEL does not apply. None of the readings taken during the real-time sampling exceeded the ACGIH ceiling limit of 3 ppm for HF. Additionally, no other chemical concentrations in excess of 25% of the OEL were found at any other location during the sampling event.

As can be seen in Table 15–3, chemical analytical results from the integrated sampling program indicated no concentrations in excess of 25 percent of the OEL for any chemicals for which sampling was conducted. Thus, the Exelan 2300 process module is in compliance with Sections 22.1.2, 22.1.2.1, and 23.5.2 of SEMI S2–0200.

Ultra-Violet Radiation

The SEMI S2-0200 evaluation of the Exelan 2300 process module on the 2300 platform includes the industrial hygiene evaluation of the potential for exposure to UV light. Measurements were recorded during normal operation of the process module. Non-ionizing radiation in the UV wavelength range is produced during process plasma generation.

UV light was measured using an International Light 1400A Radiometer survey meter (SN 3034) with a SEL 240 detector (SN 4438). Measurements were recorded throughout the normal recipe for cycling of wafers. Levels were recorded in microwatts per centimeter squared (µW/cm2) for UV at various distances from the outside skin that shields the quartz glass viewport (with protective mesh). The non-ionizing radiation monitoring results and the relevant reference standards for UV radiation are presented in Table 15–4.

Table 15–4. UV Light Survey Results

Area/Description	UV reading (mW/cm^2)	ACGIH TLV effective irradiance 5 min. exposure limit (mW/cm^2)	Operator-accessible and maintenance/service-accessible SEMI S2-0200 limit ($\mu W/cm^2$)	Result
Ambient background in work area	NA	ACGIH = 10	0.02	PASS
0.8” from viewport	0.02	ACGIH = 10	0.02	PASS
1.6” from viewport	0.01	ACGIH = 10	0.02	PASS
4.7” from viewport	0.01	ACGIH = 10	0.02	PASS

Notes:

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

$\mu W/cm^2$ – microwatts per square centimeter

Exposure limits not applicable to background sample

For the recipe described earlier, UV measurements taken at a distance of 0.8 inches from the viewport were reported to be at the maximum allowable limit of 0.02 $\mu W/cm^2$,as shown in Table 15–4. This distance is judged to be that of the closest approach for the Exelan 2300 process module under normal operating conditions, and therefore this measurement indicates compliance with SEMI S2–0200. Limits for operator–accessible areas and maintenance and service areas do not differ. The distance of 0.8 inches should be specified in the equipment manuals as the minimum distance at which an operator or service technician may view the chamber during plasma generation. All monitoring results were found to be less than 25 percent of the ACGIH TLV for a five minute exposure to UV light.

Infra-Red Radiation

To ensure adherence to SEMI S2–0200 Section 25, the evaluation of the Exelan 2300 process module includes an industrial hygiene evaluation of the potential for exposure to IR light. Measurements were recorded during normal operation of the process module. Non-ionizing radiation in the IR wavelength range is produced during process plasma generation.

IR was measured using an International Light 1400A Radiometer survey meter (SN 3034) with a SEL 623 detector (SN 4621). Measurements were recorded during use of the recipe described above. Readings in milliwatts per square centimeter (mW/cm^2) were recorded at various distances from the outside skin that shields the quartz glass viewport (with protective mesh). IR radiation monitoring results and the relevant reference standards are presented in Table 15–5.

Table 15–5. Infra-Red Light Survey Results

Area/description	IR reading (mW/cm^2)	ACGIH TLV effective irradiance exposure > 1000 seconds (mW/cm^2)	Operator-accessible and maintenance /service-accessible SEMI S2-0200 limit (mW/cm^2)	Result
Ambient background in work area	NA	ACGIH = 10	2.0	PASS
0.8” from viewport	0.032	ACGIH = 10	2.0	PASS
1.6” from viewport	0.024	ACGIH = 10	2.0	PASS
4.7” from viewport	<0.01	ACGIH = 10	2.0	PASS

ACGIH - American Conference of Governmental Industrial Hygienists

TLV – Threshold Limit Value

mWcm^2 – milliwatts per square centimeter

Exposure limits not applicable to background sample

Radio Frequency Induced Fields

The evaluation of the Exelan 2300 process module includes the industrial hygiene evaluation of the potential for exposure to non-ionizing radio frequency (RF) radiation. Measurements were recorded during normal operation of the process module. All panels, mesh screens and protective covers were in place while measurements were being taken.

RF energy was measured using a Narda Model 8511 Broadband survey meter and applicable electric and magnetic field probes for the match operating frequencies of 27 and 2 MHz in use during data collection. Measurements were taken during the process cycle at a distance of approximately 2 inches from the measurement area and included cables and cable connections, power sources and match areas. Specific locations are detailed in Table 15–7. The non-ionizing radiation monitoring data for the induced electric and magnetic fields, and the relevant reference standards are presented in Table 15–6 and Table 15–7.

All of the monitoring results for electric and magnetic fields induced by both 2 and 27 MHz non-ionizing RF radiation Matches were found to be less than the OELs specified in the S2–0200 Operator and Maintenance/ Service Accessible limits.

Table 15–6. Non-Ionizing RF Survey Results, 27 MHz

Area/ description	Result Field	Readings (mW/ cm^2)	ACGIH TLV plane wave power (S) 6 Minute-exposure (mW/cm^2)	OSHA PEL (mW/cm^2)	20% Operator-accessible SEMI S2-0200 limit (mW/cm^2)	20% Maintenance /service-accessible SEMI S2-0200 limit (mW/cm^2)
In front of RF match	E Field	<0.01	1.23	10	0.05	0.25
	H Field	<0.01	13.6	10	2.74	2.74
Right side of match	E Field	<0.01	1.23	10	0.05	0.25
	H Field	<0.01	13.6	10	2.74	2.74
Left side of match	E Field	<0.01	1.23	10	0.05	0.25
	H Field	<0.01	13.6	10	2.74	2.74

Table 15–6. Non-Ionizing RF Survey Results, 27 MHz (continued)

Area/ description	Result Field	Readings (mW/ cm^2)	ACGIH TLV plane wave power (S) 6 Minute-exposure (mW/cm^2)	OSHA PEL (mW/cm^2)	20% Operator-accessible SEMI S2-0200 limit (mW/cm^2)	20% Maintenance /service-accessible SEMI S2-0200 limit (mW/cm^2)
At connection to match	E Field	<0.01	1.23	10	0.05	0.25
	H Field	<0.01	13.6	10	2.74	2.74
At connection to generator	E Field	<0.01	1.23	10	0.05	0.25
	H Field	<0.01	13.6	10	2.74	2.74
Along length of cable	E Field	<0.01	1.23	10	0.05	0.25
	H Field	<0.01	13.6	10	2.74	2.74
In front of One Box, left and right side	E Field	<0.01	1.23	10	0.05	0.25
	H Field	<0.01	13.6	10	2.74	2.74

Notes:

ACGIH – American Conference of Governmental Industrial Hygienists

TLV - Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL - Permissible Exposure Limit

mW/cm^2 – milliwatts per square centimeter

ACGIH electric field TLV: Electric Field Strength (E) = 1842 / f = 1842 / 27 = 68.2 V/m. 27 MHz plane-wave power density (S) = E^2 / 3770 = $(68.2)^2$ / 3770 = 1.23 mW/cm^2

ACGIH magnetic field TLV: Magnetic Field Strength (H) = 16.3 / f = 16.3 / 27 = 0.60 A/m. 27 MHz plane-wave power density (S) = $37.7(H)^2$ = $37.7\ (0.60)^2$ = 13.6 mW/cm^2

IEEE C95.1 - Table 1 Maintenance and Service Accessible (controlled environments). Column #4, 27 MHz Power Density (S) = 900 / f^2 = 900 / $(27)^2$ = 1.23 mW/cm^2 E-field and

S = 10,000 / f^2 = 10,000 / $(27)^2$ = 13.7 mW/cm^2 H-field. OEL = 20% (S) = 0.25 mW/cm^2 and
2.74 mW/cm^2 respectively

IEEE C95.1 - Table 2 Operator Accessible (uncontrolled environments). Column #4, 27 MHz Power Density (S) = 180 / f^2 = 180 / $(27)^2$ = 0.25 mW/cm^2 E-field and 10,000 / f^2 = 10,000 / $(27)^2$ =
13.7 mW/cm^2 H-field. OEL = 20% (S) = 0.05 mW/cm^2 and 2.74 mW/cm^2 respectively

The measured values also pass the SEMATECH Application Guide guidance limits for uncontrolled environments, specifically 0.49 mW/cm^2 for induced electric fields.

Table 15–7. Non-Ionizing RF Survey Results, 2 MHz

Area/ description	Result field	Readings (mW/ cm^2)	ACGIH TLV plane wave power (S) 6 minute-exposure (mW/cm^2)	OSHA PEL (mW/ cm^2)	20% Operator-accessible SEMI S2-0200 limit (mW/cm^2)	20% Maintenance /service-accessible SEMI S2-0200 limit (mW/cm^2)
In front of RF match	E Field	<0.01	100	10	9	20
	H Field	<0.01	2504	10	500	500
Right side of match	E Field	<0.01	100	10	9	20
	H Field	<0.01	2504	10	500	500
Left side of match	E Field	<0.01	100	10	9	20
	H Field	<0.01	2504	10	500	500
At connection to match	E Field	<0.01	100	10	9	20
	H Field	<0.01	2504	10	500	500
At connection to generator	E Field	0.02	100	10	9	20
	H Field	0.2	2504	10	500	500
Along length of cable	E Field	0.01	100	10	9	20
	H Field	<0.1	2504	10	500	500
In front of One Box, left and right side	E Field	<0.01	100	10	9	20
	H Field	<0.01	2504	10	500	500

Notes:

ACGIH – American Conference of Governmental Industrial Hygienists

TLV - Threshold Limit Value

OSHA – Occupational Safety & Health Administration

PEL - Permissible Exposure Limit

mW/cm^2 – milliwatts per square centimeter

ACGIH electric field TLV: Electric Field Strength (E) = 1842 / f = 1842 / 27 = 68.2 V/m. 27 MHz plane-wave power density (S) = E^2 / 3770 = $(68.2)^2$ / 3770 = 1.23 mW/cm^2

ACGIH magnetic field TLV: Magnetic Field Strength (H) = 16.3 / f = 16.3 / 27 = 0.60 A/m. 27 MHz plane-wave power density (S) = $37.7(H)^2$ = 37.7 $(0.60)^2$ = 13.6 mW/cm^2

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13.7 mW/cm^2 H-field. OEL = 20% (S) = 0.05 mW/cm^2 and 2.74 mW/cm^2 respectively

The measured values also pass the SEMATECH Application Guide guidance limits for uncontrolled environments, specifically 0.49 mW/cm^2 for induced electric fields

Magnetic Field Strength

No magnets are used in the Exelan 2300 process module. Therefore, static magnetic measurements were not recorded.

Sound Pressure Level

The evaluation of the Exelan 2300 process module includes an industrial hygiene review for potential exposure to elevated sound pressure levels during operation of the tool. The process module was surveyed and no additional engineering controls such as noise reduction materials were utilized. The survey was performed by initially recording background noise levels followed by measurements recorded adjacent to the system at the required distances. Sound pressure level was measured using a Quest Sound Level Meter: Model 2400, Serial Number JN7110028.

Table 15–8 presents the results of the sound pressure level survey. Unless otherwise noted, measurements were taken 1.5 meters above the ground and at a horizontal distance of 1 meter from the system per SEMI S2–0200.

All recorded measurements were below the 80 dBA threshold in SEMI S2 02–0200 Section 27.1. The maximum expected duration of personnel exposure during normal maintenance activities is three hours.

Table 15–8. Industrial Hygiene Sound Pressure Level Survey

Location/description	Reading dBA	SEMI S2-0200 standard (continuous dBA)	Result
General area background, about 15-20 feet from system	60.4[1]	80	PASS[2]
Front of system, helium RF enclosure	68.5	80	PASS
Right side of system, VME enclosure	70.2	80	PASS
Left side of system, AC box	63.8	80	PASS
Rear side of system, TM interface	65.3[2]	80	PASS

Note**:**

dBA – decibels, A-weighted scale

1 – Recorded approximately 14.1 feet from process module

2 – Area measured not directly subject to SEMI S2–0200 Standards

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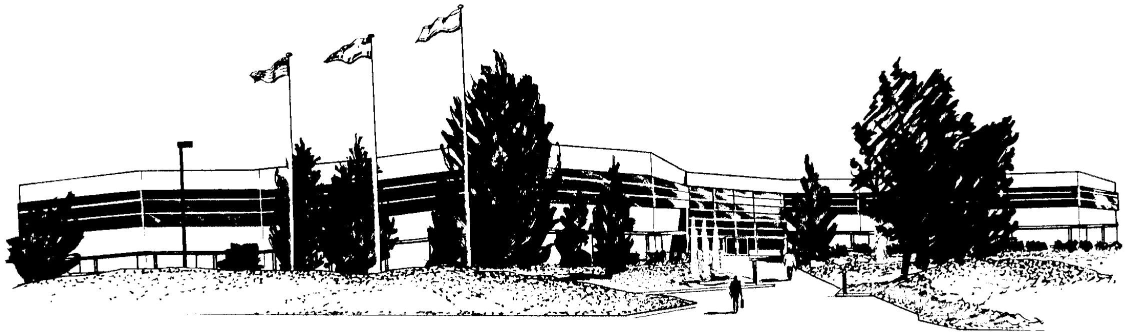

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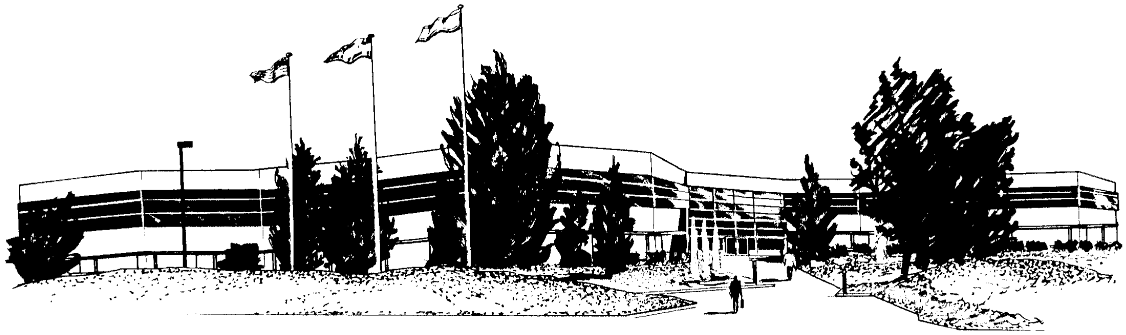

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