

Operating Procedures for the SAMCO ICP RIE System

General Overview:

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.

The SAMCO ICP RIE system consists of 5 main systems, each of which has multiple components. Each system will be discussed in the following SOP.

IMPORTANT:

You should include an hour of time in your reservation to perform a pre-etch clean and a few dummy runs before running your 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 your 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 your 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.

If you have any problems, please contact Eric Lim (eslim@mtl.mit.edu, x3-6897) or Bob Bicchieri (bic@mtl.mit.edu, x 3-6418).

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Operation

- 1) Reserve and engage the SAMCO on CORAL
 - a) CORAL disables the vent function on the load lock, so you need to engage to load or unload your samples.
- 2) Verify that the system is not in use
- 3) If necessary, set the Julabo circulator to the desired temperature (40°C is normal)
- 4) Load the wafer carrier into the chamber and run the pre-etch clean (recipe #91)
- 5) Unload the wafer carrier
- 6) Vent the load lock
- 7) Load your dummy wafer or samples
 - a) If you are running a whole 6" wafer, remove the carrier and load your wafer.
 - b) If you are running pieces, load your pieces onto the carrier. Also, loading dummy pieces of the same composition as your samples will reduce edge and etch loading effects and improve etch uniformity.
 - c) 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.
- 8) With the wafer or carrier in the etch chamber, run the desired recipe
- 9) Unload the wafer or carrier
- 10) Repeat steps 6-9 on more dummy wafers or your samples as needed.
- 11) Vent the load lock and remove the samples
- 12) Place the empty wafer carrier back in the load lock.
- 13) Pump down the load lock
- 14) Depending on the recipe you used, you may need to run a post etch clean.
- 15) If necessary, set the Julabo circulator temperature to 40°C

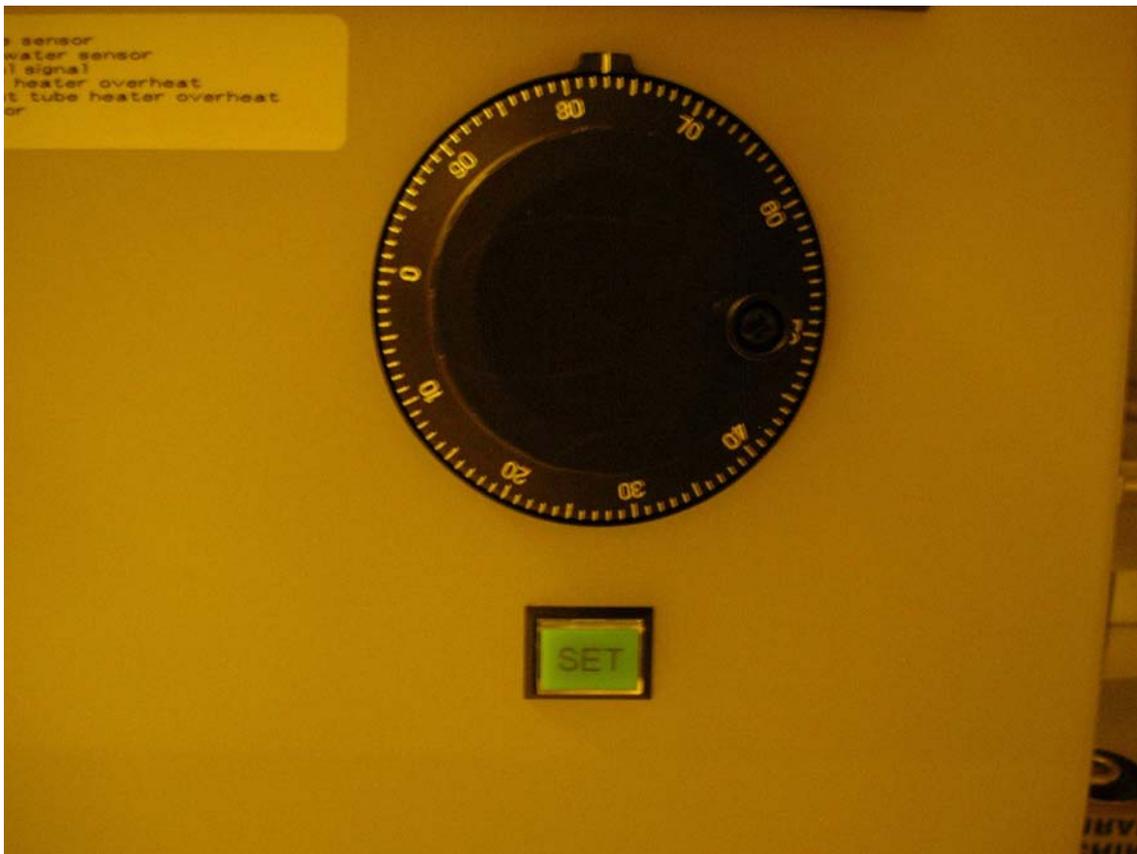
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1. Software

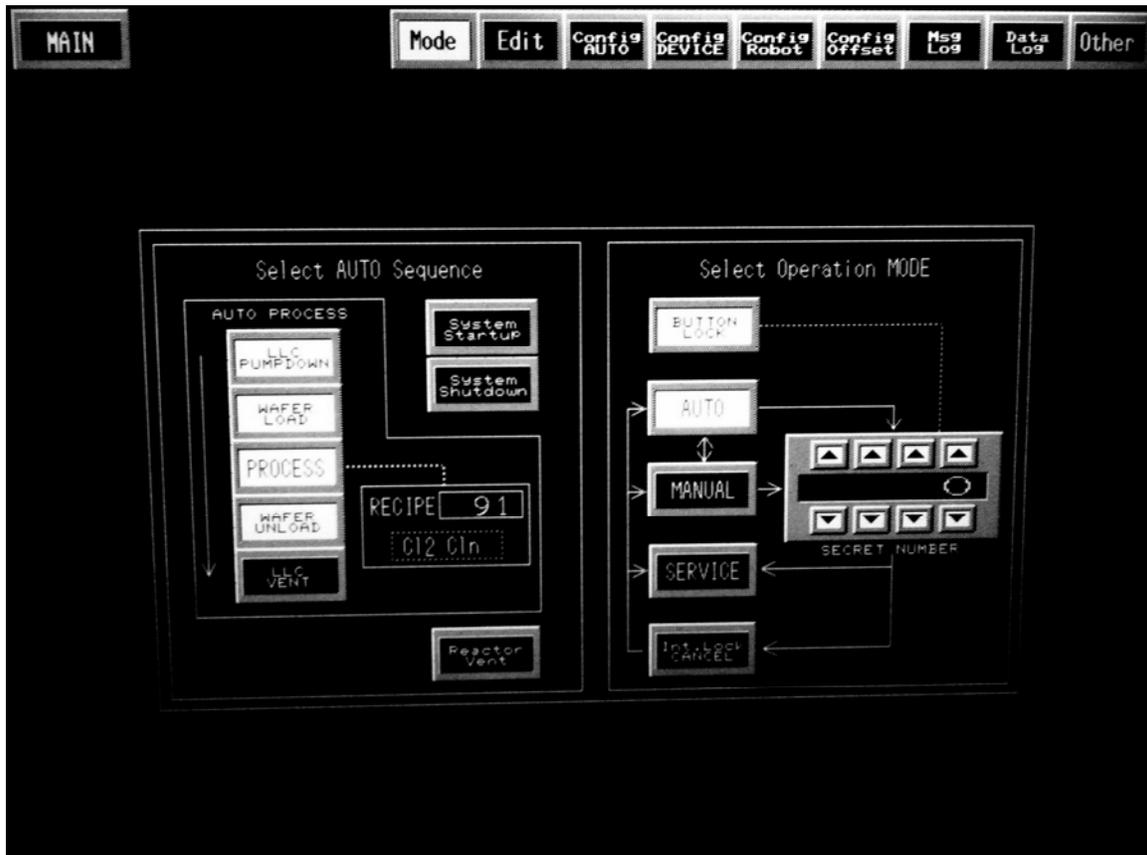
SAMCO Interface and Data Entry

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

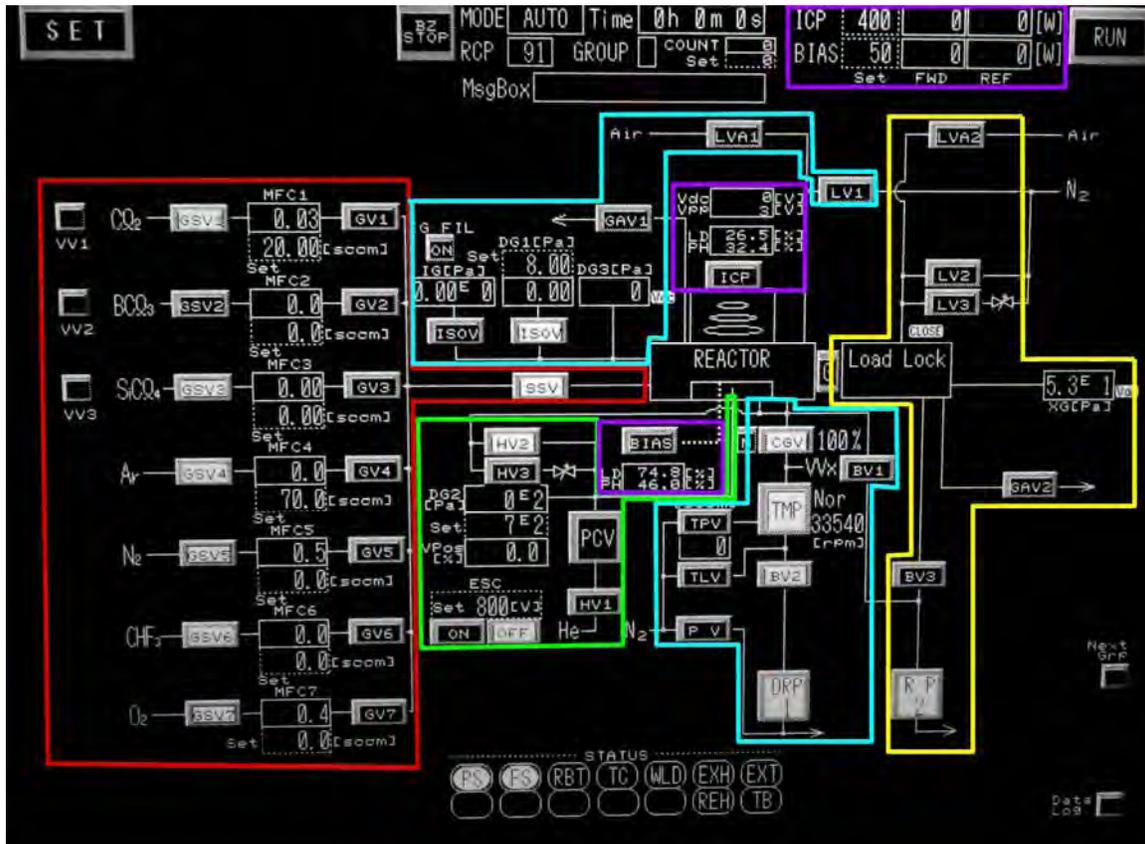


The Set Mode Screen allows the sequence of operations to be controlled. In the AUTO sequence, there are five steps (at least one step must be selected at all times.):

- 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 back side cooling system and active recipe. In the figure above, the various sub-systems are highlighted (Color 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 and 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 also is 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

The screenshot displays the 'Edit' screen for setting up a recipe. At the top, there are navigation buttons: 'MAIN', 'Mode', 'Edit', 'Config RDT6', 'Config DEVICE', 'Config Robot', 'Config OFFset', 'Msg Log', 'Data Log', and 'Other'. The main area is titled 'RECIPE' and shows '91' in a box, with a 'Comment' field containing 'C12 C1n' and a 'NEXT RECIPE' field set to 'None'. Below this is a 'STEP' section with a row of buttons for steps #1 through #10 and a 'STEP SORT' button. The 'Time' field is set to '0h 10m 0s' with an 'EPD' button. 'Step Control' includes a 'GROUP' field with 'A' and a 'LOOP COUNT' field with '1'. 'RF Power' has 'BIAS' at '50' (with 'LC' and 'EW' indicators) and 'ICP' at '400' (with 'LC' and 'EW' indicators), plus a 'Ramp UP/Down' field with 'EX'. 'APC Control' has a 'Pos' field with '8.00' [Pa] and a 'Pos' field with '100.0' [%] (with 'Hold' indicator). 'Gas Flow Rate' is divided into three columns: CO₂, BO₂, and SO₂. Each column has three 'MFC' (Mass Flow Controller) fields: MFC1, MFC2, MFC3 for CO₂; MFC4, MFC5, MFC6 for BO₂; and MFC7, MFC8, MFC9 for SO₂. Values are shown as '20.00', '70.0', and '0.0' respectively. At the bottom, 'ESC' is set to '800' [V] and 'He Pressure' is '7' x 10² [Pa]. A 'Step Copy' section in the bottom right allows copying from 'From 91-#1' to 'Copy C'. A 'SCREEN' button and a 'Next' button are also visible.

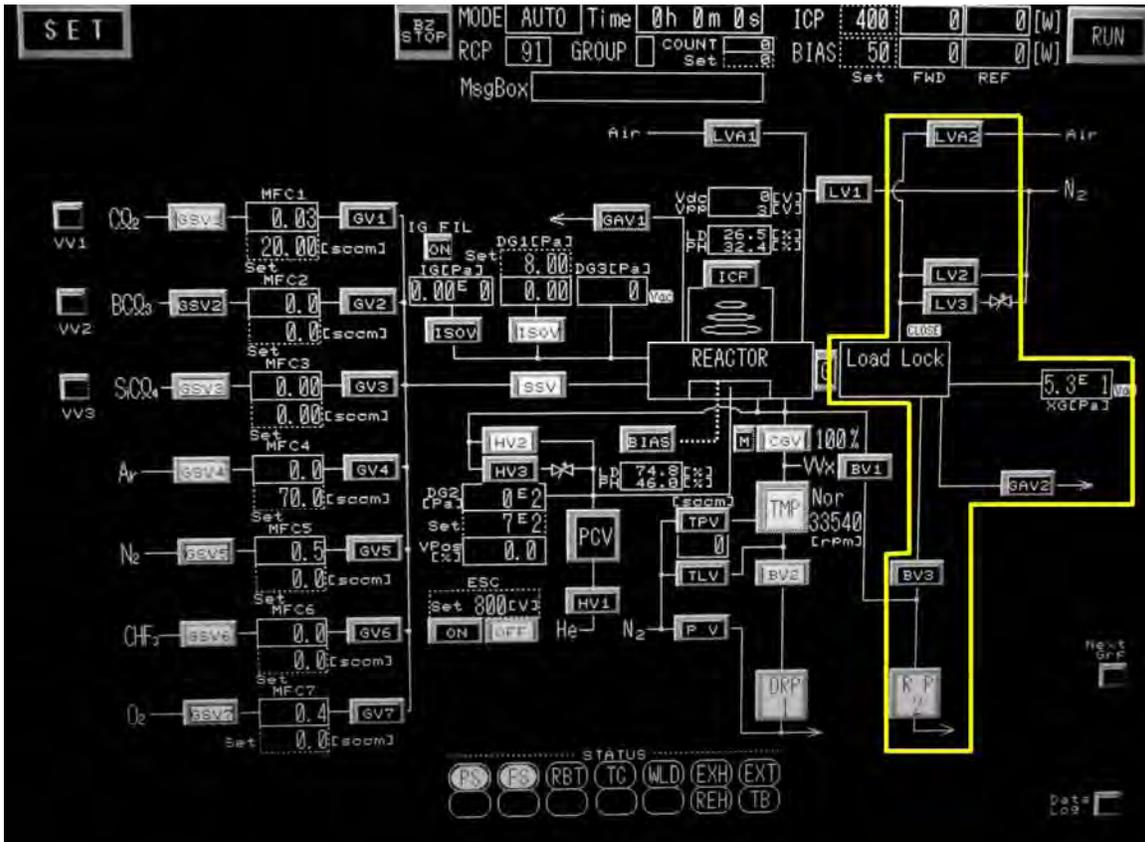
Recipes are entered in the Edit Screen. The ESC voltage and He pressure are set for the each recipe independently but do not vary from step to step within each recipe. For each step in a recipe, the gas flows, step times, ICP power, bias power and pressure/gate valve position can be controlled. In addition, 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.

2. Vacuum Systems:

Load Lock

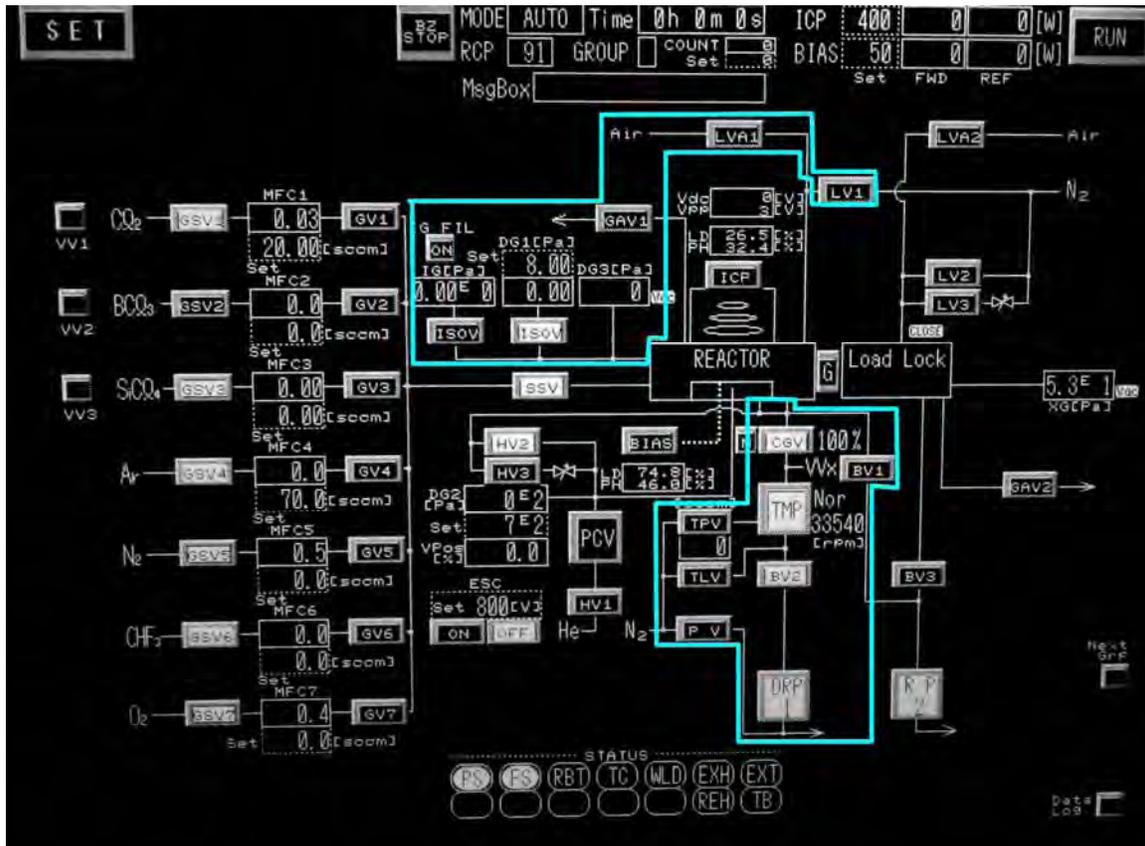


The load lock vacuum system serves two purposes, (1) to pump out the load lock chamber in order to introduce samples into the main etch chamber and (2) to pump out the etch chamber when necessary. The items associated with the Load Lock are enclosed within the yellow box.

In standby, the load lock is pumped using a rotary vane 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



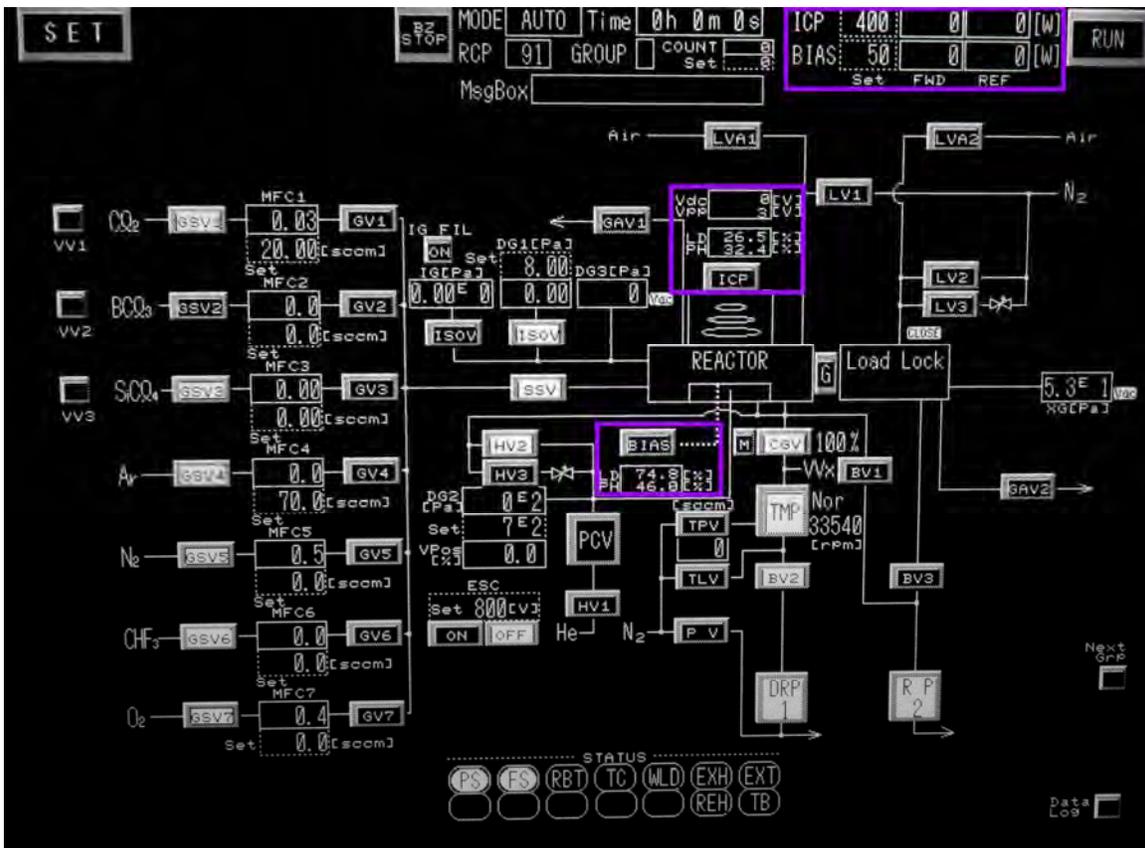
The etch chamber vacuum system is design to provide a suitable environment for the etching of III-V compound semiconductors and to safely remove the etch by-products and residual gases from the chamber. The items associated with the etch chamber are enclosed within the light blue boxes.

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.

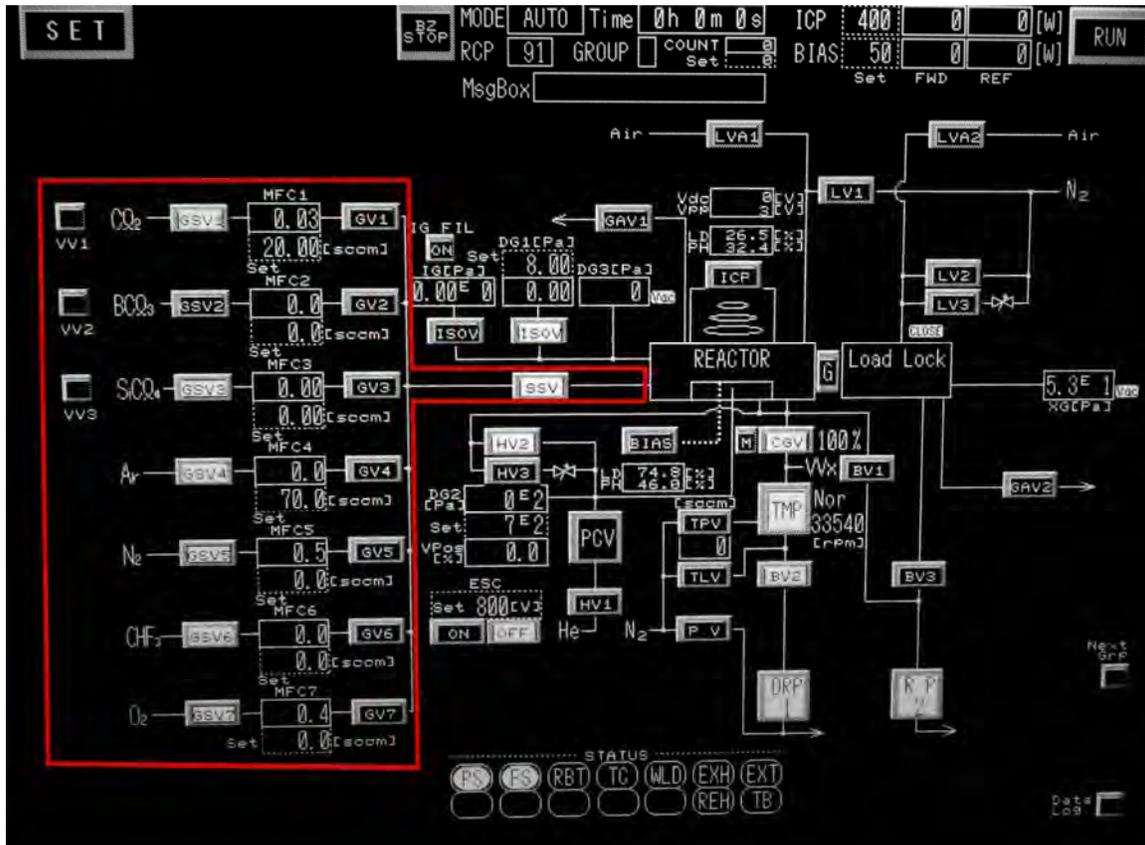
The pressure within the etch chamber is monitored via three pressure gauges: an ionization gauge (IG), the “main” pressure gauge (DG1) and a pressure monitor (DG3). The ionization gauge and the “main” pressure gauge have isolation valves (ISOV) associated with them. The ionization gauge is typically 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).

3. 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.

4. Gas Delivery System



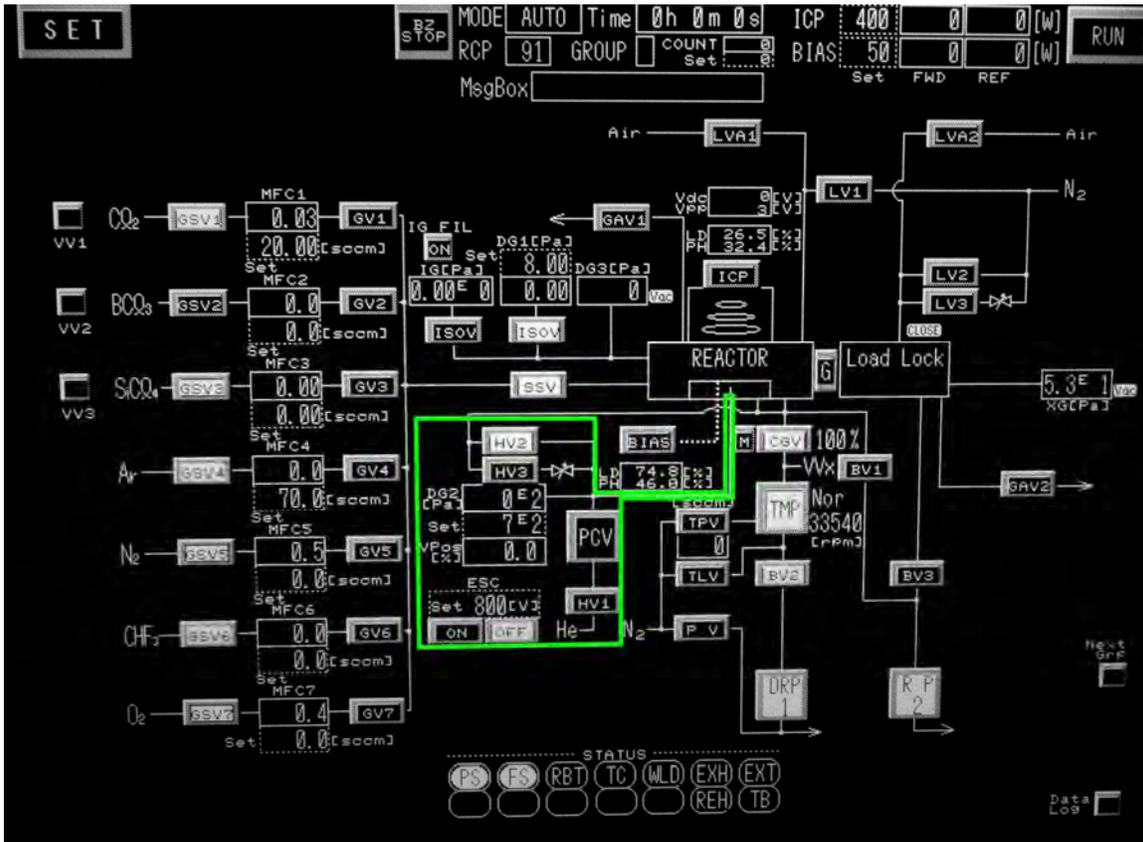
The ICP RIE system has three corrosive gases and five non-corrosive gases for etching. The corrosive gases are chlorine (Cl_2), boron trichloride (BCl_3) and silicon tetrachloride (SiCl_4). The non-corrosive etch gases are argon (Ar), nitrogen (N_2), trifluoromethane (CHF_3) and oxygen (O_2). The fifth 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	20	50	20	100	100	100	100

5. 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 its 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 the 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 30°C to 220°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, while the control unit (shown above) is placed on the wall behind the SAMCO ICP RIE system. The ICP RIE system itself ***DOES NOT*** control or set the temperature of the Julabo circulator. However, the temperature is displayed above the ICP RIE's touch screen. Due to the nature of the circulating fluid, the temperature should not be increased or decreased more than 50C in a single step. The circulating fluid flows from the Julabo circulator in the service chase to the ICP RIE system through insulated lines.

In general, due to the low vapor pressure of InCl_3 , indium containing III-V semiconductors are etched at higher temperatures than III-V semiconductors that do not contain indium. In order to reach the temperature needed to etch Indium containing III-V compounds, the set point on the Julabo circulator must be ramped up and down.

Programming the Julabo Circulator:

For temperatures below 80C:

By pressing the “T” button on the front panel, the set point can be changed. After entering the new set point, the “↵” button must be pressed to enter the new set point. This sequence should only be used if the circulator set point is to be changed by less than 50C.

For temperatures above 80C:

The Julabo control has two preprogrammed temperature profiles and one partially programmed temperature profile within its memory. The preprogrammed profile #0 and #1 ramp the circulator temperature to 100C and 220C respectively. The time at 100C or 220C is currently set at 1 hour. The following steps starts cause the circulator to start executing profile #0 or profile #1:

- 1) Press “MENU”
- 2) Scroll down to “Profile Start” and press “↵”
- 3) Enter the desired profile number and press “↵”
- 4) Verify that the profile starts at step #0; Adjust if necessary
- 5) Verify that the profile loops only 1 time; Adjust if necessary
- 6) Enter “yes” to Start the profile and press “↵”

Profile #2 is used to adjust the circulator to an arbitrary temperature for an arbitrary amount of time. The following steps are used to modify profile #2:

- 1) Press “MENU”
- 2) Scroll down to “Int. Programmer” and press “↵”
- 3) Scroll to “Edit” and press “↵”
- 4) Change to profile number to “2”. Press “↵”
- 5) Select “Step” and enter step number “1”. Press “↵”
- 6) Select “Setp” and enter the *ending* temperature of the step. Press “↵”
- 7) Select “Time” and enter the step time. Press “↵” Make sure that the circulator ramp rate is less than 10deg C/min
- 8) Repeat instructions 5 to 7 to enter additional steps into the profile.
- 9) Press “ESC” to exit this subroutine.
- 10) Scroll down to “Profile Start” and press “↵”
- 11) Enter the desired profile number and press “↵”
- 12) Verify that the profile starts at step #0; Adjust if necessary
- 13) Verify that the profile loops only 1 time; Adjust if necessary
- 14) Enter “yes” to Start the profile and press “↵”

Pressure Conversion Chart

Pascals mTorr
1 7.50061683

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