Oerlikon ICP-RIE SLR-770
User Instructions

For the Micro-Electronics Laboratory

At

University of Notre Dame

Department of Electrical Engineering

Brief Description of the Tool: Oerlikon ShuttleLock ICP-RIE SLR-7701-8R-LN2 system (ShuttleLockReady-8" Round Electrode with LN2 cooling option, shortened as ICP-770) is configured to etch, with high precision, semiconductors, metals, and dielectrics using primarily Cl-based plasma (600W 13.56MHz RIE and 1000W ICP). This ICP-RIE tool is equipped with a load-lock, a heated processing chamber wall, and a substrate electrode with a controlled temperature ranging from -10 ^{o}C to 200 ^{o}C. If you are not sure why you need to use this etching tool, you should try Plasma Therm RIE790 first.

General Precautions

Contacts

For problems, clarifications of procedures, or general information pertaining to this machine, please contact one of the following personnel.

David Heemstra	631-6733	dheemstr@nd.edu
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Mike Thomas	631-7493	mthomas8@nd.edu

In case of emergency, Please contact the Notre Dame Security at

911

1. If an **alarm** is sounding, click the "Alarm Silence" soft key at the bottom-right of the screen. This will stop the audible beeping of the alarm. Check the "Alarm" text box on the screen to see if it is something obvious such as "Above atmospheric pressure in chamber", meaning that you didn't hold down the camber lid when you started pump down. To clear the alarm, click "Hold", this rechecks the alarm condition and removes it if it no longer exists.

2. A drop of photoresist (hard baked for a couple of minutes @ 180 C.) can be used to **secure your samples** to the carrier wafer. For etches at elevated temperatures (> 60 C), refer to Page#5.

3. LN_2 is required to use temperatures below the current value of the machine.

Standby Conditions

1. Ion gauge turned "On".
2. LN2 turned "OFF"
3. Load Lock and Chamber are Pumped down.

Start procedure (Running a sample)

Please see Figure #1

1. Enable the machine in Coral
2. Verify Standby conditions according to the list on Page #2.
3. Prepare samples and **your OWN 4 inch Si carrier wafer with a single flat (see the right photo)** for piece samples (wafers with two flats will lead to He leak). It is recommended that you coat the carrier wafer with a layer of photoresist, completely remove PR on the backside and edges, and **thoroughly bake it** for a better controlled delicate etch. There will be a public carrier wafer in the machine, however, use it at your own risk! Always store the public carrier wafer in the provided flouroware wafer box when you unload it.

4. Turn off the ion gauge.
    a. On the ICP computer, go to "Utilities" and then "Ion Gauge OFF".
5. On the ICP computer, go to "Utilities", then "Load-Lock", and "Vent" to vent the Load Lock chamber.
6. After about a minute, "Lock Vent Complete" will appear in the info line, and then open the Load Lock lid.
7. (If you are using an etch recipe at elevated temperature, refer to Page#5 for how to load samples and conduct the etch properly.) Insert wafer or samples on carrier wafer as appropriate (only 4 inch wafers are accepted). Load the small pieces of samples on a Si carrier wafer WITH a drop of photoresist in between, otherwise your photoresist mask will likely be burned. On wafers, watch your placement carefully. Double check your full wafer or the Si carrier wafer is in the pocket completely.
8. Close Load Lock lid, making sure it shuts completely.
9. On the ICP computer, go to "Utilities", then "Load Lock", then "Pump". After "Pumping Lock with mech pump" is displayed in the info box (the pressure inside the load lock should be ~ 900 mTorr), continue on with the procedure.
10. On the ICP computer, go to "Service", "Maintenance", and then "Wafer Handling".
11. Lower left of the screen, click the "Load" soft key.
12. Wait while the system loads your samples into the process chamber. "Wafer/tray load complete" will come up in the info dialogue box when this is done. Select "Exit" to return to software
13. Load Recipe

    Go to "Process", "Chamber" and then "Load".
    a. Select your recipe and depress the "load" button
    b. You will be returned to the System screen.

14. When ready to start your recipe, press “Ready” on the bottom of the screen.
15. The machine may take a while to reach temperature compliance.
16. When “Ready” mode is achieved, click “Run” to start your recipe.
17. The machine then takes over and runs your recipe file.
18. Processing should be monitored on the ICP computer. You must log the power, DC bias, Gas Flow, pressure and time
19. When process is complete, a “Process Complete” window pops up with information on the process.
20. Click “OK” on the “Process Complete” window if needed.
21. On the ICP computer, go to “Service”, “Maintenance”, and then “Wafer Handling”.
22. Lower left of the screen, click the “Unload” soft key.
23. Wait while the system loads your samples into the process chamber. “Wafer/tray load complete” will come up in the info dialogue box when this is done.
24. Click “Exit” on the lower right of the screen.
25. On the ICP computer, go to “Utilities”, then “Load Lock”, then “Vent”. After “Lock Vent Complete” is displayed in the info box, continue on with the procedure
26. Lift up on the Load Lock Lid.
27. Unload Samples and when done be sure to reinstall the system carrier wafer.
28. Close Load Lock lid.
29. Click “Window” and then “Chamber diagram”.
30. Click “Utilities”, “Load Lock”, and “Pump” to pump down the Load Lock. After “Pumping Lock with mech pump” is displayed in the info box, continue on with the procedure.
31. Return the System from “Ready” to “Standby” condition in software
32. Turn on the ion gauge.
    a. On the ICP Computer, Go to “Utilities” and then “Ion Gauge ON”.
33. Turn off LN2 if used during process.
34. Clean up the equipment, samples, trash and accessories you may have used.
35. Disable machine in Coral and completely filled out the run data online.

Etching at Elevated Temps (>60 C):

There is Massive potential for equipment damage if LN2 is turned ON after a high Temperature process has completed! Users must stay logged into the machine in CORAL until the temperature drops to less than 60C on its own without the use of LN2. Users must ensure that they reserve the machine for a long enough time period (typically takes 3 hours to cool) to allow for this to occur. Failure to do so can result in substantial equipment damage!

1. Sample preparation:
   - Apply a tiny drop of High Vacuum Grease on your own carrier wafer. Too much grease will likely lead to grease leaking out under the sample thus contaminating the process chamber and damaging the etch.
   - Put the sample on top of the grease drop. Then move your sample gently to spread it out to an even and THIN layer. If it is too thick, grease will leak out at elevated temperatures!
   - Inspect whether there is any grease leaking out from under the sample. If you have accidentally applied too much, remove your sample and clean up the grease before trying again. ABSOLUTELY NO GREASE EXPOSED to the PLASMA!
2. Load sample:
   - Follow the loading procedures shown in Page#3.
3. Run an etch process:
   - Turn on the valve on the LN2 tank
   - Utilities-> Set Standby Temperatures
   - Enter the desired temperature
   - Wait till the chamber reaches the desired operating temperature.
   - Turn on the ion-gauge to check whether the chamber pressure reaches the base-pressure of 1e-6 Torr. This process takes > 20 minutes due to outgassing at elevated temperatures.
   - Turn off the ion-gauge and run the etch recipe (auto or manual).
   - After the etch is over, go Select Utilities-> Set Standby Temperatures and Enter 30 ^{o}C.
   - Purge the chamber (purge+vac) for at least twice.
4. Unload sample:
   - Wait until the substrate electrode temperature cools down below 50 ^{o}C.
   - Follow the unloading procedure in Page#4.
   - Turn off the valve on the LN2 tank after the temperature reaches 30 ^{o}C,
5. Clean the High Vacuum Grease:
   - Use cleanroom Q-tips and Toluene to clean the grease off from the backside of the sample and the carrier wafer.
   - Follow up with a rinse using ISO (IPA).

Manual Mode operation

Figures #2 and #5 illustrates these instructions.

1. Go to “Service” and “Manual Mode”.
2. This will bring up the manual mode screen for use.
    a. Set time as needed or for a maximum etch time.
    b. Set your gas flows as needed in the center of the screen. (All needed gases should be turned on to at least a low flow rate.)
    c. Click Gas “ON” at the top of the screen to start gas flowing.
    d. Allow time for gas to stabilize. (e.g. 5-10 seconds.)
    e. Set pressure set point as desired.
    f. Click Pressure “ON” to start the throttle valve.
    g. Allow time for pressure to stabilize. (e.g. 5-10 seconds.)
    h. Click Helium “ON” to start the Helium backpressure flow.
    i. Allow time for the Helium pressure to stabilize. (e.g. 5-10 seconds.)
    j. To ignite plasma. (Read Appendix B on how to ignite plasma if you are not sure. Two examples are illustrated below.)
        i. **At regular power settings** (The system automatically starts the ICP power after the RIE power by several seconds)
            1. Set RF1 (RIE) power at a reasonably high value. (e.g. 30 W.)
            2. Set RF2 (ICP) power at a reasonably high value. (e.g. > 500 W.)
            3. Click “RF” to turn on the plasma and time the etch. If it does not light up, report to lab staff
        ii. At low power settings
            1. Set RF1 (RIE) power at a reasonably high value. (e.g. 35 W.)
            2. Click “RF” to turn on the plasma until you see plasma (it normally takes ~ 3 seconds)
            3. Set RF2 (ICP) power at desired value. (e.g. 250 W.) The plasma should get much brighter.
            4. Ramp down the RF1 (RIE) power if needed. (e.g. from 35 W to 5 W.) The plasma should be sustained. If it is not, report to lab staff.
    k. Time the process as needed after the plasma is ignited and stabilized as described above. When your process is complete, click “All OFF” in the upper right corner of the display.
    l. Turn on “Purge” at the upper middle of the screen for one minute.
    m. Turn off “Purge” for 2 minutes, this evacuates the chamber.
    n. Turn on “Purge” for one minute.
    o. Turn off “Purge” for 2 minutes, This evacuates the chamber.
    p. Exit “Manual Mode “by pressing “<EXIT>” on the upper right of the screen.
3. Remove sample and return machine to Standby condition.

Making a recipe

To be able to create a recipe, the ICP computer must be in “Standby” and not in “Ready” mode. Figure #3A-F illustrates these procedures along with file name “Training.prc” on the ICP computer. **See Appendix A for an example process recipe.**

1. From the “Standby” mode, go to “Process”, then “Chamber”, and “New”.
2. The Process Editor will pop up.
3. The “Initial” step will be open. This will set the process baseline.
    a. Enter “Name”.
    b. Enter “Description”. In description list your NETID and current date.
    c. “Pump” should be left at “Turbo”.
    d. Enter “Base Pressure” to be a minimum of 1e-6.
    e. Enter “Hold Time”. The amount of time you want the system held for your recipe, 10 sec is most likely enough and is the default value.
    f. “Data Logging” should be left at “No Log”.
    g. Enter desired temp in “Temperature Channels” and “Substrate” field.
    h. Click “OK” when completed with step.
4. To add a step, highlight the step before you want to insert and click ”Process” on the lower left of the screen. Adding steps happen after the highlighted step.
    a. Enter step “Description”.
    b. “Helium Cooling” should be checked on all recipes.
    c. Under “Pump” enter your desired “Pressure” and “Pump (always Turbo)” if needed.
    d. Under “Gas Channels”, enter desired flow rates of required gases.
    e. Under “RF Generators”, enter desired “Set points” for RF1 (RIE) and RF2 (ICP).
    f. “AMN” should be left at “Auto”.
5. You must add 2 x (“Purge” and “Evac”) steps before an “End”. (See sample recipe)
    a. Default settings should be used with the following times.
    b. “Purge” for 1 minute.
    c. “Evac” for 2 minutes.
6. In the “End” Step:
    a. Enter “End” in description.
    b. Defaults in the “Final Pump”, “Pressure”, and “Hold Time” should be fine for most processing.
    c. Click “OK” when finished.
7. When completed with steps, click “Save” in the lower right of the screen.
8. Name your process recipe and click “OK”.
9. Click “Exit” to exit Process Editor.

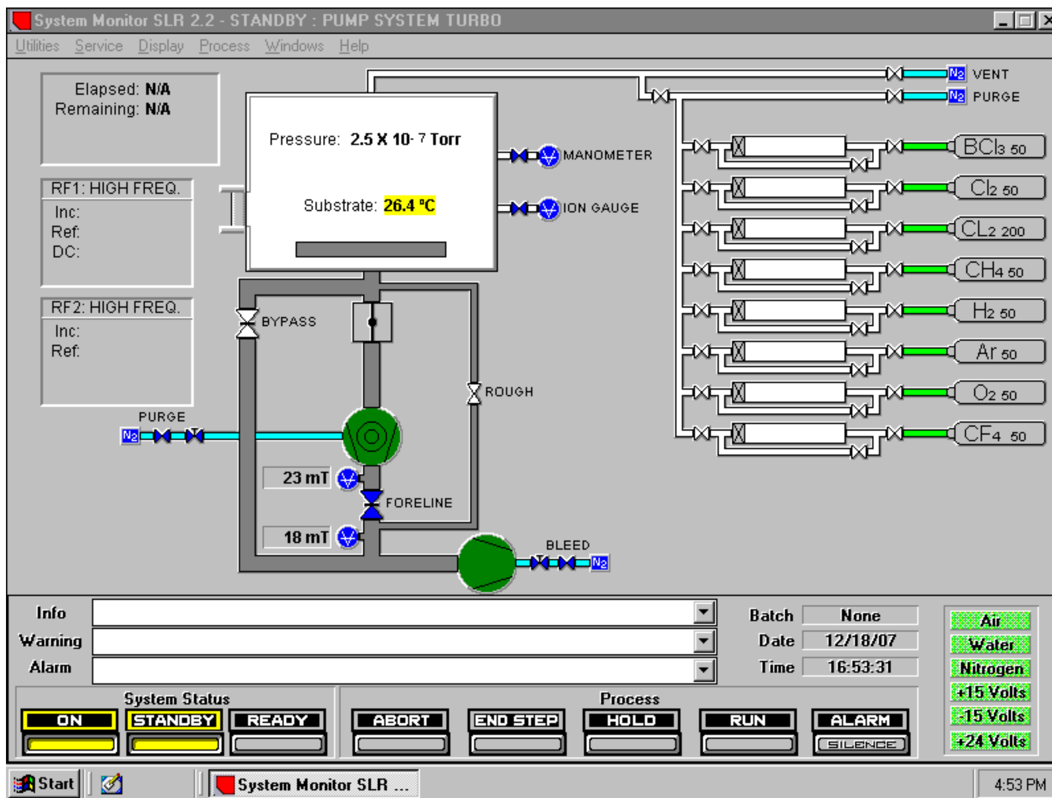

Figure 1: System Diagram.

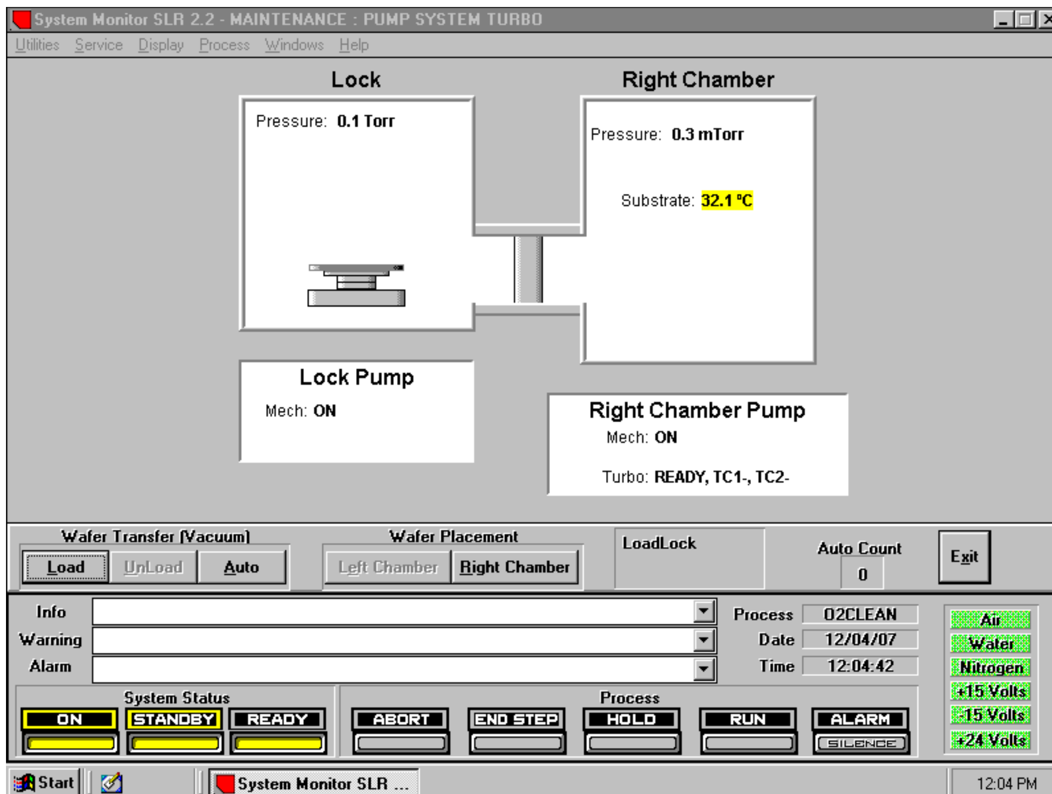

Figure 2: Wafer Handling Diagram.

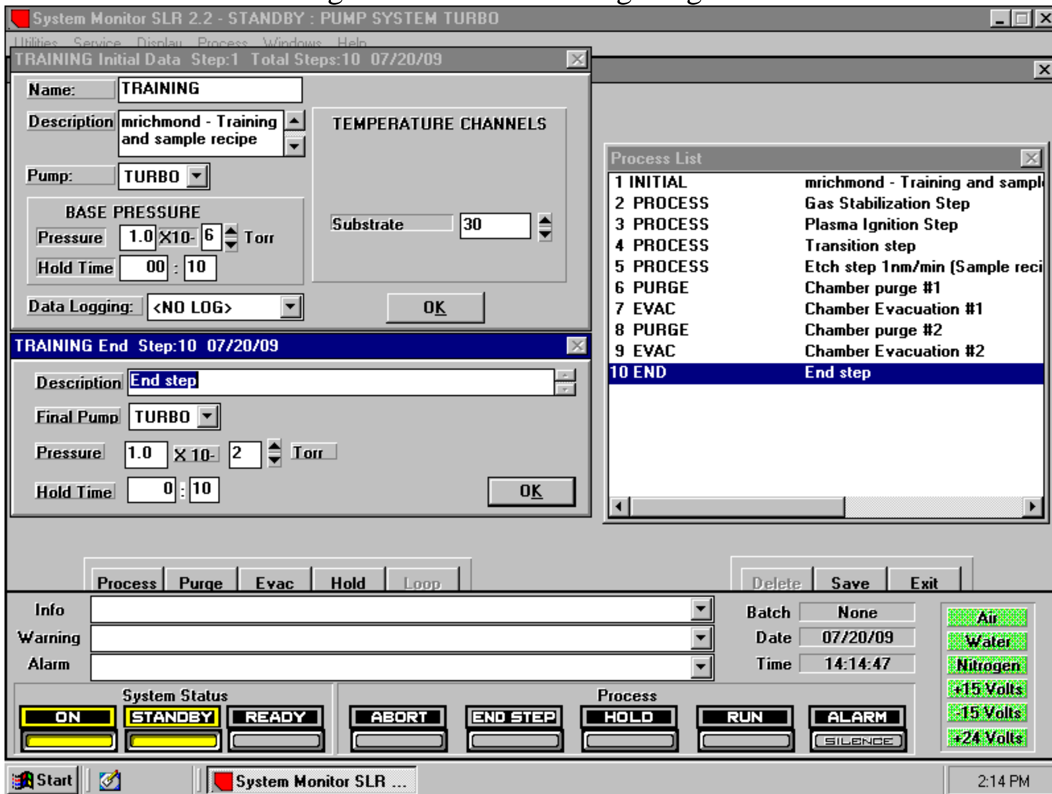

Figure 3A: Sample Recipe - Initial and End Steps.

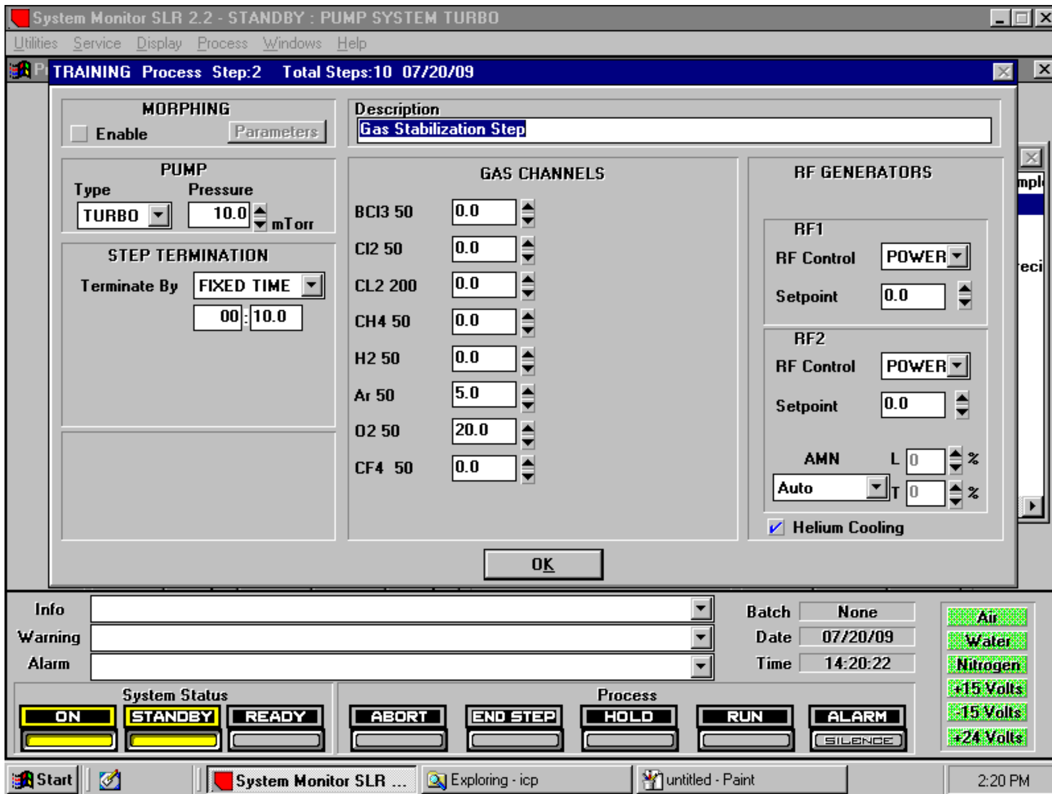

Figure 3B: Sample Recipe - Gas Stabilization Step.

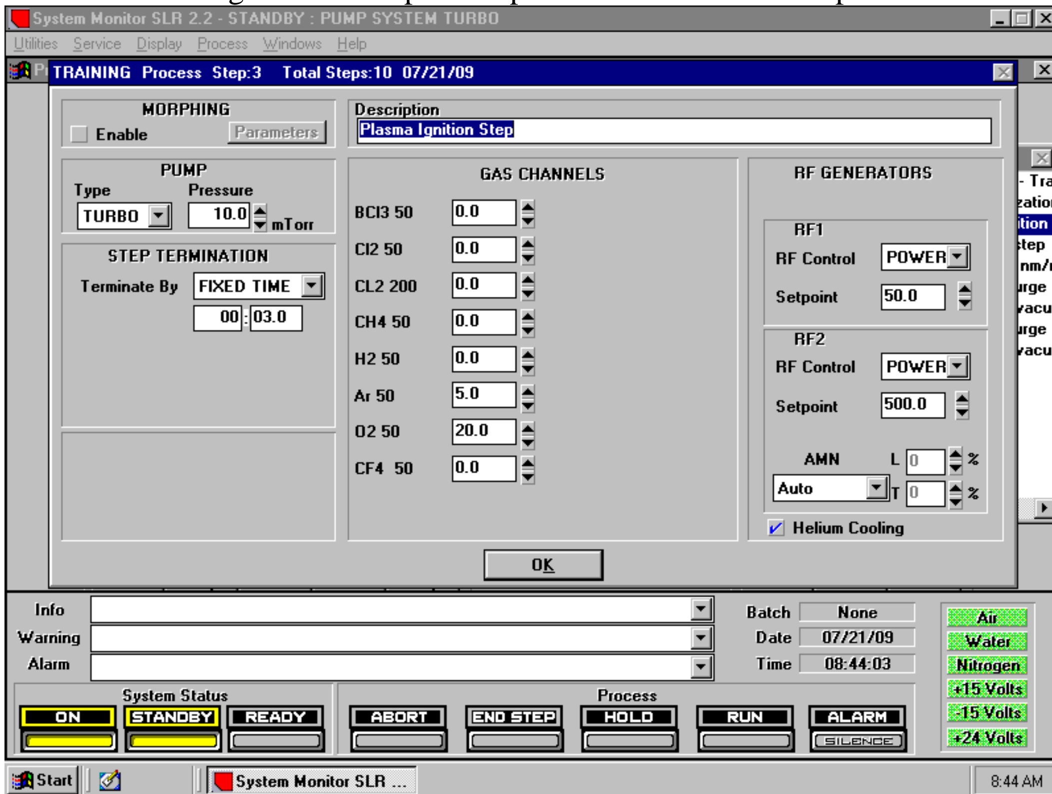

Figure 3C: Sample Recipe - Plasma Ignition Step.

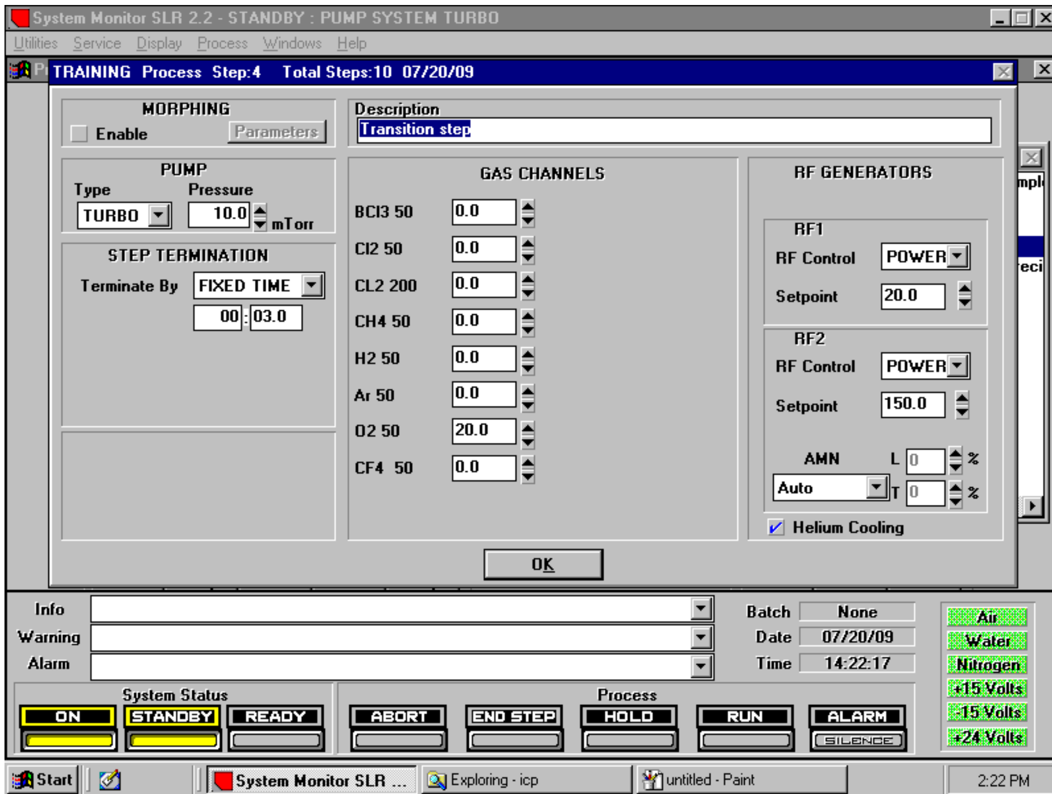

Figure 3D: Sample Recipe - Transition Step.

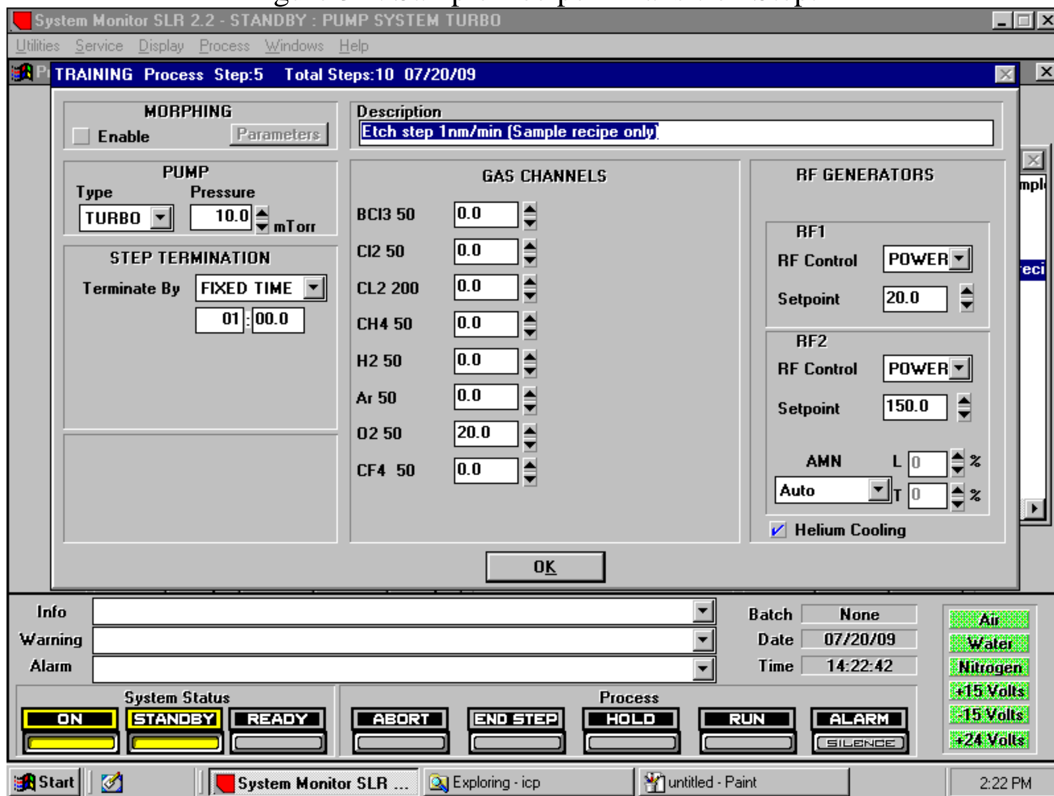

Figure 3E: Sample Recipe - Process Step.

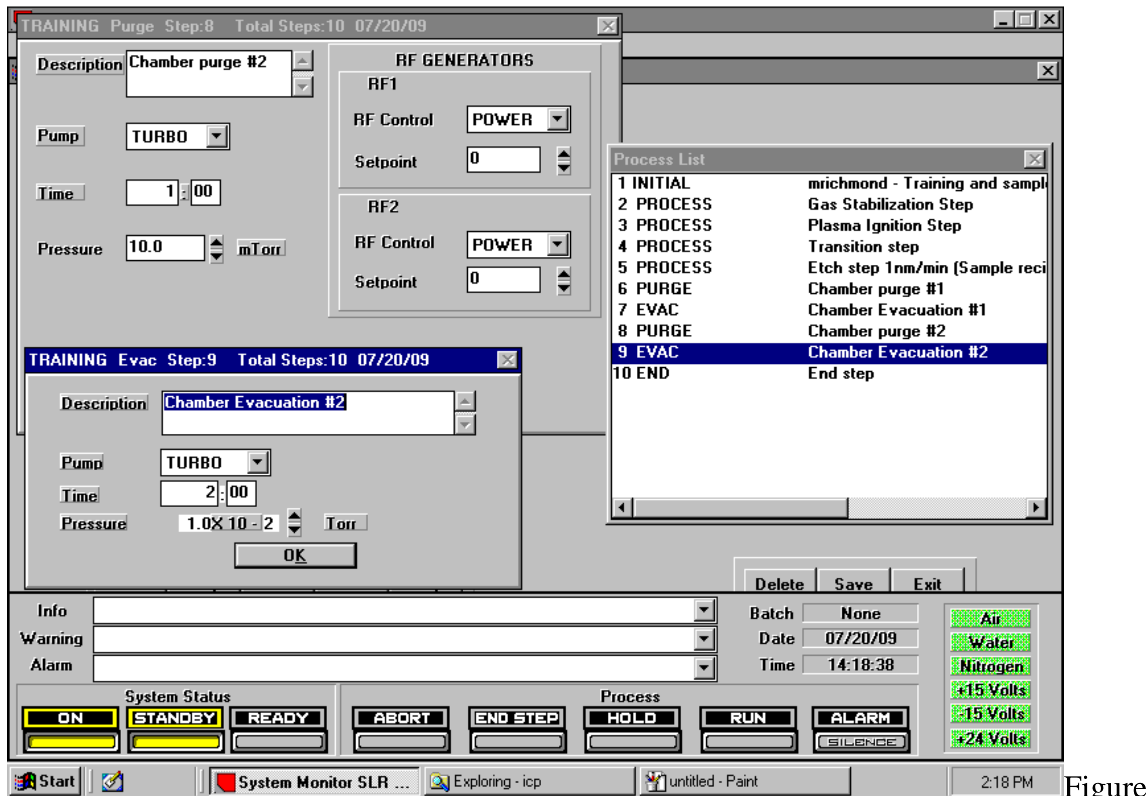

Figure 3F: Sample Recipe - Purge and Evacuation Steps.

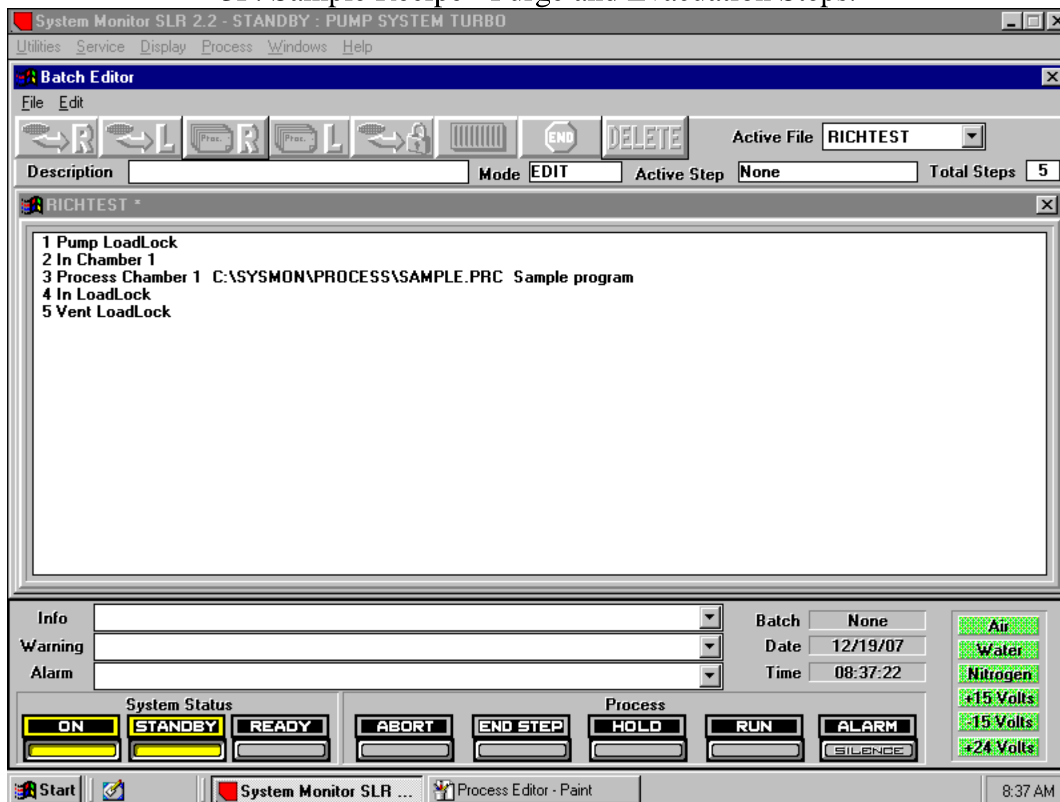

Figure 4: Batch Editor.

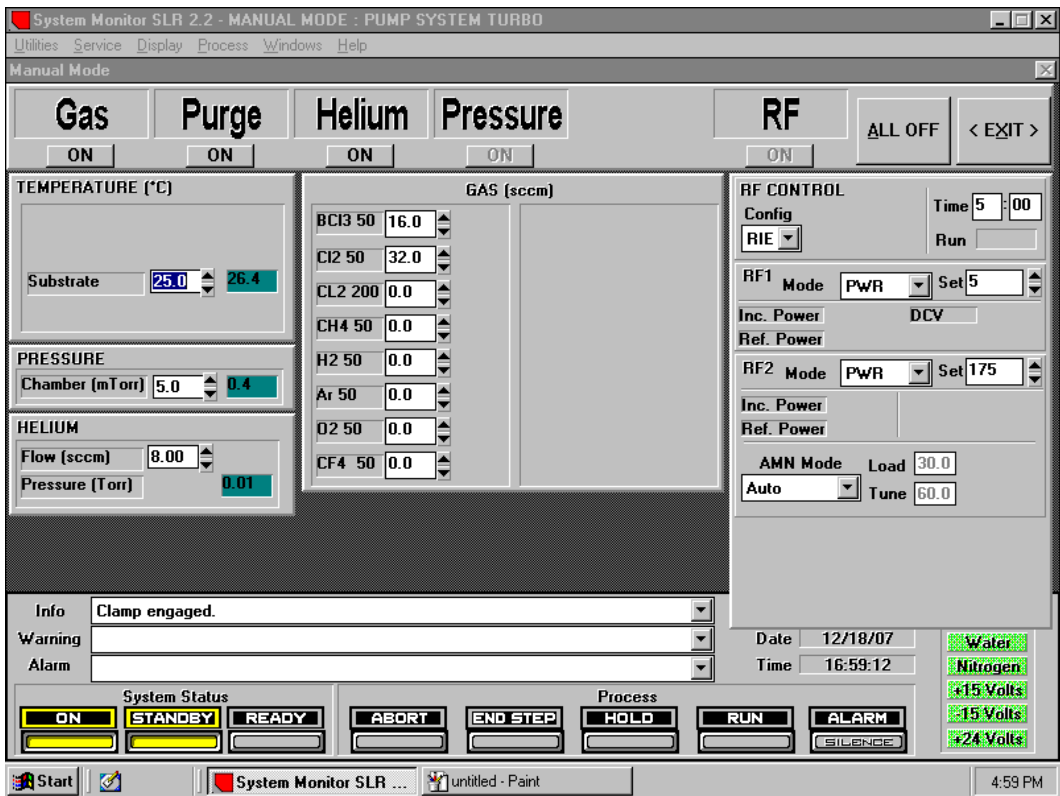

Figure 5: Manual Mode operation.

Appendix A: Sample Recipe

1. Initial step.
    a. Name: Enter name of your recipe so you can find this recipe
    b. Description: Netid required in here and enter recipe description in here. (failure to place netid can result in recipe being deleted)
    c. Pump: Default of Turbo.
    d. Base Pressure: Base pressure must be 1e-3 or better vacuum.
    e. Hold time: Default at 10 seconds or increase as needed.
    f. Data logging: Default set to “no logging”.
    g. Substrate Temperature: Enter desired substrate temperature.
2. Stabilization step.
    a. Pressure: Enter desired Chamber pressure in mTorr.
    b. Helium Cooling: Required to be checked.
    c. Gas Channels: Enter desired gases and flow rates.
    d. Time: Enter desired processing time. (e.g. 10 sec)
    e. RF1 Power: Enter RF1 (RIE) power = 0.
    f. RF2 Power: Enter RF2 (ICP) power = 0.
    g. AMN Mode: AUTO → Never use anything except AUTO
4. Ignition step: ICP (may be skipped if using regular power settings).
    a. Keep the Pressure and Gas flows as stabilization step
    b. Helium Cooling: Required to be checked
    c. Time: Enter 5 to 10 sec.
    d. RF1 Power: Higher than desired Main Etch
    e. RF2 Power: Higher than desired Main Etch
    f. AMN Mode – AUTO Only
5. Main Etch Process step.
    a. Pressure and Gas – Keep same values as previous step
    b. Helium Cooling: Required to be checked.
    c. Time: Enter desired processing time
    d. RF1 Power: Enter Desired RF1 (RIE) power
    e. RF2 Power: Enter Desired RF2 (ICP) power
    f. AMN Mode – AUTO Only
6. Chamber Purge #1.
    Description: Chamber Purge #1.
    a. Pump: Defaults to Turbo.
    b. Time: 1 minute.
    c. Pressure: 10mTorr.
    d. RF1 Power: 0.
    e. RF2 Power: 0.
7. Chamber Evacuation #1.
    a. Description: Chamber Evacuation #1.
    b. Pump: Defaults to Turbo.
    c. Time: 2 minutes.

   d. Pressure: 1e-2.
8. Chamber Purge #2.
   a. Description: Chamber Purge #1.
   b. Pump: Defaults to Turbo.
   c. Time: 1 minute.
   d. Pressure: 10mTorr.
   e. RF1 Power: 0.
   f. RF2 Power: 0
9. Chamber Evacuation #2.
   a. Description: Chamber Evacuation #1.
   b. Pump: Defaults to Turbo.
   c. Time: 2 minutes.
   d. Pressure: 1e-2.
10. End Step.
   a. Description: Enter description. (e.g. End step)
   b. Final Pump: Default to Turbo.
   c. Pressure: Default to 1 x 10-2.
   d. Hold Time: Default to 10 seconds.

Appendix B: Plasma Ignition

1. PURPOSE: The purpose of this document is to notify all Plasma-Therm Customers and Plasma-Therm Field Personnel of Basic theory and steps required to "Ignite" a plasma in ICP equipment.

2. SCOPE:
The Plasma Therm Inductively Coupled Plasma (ICP) source is used to generate high density plasma for both etching and deposition processes. Inherent to this technique is the need for some minimum plasma density before power can be effectively coupled through an inductive mechanism. As a result, it is difficult to operate inductive plasma at low power levels (low plasma density) and it may also be difficult to initially light inductive plasma. This has consequences not only for process reproducibility but also for system safety.

In particular, damage can occur to the ICP source in the event RF power is continuously applied but no plasma is present.

In order to prevent possible damage and ensure reliable plasma lighting, it is necessary to implement an ignition sequence at the beginning of each etch process. The ignition sequence relies on the initial presence of low density plasma which is created using the substrate bias RF (RIE). Once this plasma is established, then the ICP can be lit by coupling power into the RIE plasma. The ability to light and maintain inductive plasma is highly dependent on the process gases used, the process operating pressure, system condition and even the substrate material.
Consequently, a reliable ignition sequence must be determined for each individual process used. **The procedure to accomplish this is detailed below.**

RESPONSIBILITY AND AUTHORITY

3.1 It is the responsibility of the Individual performing this instruction to have technical knowledge of the ICP Etcher, software and the related supporting equipment.

3.2 The Technical Support Manager is responsible and has the authority to maintain and revise this work instruction.

3.3 It is the responsibility of the Supervisor/Manager that all Field Service Engineers or Maintenance Personnel responsible for the tool have been trained on how to successfully perform the steps in this Work Instruction.

4. PROCEDURE - A process should be built consisting of the following steps:

4.1 Stabilization step
Process conditions established, but no RF applied. These conditions (gas flow and pressure) may be different from the desired main process conditions and should be chosen based on ease of plasma ignition. Generally the pressure should be 5-10mTorr, though for certain gases (notably SF_6) a higher pressure may be necessary. For multi gas processes, the gas ratio may also be different during this step, with the flow rate of **"easy to light" gases such as Ar, O_2 or N_2** increased. Any gases which will be used in the main etch should be turned on at this point, even if at a very low value. **Avoid turning gases on during later steps as a flow burst may cause unstable plasma conditions.** RIE and ICP matching network mode set to "default": this ensures matching networks are always at the same position at the start of the process. The position to set the Load and Tune values will be derived from the following ignition steps where plasma is 'lit' and the RF Reflected power is at a minimum. Step time is typically 5 seconds.

4.2 RIE ignition step
Same conditions (gas flow and pressure) as Step 4.1.
RIE matching network set to "auto" mode.

RIE power applied. This should be high enough (50-100Watts) to ensure reproducible lighting of an RIE plasma. The presence of plasma should be visually verified.
Step time typically 3-5 sec. (long enough for reasonable RF match)

4.3 ICP ignition step
Same conditions (gas flow and pressure) as Step 4.1.
ICP matching network set to “auto” mode.
ICP power applied. This should be high enough (500-1000Watts) to ensure reproducible lighting of an ICP plasma. The presence of stable plasma should be visually verified.
Step time typically 3-5 sec. (long enough for ICP to match to low reflected power)

4.4 Transition step
This step may be needed to transition between the process conditions of the ignition steps and the main etch, especially if the main etch gas flows or pressure are very different from those used in the ignition steps. The intent is to avoid rapid fluctuations in the process conditions which may cause an RF mismatch and possible plasma extinguishing. The process conditions should be intermediate between the ignition and main etch steps. The presence of stable plasma should be visually verified. Step time is typically 3-5 seconds.

4.5 Main etch
Process conditions of main etch used, from the customers etch process.
The presence of stable plasma should be visually verified.

4.6 Summary
The above steps illustrate the most generic approach to building an ignition sequence. In some instances it may be simplified. In the system Setup (RF section) a variable delay time (ICP RF Generator Go On delay) can be set. This automatically forces a delay between the RIE turn on and the ICP turn on so that it is possible to employ a single ignition step in which both RIE and ICP are used. The delay (typically set to 3000mSec) ensures that RIE plasma lights and tunes before the ICP turns on. This effectively combines steps 4.2 and 4.3 above into a single ignition step. It should be noted that the delay is a global variable and is then used in all processes: for processes requiring more flexibility in the ignition step then the separate RIE/ICP steps should be used. If the main etch process conditions alone will light reproducibly without additional ignition steps, then steps 4.2, 4.3 and 4.5 can further be combined (using the ICP Go On Delay) into a single step. Before implementing this simplified approach, reproducible lighting of this step must be verified under all expected conditions.