CORAL Name: RIE-Cl2-SAMCO-200iP

Location: Bay 6U, room 12-3110B
Purpose: Etching
Contacts: Eric Lim, Bob Bicchieri, Donal Jamieson

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Introduction

The purpose of the SAMCO Model 200iP Inductively Coupled Plasma Reactive Ion Etcher (ICP RIE) is to etch III-V compound semiconductors using chlorine-containing etch gases. To accomplish this objective, the ICP-RIE system utilizes high-density plasma that is created through the use of two RF power supplies. In addition, the system utilizes a load lock chamber to reduce etch chamber pump-down times and also to prevent accidental exposure to chlorine-containing gases and etch by-products when samples are removed from the system.



Safety

Hazards present on system are high voltage, RF radiation, and pressurized gases. Chlorine (Cl_2), boron trichloride (BCl_3) and silicon tetrachloride ($SiCl_4$) are toxic if inhaled. Cl_2 and oxygen (O_2) are strong oxidizers and can cause or intensify a fire. Argon (Ar), Nitrogen (N_2), and trifluoromethane (CHF_3) can displace oxygen and cause rapid suffocation. Under normal operation, the user is protected from these hazards by the tool panels and interlocks, and by the Toxic Gas Monitoring System (TGMS). Do not attempt to open or remove any panels as you risk exposing yourself (and others) to these hazards.

Mechanical pinch/crush points exist with the load lock lid and robot arm. Exercise care when loading/unloading samples and carriers from the load lock.

IMPORTANT: The SAMCO ICP RIE system is configured with an anti-fogging window electrode to allow for future addition of an endpoint system. Because of this, the ICP power must be limited to 500W or lower to prevent arcing or discharge to air.

If the tool is behaving dangerously or making loud noises, press the red EMO button, alert the staff, and shutdown the system on Coral. DO NOT attempt to re-energize the tool!

User Qualifications and Responsibilities

During training users will learn to run wafers and edit recipes. To be considered qualified, a user needs to be trained by the staff in charge, be up to date with safety trainings, and have a PTC approved process. There are restrictions to what materials are allowed in the etch tool and what type of recipes can be run (see appendices). Circumventing these restrictions or running processes/materials that have not been approved by the PTC can lead to disqualification from the tool.

Users are expected to leave the system with the ceramic carrier in the load lock and to pump down the load lock before disengaging from CORAL.

Users should include an hour of time in their reservation to perform a pre-etch clean and a few dummy runs before running samples. A pre-etch clean should be performed to ensure a consistent chamber starting state. The dummy runs should be performed using the same recipe as the samples. The dummy runs are necessary to condition the chamber and achieve more repeatable results. Extra time may also be needed for the chuck temperature to stabilize if the recipe runs at a significantly different temperature than the standard 40°C setpoint. A post-etch clean may also be required, depending on the specific recipe running.

If you encounter any problems while operating the machine, report them immediately in CORAL so that the staff can address them in a timely fashion.

Operating Procedures

1. Reserve and engage the tool in CORAL. CORAL disables the lid sensor on the load lock, so the user needs to engage in order to run any process on the tool. Verify that the system is not being used and the ceramic carrier is in the load lock.
2. If necessary, use the EasyTemp software on the data collection computer to set the Julabo circulator to the desired temperature (40°C is normal, but it can be set as high as 250°C).
3. On the SET MODE screen make sure the LLC PUMPDOWN, WAFER LOAD, PROCESS, WAFER UNLOAD, and LLC VENT buttons are highlighted.
4. Enter set the RECIPE field to 91. Comment should say “Cl2 Cln”.
5. Make sure the ceramic carrier is positioned properly on the robot arm.
6. On the MAIN screen, press and hold the RUN button until you hear a loud beep.
7. The machine will load the carrier, run recipe 91, unload the carrier and vent the load lock.
8. Load the dummy wafer or samples.
9. If running a whole 6” wafer, remove the carrier and load the wafer.
10. If running pieces, load the pieces onto the carrier. Also, loading dummy pieces of the same composition as the samples will reduce edge and etch loading effects and improve etch uniformity.
11. To achieve the best results, the etch chamber should be conditioned prior to etching any device wafers. The etch chamber can be conditioned by running the desired etch recipe on dummy wafers for an extended amount of time.
12. On the SET MODE screen, set the RECIPE field to the recipe number you want to run.
13. Repeat steps 5-9 on more dummy wafers or the samples as needed.
14. Open the load lock lid and remove the samples.
15. Place the empty wafer carrier back in the load lock.
16. Close the load lock lid.
17. On the SET MODE screen, make sure only the LLC PUMPDOWN button is highlighted.
18. On the MAIN screen, press and hold the RUN button until you hear a loud beep.
19. If necessary, set the Julabo circulator temperature to 40°C.
20. Once the LLC pumpdown is complete, disengage the tool on CORAL.

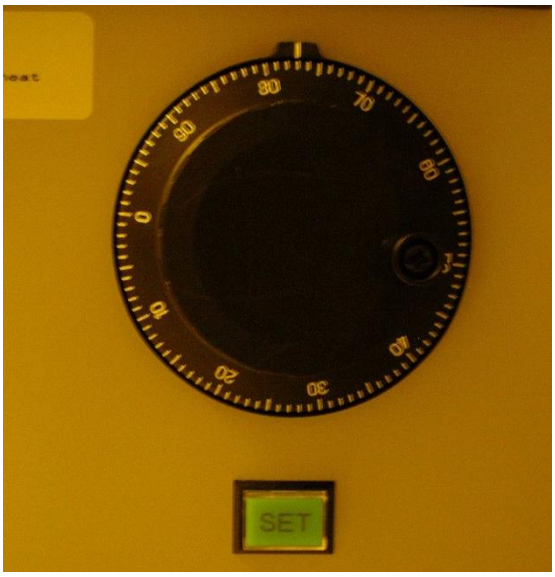
Appendices

Software

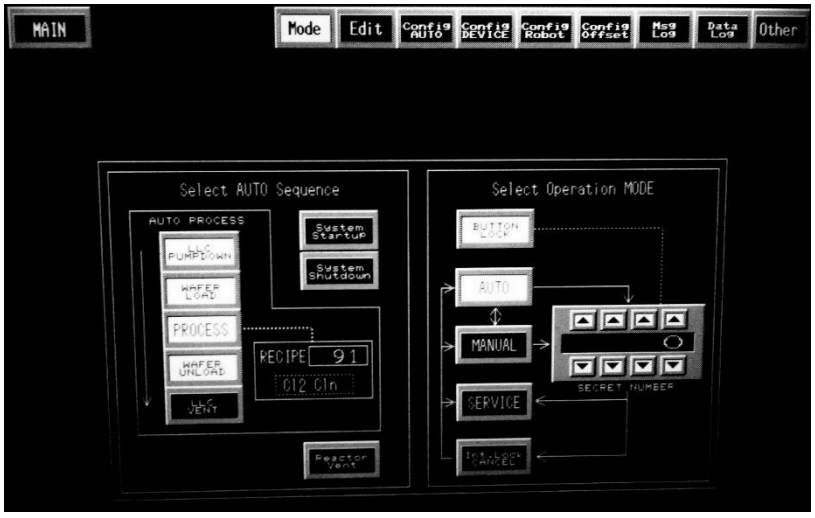
SAMCO Interface and Data Entry

The SAMCO uses a touch screen interface. General options, valve states, and field selection are toggled by touching the appropriate field on the screen.

Alpha-numeric data is entered into the SAMCO control program by selecting the appropriate field using the touch screen, spinning the rotary dial below to select the correct value/character, then pressing the “Set” button. If the “Set” button is not pressed, the new data is not entered into the selected field and that field reverts back to its previous value when a different field is selected.



Set Mode Screen



The Set Mode Screen allows the sequence of operations to be controlled. In the AUTO sequence, there are five steps (at least one step must be selected at all times.):

1) Load lock Chamber Pump Down
2) Wafer Load
3) Run a Process using Recipe (##)
4) Wafer Unload
5) Load lock Chamber Vent

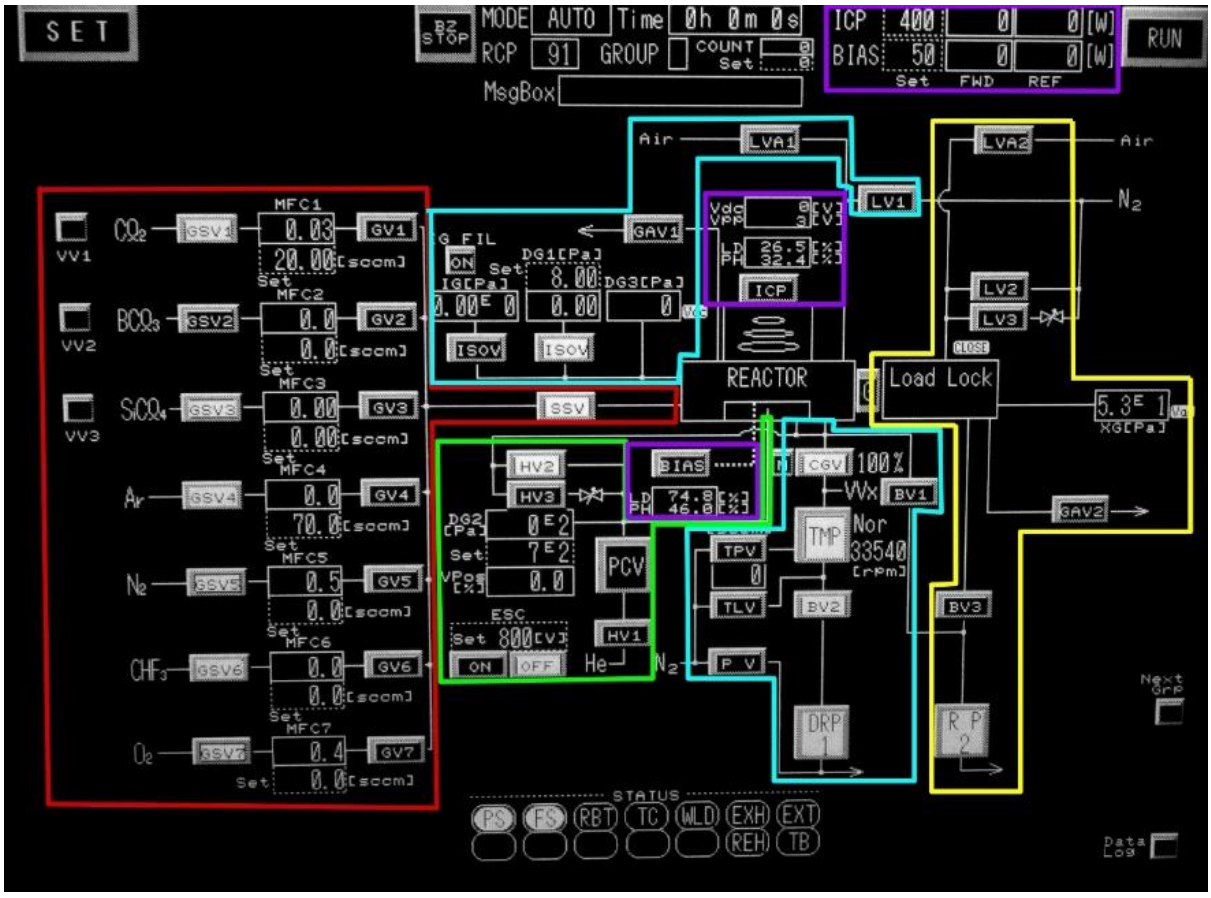
In addition, the mode of operation can be selected. To enter different modes you will need to enter the correct passcode. Normal users will run the system in automatic mode. Manual and Service modes are for staff use only. Pressing the MAIN button at the upper left corner of the display will bring you to the Main screen .

Main Screen

The Main screen displays the status of all the valves, pressure gauges, turbo pumps, gas flows, RF power supplies, He backside cooling system, and active recipe.

In the figure below, the various sub-systems are highlighted. (The color is added for clarity. The screen on the tool is monochromatic).

- The gas delivery system is highlighted in red.
- The load-lock vacuum system is highlighted in yellow.
- The etch chamber vacuum system is highlighted in light blue.
- The RF system is enclosed by purple boxes.
- The He backside cooling system and electrostatic chuck are highlighted in green.

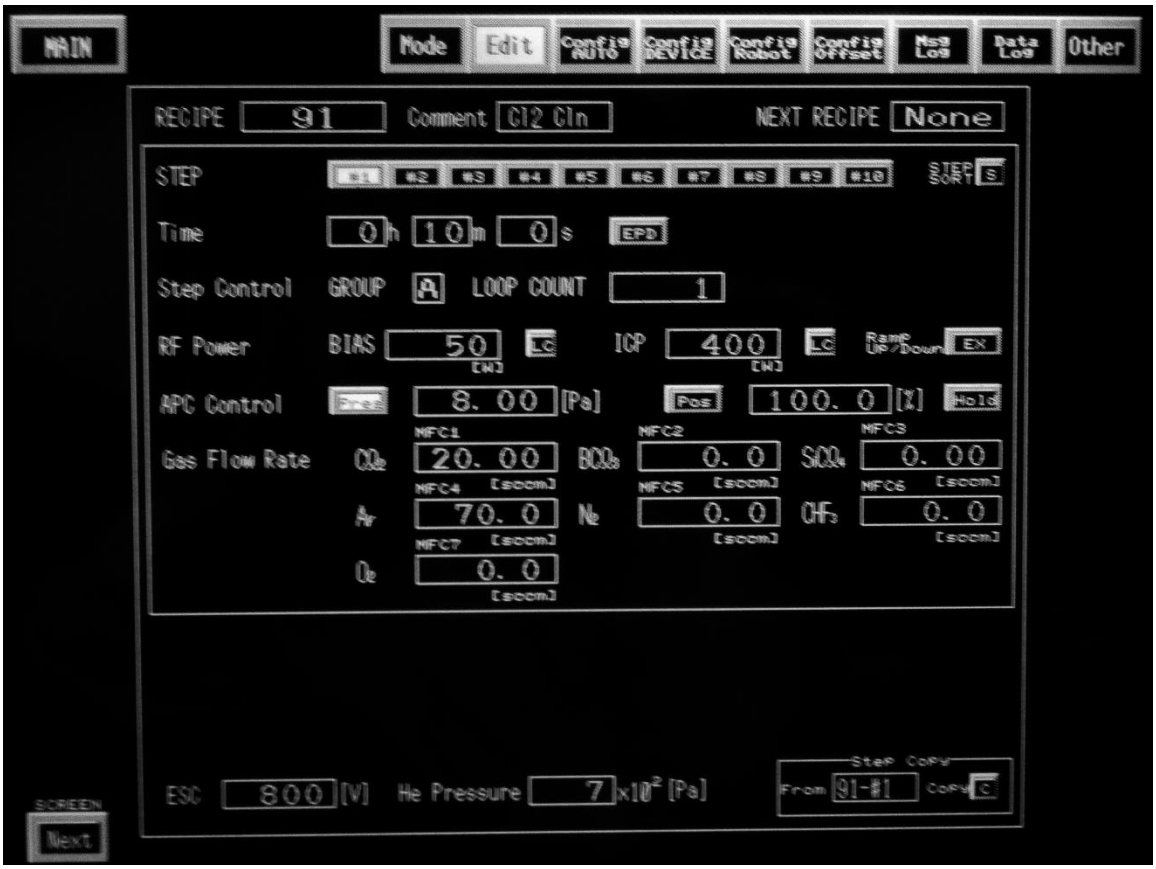


The status of the interlock and warning conditions are also displayed on the Main Screen. In normal operation only the PS (pneumatic pressure sensor) and FS (cooling water flow sensor) should be lit. The TC (gas line heater over temperature), TC2 (exhaust gas line heater over temperature) indicators should be off, and the RBT (robot) status indicator should be on only when the robot arm is active.

The main screen is also used to start a sequence/recipe by pressing and holding the RUN button in the upper right hand corner of the touch screen. When the system is operated manually, the valves are opened and closed

by touching the valve on the touch screen. Pressing the SET button in the upper left corner of the display switches back to the Set screen.

Set Edit Screen



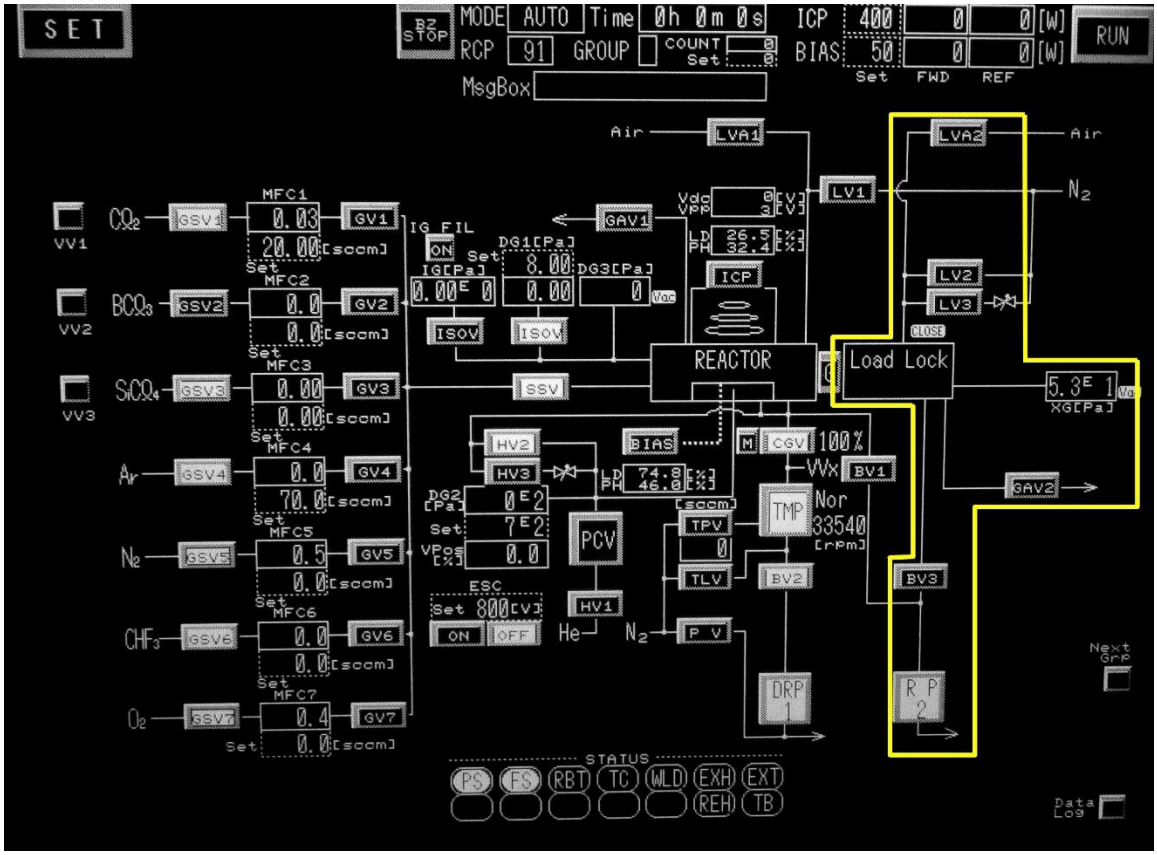
Recipes are entered in the Edit Screen. The ESC voltage and He pressure are set for the each recipe independently but do not vary from step to step within each recipe. For each step in a recipe, the gas flows, step times, ICP power, bias power and pressure/gate valve position can be controlled. In addition, steps can be looped and at the completion of this recipe, another recipe can be executed automatically. The recipe ends at the first step in the recipe with a time of 0:00:00.

The operation of the main gate valve can be controlled in one of two methods: pressure control or position control. In pressure control, the chamber pressure is set and the gate valve position is adjusted to achieve the desired pressure. In position control, the gate valve position is set and the pressure will vary depending on the gas flow. The use of pressure control is recommended.

By using the control in the lower right hand corner, entire recipes or a single step of an existing recipe can be copied into the recipe that is being edited.

Vacuum Systems

Load Lock



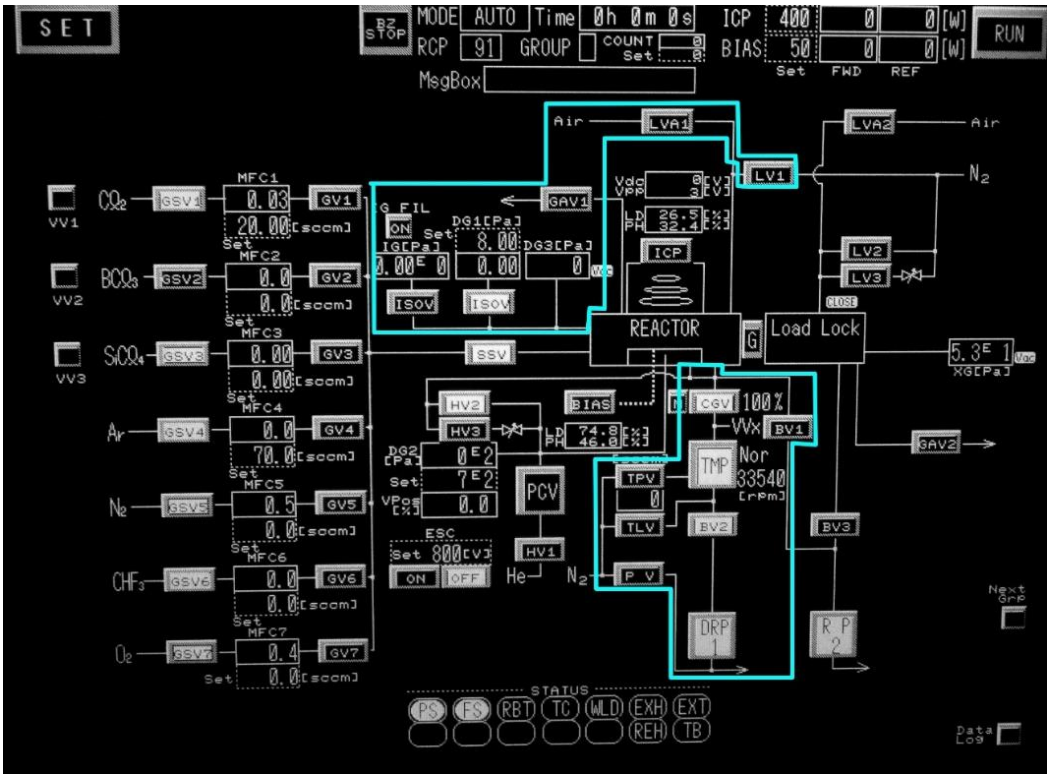
The load lock vacuum system serves two purposes, (1) to pump out the load lock chamber in order to introduce samples into the main etch chamber and (2) to pump out the etch chamber when necessary. The items associated with the Load Lock are enclosed within the yellow box.

In standby, the load lock is pumped using a dry roughing pump (RP2) through valve BV3. In order to pump the load lock chamber from atmospheric pressure to base vacuum, valve BV3 is opened allowing the roughing pump to evacuate the chamber. Pressure gauge XG is used to monitor the load lock pressure.

In order to vent the load lock, first valve BV3 is closed, then nitrogen is introduced into the chamber in two stages through the valves LV3 and LV2. Nitrogen is first introduced into the chamber at a low flow rate via a needle valve and valve LV3. At a sufficiently high pressure, the nitrogen flow rate is increased via opening valve LV2 and closing valve LV3.

Etch Chamber

The etch chamber vacuum system is designed to provide a suitable environment for the etching of III-V compound semiconductors and to safely remove the etch by-products and residual gases from the chamber. The items associated with the etch chamber are enclosed within the light blue boxes.



In stand-by, the etch chamber is pumped using a turbo pump (TMP) and a dry roughing pump (DRP1) via valves BV2 and CGV. The conductance through main gate valve (CGV) can be controlled via an automatic gate valve controller. The gate valve controller adjusts the position of the CGV to reach and maintain the set pressure of the etch chamber during the etch steps. The position of the main gate valve (CGV) should be recorded when recipes are being executed in order to monitor the performance of the turbo pump and the dry roughing pump. The CGV should be 100% open unless a recipe is being run. When the corrosive gases are flowing, nitrogen is introduced into the turbo pump via valve TPV. The nitrogen flow is displayed beneath the TPV valve indicator.

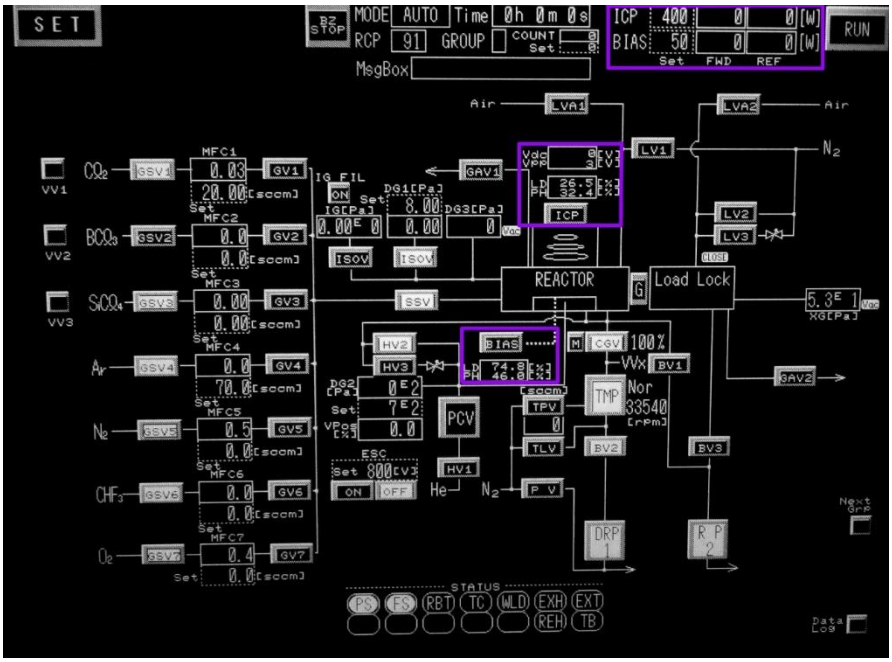
The etch chamber is vented with nitrogen through valve LV1 and is purged with air through valve LVA1. The etch chamber is purged with air prior to opening the etch chamber to prevent the accidental exposure of toxic/corrosive gases. Initial pump down of the etch chamber from atmosphere is done with the load lock roughing pump RP2 through valve BV1. Once the crossover pressure has been reached, the system switches to normal standby pumping using the turbopump TMP and dry rough pump DRP1.

The pressure within the etch chamber is monitored via three pressure gauges: an ionization gauge (IG), the "main" pressure gauge (DG1) and a pressure monitor (DG3). The ionization gauge and the "main" pressure gauge have isolation valves (ISOV) associated with them. The ionization gauge is typically off and its isolation valve is typically closed. The isolation valve to the "main" pressure gauge is typically open. The "main" pressure gauge (DG1) displays the current pressure within the box with the solid lines while the pressure set point is displayed within the box with the dashed lines. While running a recipe, these two readings should be identical.

The pressure from the DG1 provides the feedback necessary to control the position of the main gate valve (CGV).

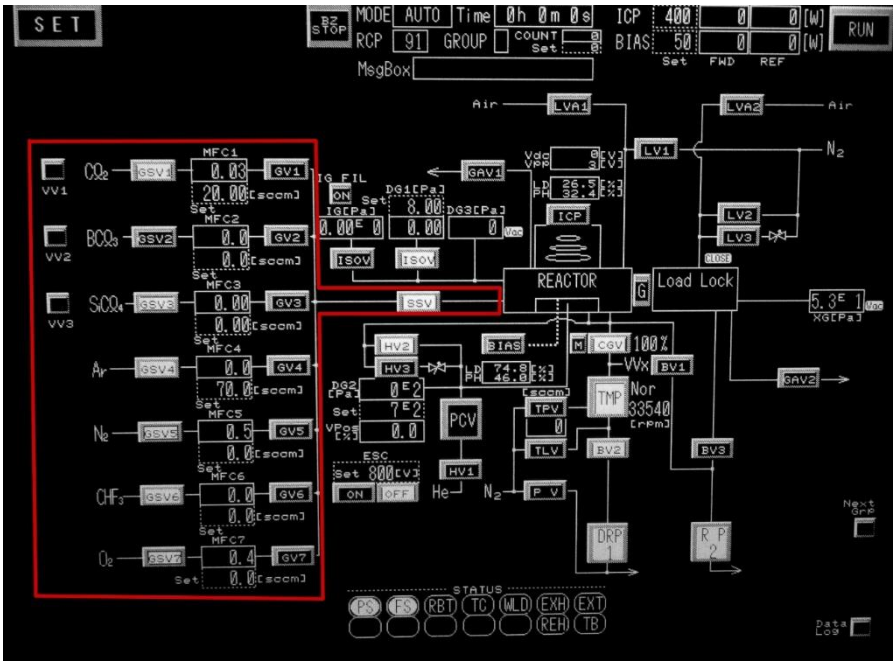
RF Power Supplies

The ICP RIE system contains two RF power supplies, the ICP RF power supply and the RF bias power supply. The two RF power supply sections are highlighted by purple boxes. Both RF power supplies have automatic tuning circuits to minimize the reflected power. The RF set points, reflected power and forward power are displayed in the upper right hand corner of the screen.



Gas Delivery System

The ICP RIE system has three corrosive gases and five non-corrosive gases for etching. The corrosive gases are chlorine (Cl_2), boron trichloride (BCl_3) and silicon tetrachloride ($SiCl_4$). The non-corrosive etch gases are argon (Ar), nitrogen (N_2), trifluoromethane (CHF_3) and oxygen (O_2). The fifth non-corrosive gas is helium (He) which is used to control the sample temperature during the etch and is discussed in section 5. The gas delivery system is enclosed within the red box.

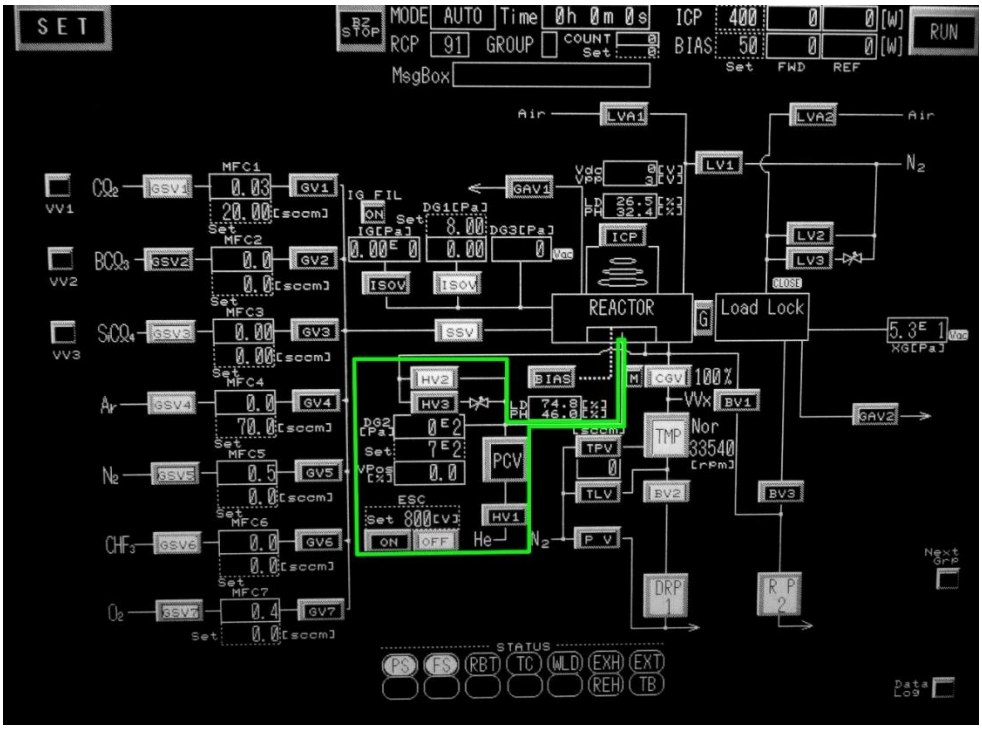


Each of the six processing lines has an upstream valve (GSV#) and a downstream valve (GV#) associated with it where # designated the line number along with a mass flow controller. The MFC set point is the number within the box with the dashed lines while the actual flow is displayed within the box with the solid lines. The maximum flow for each gas is shown in the following table.

Gas #	1	2	3	4	5	6	7
gas	Cl_2	BCl_3	$SiCl_4$	Ar	N_2	CHF_3	O_2
Max flow (sccm)	20	50	20	100	100	100	100

Miscellaneous Systems

Two additional sub-systems are highlighted in the figure below. The first sub-system is associated with the electrostatic chuck (ESC). The second sub system is the He backside cooling system.



Electrostatic Chuck

The electrostatic chuck is used to hold the sample carrier to the lower electrode in the system. The standard operational voltage for the electrostatic chuck is 800V.

Helium Backside Cooling System

The Helium backside cooling system is used to control the sample temperature during etching. Helium flows behind the sample in order to maintain the sample at a particular temperature during etching. The He flow is controlled via an automatic valve positioner (PCV) along with a needle valve and pneumatic valves HV1, HV2 and HV3. Valve HV1 is the He shut-off valve. When valve HV2 is open, the He back-side cooling sub-system is pumped out via the etch chamber turbo pump (TMP). When the He backside cooling system is being used, He flows beneath the sample through valve HV3 and it associated needle valve along with the automatic valve positioner. The position of the automatic valve (PCV) is to be recorded. Pressure gauge DG2 monitors the pressure within He backside cooling sub-system and hence provides the control signal to the automatic valve positioner. The temperature of the chuck is controlled via the external Julabo circulator.

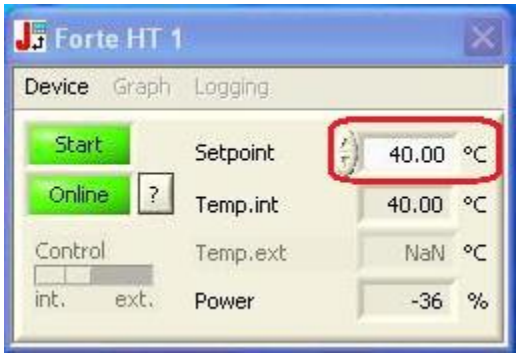
Julabo Circulator

The Julabo circulator ultimately controls the temperature of He for the back side cooling system. The circulator allows the sample temperature to be controlled from 40°C to 250°C. The lower limit is determined by the circulator's cooling capacity and the amount of power/heat that is being generated by the plasma within the chamber. The circulator itself is located in the service chase, and is controlled by software on the data collection computer next to the RIE-Cl2-Samco-200iP. The ICP RIE system itself *DOES NOT* control or set the temperature of the Julabo circulator. The circulating fluid flows from the Julabo circulator in the service chase to the ICP RIE system through insulated lines.

Due to the low vapor pressure of $InCl_3$, Indium containing III-V semiconductors are etched at higher temperatures than most other materials, so the set point on the Julabo circulator should be raised when etching films containing Indium.

Programming the Julabo Circulator:

On the data collection computer, enter the desired temperature in the "Setpoint" field in the Forte HT1 window:



Tips and Tricks

- IMPORTANT: The SAMCO ICP RIE system is configured with an anti-fogging window electrode to allow for future addition of an endpoint system. Because of this, the ICP power must be limited to 500W or lower to prevent arcing or discharge to air.

- Include an hour of time in the reservation to perform a pre-etch clean and a few dummy runs before running samples. A pre-etch clean should be performed to ensure a consistent chamber starting state. The dummy runs should be run using the same recipe as the samples. The dummy runs are necessary to condition the chamber and achieve more repeatable results. Extra time may also be needed for the chuck temperature to stabilize if the recipe runs at a significantly different temperature than the standard 40°C setpoint. A post-etch clean may also be required, depending on the specific recipe you are running.

- Only disengage on CORAL when the system is idle. If you disengage before the batch is finished, the system will think the load lock lid has opened and will abort.

Common Errors/Failures

"He V Pos. Upper Err" message

This means the system is flowing more He then expected to maintain the backside He cooling pressure. This is normally due to residue or debris on the backside of the carrier. To recover you should unload the carrier from the chamber, vent the load lock, then remove your samples from the carrier

To recover your sample:

- Go to the SET MODE screen and make sure only the "WAFER UNLOAD" and "LLC VENT" buttons are highlighted
- Go to the MAIN screen and press and hold the RUN button until you hear a loud beep.

The system will then pump out any residual gas, dechuck and transfer the wafer to the load lock, then vent the load lock.

At this point, samples can be removed. Wipe the backside of the carrier or wafer with isopropyl alcohol or acetone, then try to run again. You can also try wiping the backside twice or try using a different wafer. If the system still won't run, this means there is probably debris on the electrostatic chuck and the chamber will need to be wet cleaned by staff. Collect your samples, then put the system in Shutdown on CORAL and disengage.

System aborts during process

If any of the process parameters are outside a pre-defined window for too long, the system will abort. The process will stop, and the sample will stay in the chamber.

To recover your sample:

- Go to the SET MODE screen and make sure only the "WAFER UNLOAD" and "LLC VENT" buttons are highlighted
- Go to the MAIN screen and press and hold the RUN button until you hear a loud beep.

The system will then pump out any residual gas, dechuck and transfer the wafer to the load lock, then vent the load lock.

Pressure Conversion Chart

Pascals	mTorr	
0.005	0.0375	
0.25	1.875	
0.5	3.750	
1	7.50	
2	15.00	
3	22.50	
4	30.00	
5	37.50	
6	45.00	
7	52.50	
8	60.00	
9	67.51	
10	75.01	
15	112.51	
20	150.01	
25	187.52	
50	375.03	
100	750.06	
2700	20251.67	
100000	750061.68	