UBC AMPEL Nanofabrication Facility
Standard Operating Procedure for PlasmaQuest ECR II Etching

Revised by: **Dr. Andras G. Pattantyus-Abraham**, October 19, 2006

This S.O.P. is only for trained and qualified personnel as a part of AMPEL's Safety Program, in compliance with WCB regulations and the UBC Safety Policies.
NOTE: ECR Users must ensure that someone is always in earshot of the alarm systems at all times during ECR start-up, operation, and shut-down.

GAS STARTUP OUTSIDE CLEANROOM

1. Preliminary Inspection

Inspect gas cabinet area to ensure all equipment is in functioning order as follows:
a) Ensure exhaust is working.
b) Ensure doors self close.(not the case right now)
c) Ensure both line heaters are warm to touch:
  i) External orange heater
  ii) Internal aluminum wrapped heater. (set to 40 Volts on controller)
d) Ensure gas cylinders have mass (between 0-15 lbs each)
e) Both mechanical pumps are working and fluid level within range on window.
f) Gas Monitoring system is on and appears to be functional and working.

2. Gas Opening Sequence

a) Looking through the cleanroom window, check that both Main ECR Toggle valves are off inside ECR Gas Box. This should be indicated by the bright tags pointing down and parallel to the gas line.
b) Ensure that the ASC 110 (Automatic Sequence Controllers) are on. If not, turn them on and at the prompt enter code: 1111.
c) The ASC 110 buttons (1,2,3,4,5,6 & 7) should not be illuminated and no green indicators should show inside the cabinet, indicating all valves are closed.
d) Put on full length chemically resistant glove, open APTECH low pressure manual shut-off valves for Cl_2 and BCl_3 by reaching into the gas cabinet through the window and turning knobs with by hand with gloved arm, and holding window with other hand. (Shows RED = *OPEN* and BLUE = *CLOSED*)
e) Fully open gas cylinders valves inside cabinet, one at a time with gloved arm, holding window with your other hand. Remove glove when done.
f) Open ESO by pressing button 7; Valve V6 should now indicate green.
g) Check inlet pressures from the cylinders to regulator (displayed on the ASC 110 as *Inlet Pressure*); these should be approximately: Cl_2 - 85 psig (must be above 60 psig)
BCl_3- 5 psig (must be above 2 psig)
If pressures are very different, shut off main cylinder valves and contact Cleanroom Engineer immediately.
h) Open HPROC by pressing button 4; Valve V1 should now indicate green.
i) Check outlet pressures at the regulator on the low pressure side (displayed on the ASC 110 as *Outlet* Pressure); these should be approximately: Cl_2 - 20 psig (must be above 10 psig)
BCl_3- 3 psig (must be above 2 psig)
If pressures are very different, shut off main cylinder valves and contact Cleanroom Engineer immediately.
j) Open LPROC by pressing button 1; Valve V7 should now indicate green.
If pressures change from (h) above, shut off LPROC (Button 1) and contact Cleanroom Engineer immediately.
k) Open helium cylinder; if needed, open argon, oxygen and CF_4. Check that contents of each bottle are above 100 psig. and that the outlet pressures do not exceed 20 psig.
l) Check that the contents of the nitrogen cylinder is above 100 psig. The outlet pressure should be above 5 psi and below 20 psi.
m) Wait one minute to ensure there are no leaks (gas sensors take 30-45 seconds to respond.)
n) Proceed to cleanroom.

GAS SHUT-DOWN PROCEDURE AT THE GAS CABINET

Carry out the following procedure for both Cl_2 and BCl_3 manifolds.

NOTE: The gas lines are set up such that they may be evacuated and purged with N_2. However, due to the risk of introducing moisture into the BCl_3 lines, the lines are not vented under normal circumstances.

For Cl_2 and BCl_3:

1. Close ESO valve using the ASC 110 controller
2. Close HPROC valve.
3. Close gas cylinders through the window, using a gloved hand.
4. Close LPROC valve.
5. Close APTECH low-pressure shut-off valves by turning clockwise (RED = *OPEN*, BLUE = *CLOSED*).

Other gases:

1. Close helium gas cylinder valve.
2. Close argon, CF_4 and O_2 cylinder valves if necessary.

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GAS START-UP INSIDE CLEANROOM

If the turbo pump is not running, perform ECR system startup (contact Super-User).

1. Turn on main chamber pressure gauge if necessary.
2. Check that turbo pump is running, main chamber pressure is $<10^{-6}$ Torr, and computer is not frozen.
3. At the back of the ECR, access Gas Box and close all bypass valves (only Cl_2 and BCl_3 should be open).
4. Open main input toggle valves for each gas to be used.
5. Replace Gas Box cover.
6. Check that N_2 pressure is above 0 and below 5 psi. **If there is no N_2, the ECR cannot be operated - the turbo pump will be damaged by the corrosive gases.**
7. Check coolant level in chiller. Add deionized water (or other mixture as required) to raise level between markings.
8. Turn on chiller: at right rear, turn main power switch to **"O"** from **"I".**

FOR SAMPLE CHILLING:

i) At right, lower front, turn refrigeration power switch ON.
ii) At right, upper front, if operating below 20° C select "LO", if operating above 20°C select "HI"
iii) At the front, using the three buttons select the desired temperature between 5-25 °C.
iv) Do not set below 5°C when using water as coolant to avoid freezing and damage to pump.

FOR SAMPLE HEATING:

i) At right, lower front, ensure refrigeration power switch is off.
ii) At the front, using the three buttons select the desired temperature between 25-80° C.
iii)Do not set temperature above 80° Celsius when using water as recirculating fluid.

8. Plug in DC bias display (SEV-2DC) from RF Supply to wall outlet.
9. On the main ECR rack, ensure all breakers are ON (VAT valve, turbo, computer, RF, microwave)
10. Turn on the LINE switch at the bottom of the RF rack.
11. Turn on the AMN-PS-2 auto-matching unit (white ON button).
12. Check that the turbo pump is operating at full speed (~826 Hz on TCP-380 controller). If it is in standby mode (~550 Hz), press the standby button to bring it up to full speed again.

GAS SHUT-DOWN PROCEDURE IN CLEANROOM

Once all processing is completed, and the final processed substrates have been removed,

1. Close all main input toggle valves in the Gas Box to the mass flow controllers.
2. Open bypass valves **ONLY** to Cl_2 and BCl_3 in very short bursts, and slowly purge gas around MFC, so as not to exceed a turbo-roughing pump pressure of 2000 mTorr.
3. Leave **ONLY** bypass valves to Cl_2 and BCl_3 open. Leave the bypass valves for Ar, O_2 and CF_4 closed.

ECR SYSTEM STANDBY

Place load lock under vacuum (RUN mode, PUMP DOWN)

1. Turn chiller refrigeration button to OFF and then main power button to "**O**".
2. Unplug SEV-2DC RF DC bias display.
3. Turn off HFS-500E RF generator LINE switch, and turn off AMN-PS-2 auto-matching unit.
4. Turn off AX2110 microwave power supply.
5. Turn off ECR circuit breakers on front panel labelled Microwave and RF Generator.
6. Place turbo pump in standby mode.
7. Log off from the PlasmaQuest software.

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GENERAL PLASMA ETCHING INSTRUCTIONS

A successful etch run depends on the following: a tuned microwave cavity, RF power supply matched to chamber, and a known etch rate. It may also depend on the cleanliness of the plasma chamber. In general, a plasma etch run will involve the following steps:

i) Run plasma on dummy sample for 5 min while adjusting microwave and RF parameters.
ii) Run plasma on test sample to determine etch rate.
iii) Run good sample.

For etching small samples, it is necessary to ensure good thermal contact with the carrier wafer. Use a very small dab of vacuum grease under the sample to achieve this. Do not expose any of the grease to the plasma. After etching, the grease should be removed from the carrier wafer with acetone and a wipe.

In the current system, the microwave power (controlling the ion density in the plasma) is set by the software program, while the RF power and DC bias (controlling the ion energy impacting the substrate) is set manually by the user.

SAMPLE LOADING

Enter RUN mode.

1. Vent the load lock (LL → ATM).
2. Mount the test sample on the carrier wafer with a small amount of grease
3. Pump down the load lock (PUMP DOWN) (Note that this button disappears immediately after an etch process – it can be brought back using the RUN button.) Do not use the LOAD button before pumping down! The pressure sensor has occasional glitches that could induce the system into opening the gate valve before the load lock is pumped down, thus crashing the turbo pump.
4. Load the wafer into the chamber (LOAD).
5. Wait for sample to reach chuck temperature (typically 30 min – not necessary for plasma tuning).

PLASMA ETCHING

In case of any emergency where you are unsure what to do, push EPO button and evacuate immediately.

1. Turn on the microwave power supply and select REMOTE operation.
2. Ensure that the microwave tuning parameters are correct.
3. Choose EDIT mode; REVIEW STEPS AND ENSURE SETTINGS ARE CORRECT.
4. Close EDIT mode and select RUN mode.
5. Press the START  button, and click on "Wafer Already in Chamber."
6. The system will now process the recipe. Typically the first step introduces the correct gas mixture into the chamber and waits for the flow rate to stabilize. This can also be used to further cool the sample with the backside He flow.
7. When the system turns on the microwave power, press RF ON and increase the power to the desired value. IMPORTANT: The power dial must always be turned down when RF ON/OFF is pressed, otherwise the switch will deteriorate over time.
8. Once the recipe is done (within ~1 s from the end), turn the RF power down and press RF OFF.
9. Unload the sample or process further as needed.
10. Once processing is complete, shut down all gases and place system into standby as described in the S.O.P.

PLASMA TUNING

The microwave tuning and RF matching can be achieved by running a test plasma:

1. Load a small test piece as described above.
2. Run the plasma as described above, at the desired microwave power and RF bias.

    i) *Microwave Tuning* Tune the cavity by adjusting the three stubs on top of the etch chamber. The brightness of the plasma can serve as a first indicator of proper tuning. The reflected microwave power should be minized (< 10 W). Record the microwave tuning parameters in a text file on the computer, for future reference.

    ii) *RF Tuning* Usually the RF auto-matching network will perform correctly, but it needs a fixed amount of time to balance if the values are initially incorrect. Typically, the LOADING is around 60 to 80, while the TUNING is near 140. These values will change if the RF power is left ON after the microwave power has been turned off, so it is essential that the RF be turned OFF immediately after the completion of an etch recipe.

3. Note both the DC bias on the red LED display and the forward RF power. The reflected RF power should be below 5 W.
4. If the RF power at a given DC bias differs from previous plasmas, the plasma is most likely affected by some contaminants in the chamber. Run the plasma until the correct RF power is obtained. This may require several minutes.
5. If doing a multistep etch process, repeat the above process for all etch recipes, as the microwave parameters will be slightly different for each process.

ETCH RATE DETERMINATION

The etch rate for a given recipe can be conveniently determined by using resist-coated substrates and the alpha-step profilometer. If the substrate is sufficiently hard, the resist can be patterned simply by scratching it with a tweezer. Otherwise it should be patterned by photo- or e-beam lithography. The substrate can then be etched for a set period of time, so that trenches are obtained. The profilometer will typically provide good results in trenches deeper than 50 nm. Note that there is some dead time in any etch recipe, as the plasma takes a few seconds to reach full power. As such 2-3 runs of different duration may be necessary to determine the etch rate accurately for very short etch runs.

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ECR SYSTEM STARTUP

*** REQUIRES ACCESS TO SERVICE MODE * Contact Cleanroom Manager or a Super-User.**

System startup has to be done carefully to avoid damaging the turbo pump. In particular, the turbo pump should NOT be turned on until the PQ program is running, and all the steps described below have been carried out, to avoid the possibility of exposing the turbo pump to high intake pressures.

The two roughing pumps (load lock and turbo backing pumps) must be turned on outside the cleanroom. Make sure the N_2 tank is not empty.

Inside the cleanroom, push the PlasmaQuest system power button on the electrical distributor panel. On the ECR rack, turn on the breakers for the gate valve, turbo pump and computer. Turn on the main chamber pressure gauge. Allow the computer to boot and start the PQ.EXE program. Once the program is running, it will give alarms for the turbo pump. Turn these off by pushing on the red alert symbol with the exclamation mark. In SERVICE mode, turn on the backing pump valve, then start the turbo pump by turning on the TCP-380 controller. After a self-check it should start spinning up. At this point, the main chamber usually needs to be brought down below 100 mTorr before the throttle valve to the turbo can be opened. Avoid opening the throttle valve if the chamber is above 100 mTorr.

Once the turbo pump is up to speed, press SYSTEM RESET. The software will then go through the appropriate sequence to reach normal conditions. Note that it will use the load lock roughing pump to bring the main chamber below 100 mTorr. If for some reason, System Reset does not work, the main chamber can be roughed out manually in SERVICE mode by opening the gate valve to the load lock.

ECR SYSTEM SHUTDOWN

It is recommend that N_2 be streamed through the turbo pump for 15 min prior to shutdown. This is accomplished in SERVICE mode with the N_2 PURGE GAS command. Once this is done, close the throttle valve, turn off the TCP-380 turbo controller and let the pump spin down. In SERVICE mode, close the backing pump valve and exit the software. Turn off the computer. After about 10 min, turn off all breakers, then power off on the distributor panel (or use the EPO button).

ECR CHAMBER CLEANING

The plasma chamber can become contaminated over time. An unstable (flickering) plasma is one indication that cleaning is required. It is recommended that the chamber be vented and cleaned per the PlasmaQuest manual instructions. Typically, the residues will be highly soluble in DI H_2O. As these residues may contain arsine, appropriate filtering masks must be worn.

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ECR SYSTEM ERRORS

Contact the Cleanroom Manager or a Super-User in case of any system error.

All interlock failures (water, turbo pump, pressure) cause an alarm to sound. This alarm can be turned off on the interlock panel. This panel is brought up by clicking on the red alarm symbol  . The alarm associated with an interlock failure can be disabled by pushing on the corresponding numbered button.

a) water interlock: ensure that city water is properly flowing.
b) turbo pump: identify cause of turbo pump shutdown and rectify.
c) pressure: if turbo pump is operating properly, and there are no vacuum leaks, press the SYSTEM RESET button to allow the system to return to proper operating vacuum levels.

Contact the Cleanroom Engineer or the ECR super-user if the problems cannot be solved.

CRITICAL ISSUES

The table below lists the critical situations that can arise for the ECR etcher system. They are listed from most to least serious.

Situation	**Effect**
Gas leak	Serious health hazard 
N_2 bottle empty	Corrosion of turbo pump components $$
Turbo pumping on chamber above 100 mTorr	Damage to turbo rotors $$
Air leak into gas lines	Clogging due to BCl_3 reaction with moisture $$
Reflected RF > 10 W	Damage to RF power supply $$
Excess grease on wafer	Process contamination 
Base pressure > 10^{-6} Torr	Process contamination