# Penn State Nanofabrication Facility

## Plasma Therm 720 Reactive Ion etching System

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**Materials: This is not a dedicated system:**

- This machine can be used for etching all materials with the exception of those containing lead.

**Available Process Gases:**

- $Cl_2$
- $SF_6$
- $CF_4$
- $CHF_3$
- $C_2F_6$
- $O_2$
- **Ar**
- $H_2$

**Safety Note:**

- ! During power outages the system will shutdown automatically.
- ! In case of an emergency, hit the red power off (EPO) button on the right hand side on the system to power down the system. ***This will also shut off the master gas valve!***
- ! The system is interlocked so you must sign into the equipment through the portal prior to using it.
- ! This tool uses a corrosive gas ($Cl_2$ ) so when creating recipes make sure that you evacuate and purge the system properly.

**Note:** If you are unable to vent the loadlock it is because you aren't logged into the system via the Portal!

## A. Overview of the PlasmaTherm 720 Reactive Ion Etcher (RIE) and Processing Issues

Figure 1: System Overview

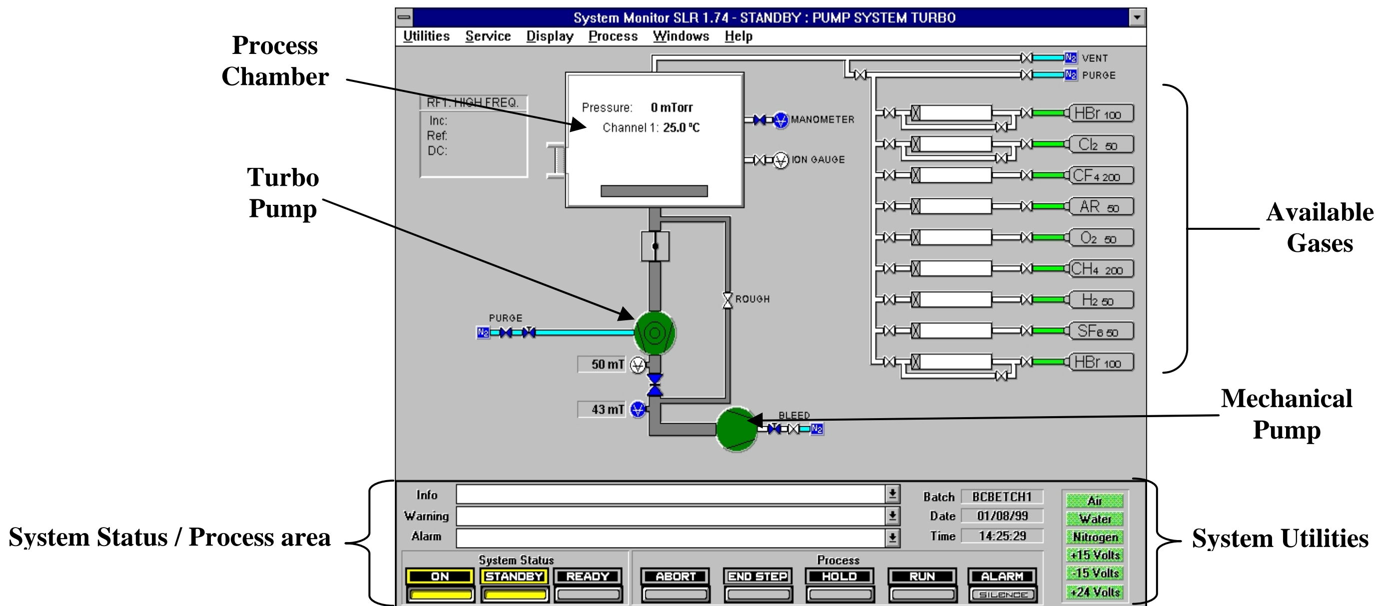



Figure 2: Control Chamber Details

## Chamber Cleaning Information

Etch processes produce etch by-products that may contain carbon, silicon, silicon oxides, and nitrides as well as chlorides, and fluorides from the etch chemistries. Over time, these by-products accumulate on the chamber walls and may eventually flake off, thus generating particle contamination. Additionally, as residues build up in the chamber, the deposits begin to participate in the etch process in ways that can affect the etch rate, etch profile, critical-dimension control as well as many other etch parameters. To prevent such occurrences, etch systems must be periodically shut down for scheduled--and sometimes unscheduled--chamber wet and dry cleans.

A wet clean (which only the staff perform) involves opening the chamber for manual removal of deposited etch by-products. This is done using Acetone, IPA, and DI water. Once a wet clean is preformed the chamber is then pumped down and cleaned using a plasma cleaning recipe (CHMBRCLN.BCH) which runs for approximately 2 hours. The dry clean chemistry used consists of a combination of fluorine and oxygen gases. Fluorine-containing gases are very effective at removing silicon-based residues and will also clean silicon oxides. Oxygen cleans off organic by-products of the photoresist that are removed during the etching process.

## Etch Repeatability Information

Ensuring a well conditioned chamber prior to running any etch is important in obtaining repeatable results. By following the following procedure there should be no issue with repeatability with your etching process.

1) Run the chamber cleaning process (CHMBRCLN.BCH) for a total of 20 minute (10 minutes per process step).

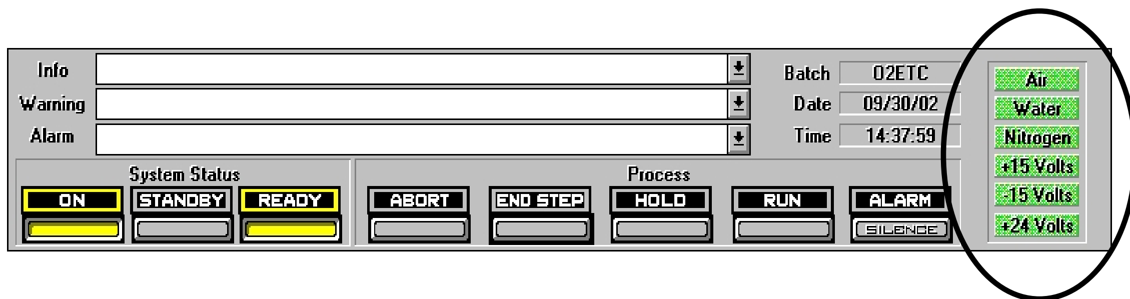
2) Run your etch process for 2 minutes with just the carrier wafer.

3) Run your etch process with a test sample (with the exact same material that you are trying to etch) and verify the etch rate. If the etch rate is correct then you can run you real sample. If the etch rate is still not correct try running the condition steps one more time. If after the second conditioning you still are unable to achieve repeatable results please contact Guy Lavallee at glavallee@psu.edu or ext 5-9339 or Bill Drawl at wrd1@psu.edu or etc 3-8558

## System Modes

An active system is always in one of four different modes: Equipment-On, Standby, Ready, or Running a process. The Mode is indicated in the System Status / Process area (a lit button indicates the current mode of the system). To the far right of this area there is a group of utilities that the machine needs to be operational: Air, Water, Nitrogen, +15 Volts, -15 Volts and +24 Volts. These indicators should be green for the machine to be operational.

**NOTE:** If they are yellow or red the system will be in an alarm condition and will be non-operational. If this case you should immediately notify a staff member.



## B. Using the RIE

The Reactive Ion Etcher has eight main steps:

**1.** User Login/Sign in
**2.** Loading Samples
   i. Venting the Loadlock
   ii. Loading Sample
   iii. Pumping the Loadlock
**3.** Creating and Loading a Batch/Process file
**4.** Running a Batch file
**5.** Clearing Alarms
**6.** LogOut of the system

## 1. User Login

a. When you first arrive at the system it should be in the following state:
   a) The system (Load Lock and Process Chamber) should be under vacuum.
   b) There should be a user login screen on the monitor.
      1. The User login is **2460**.
      2. The Password is **2460**.

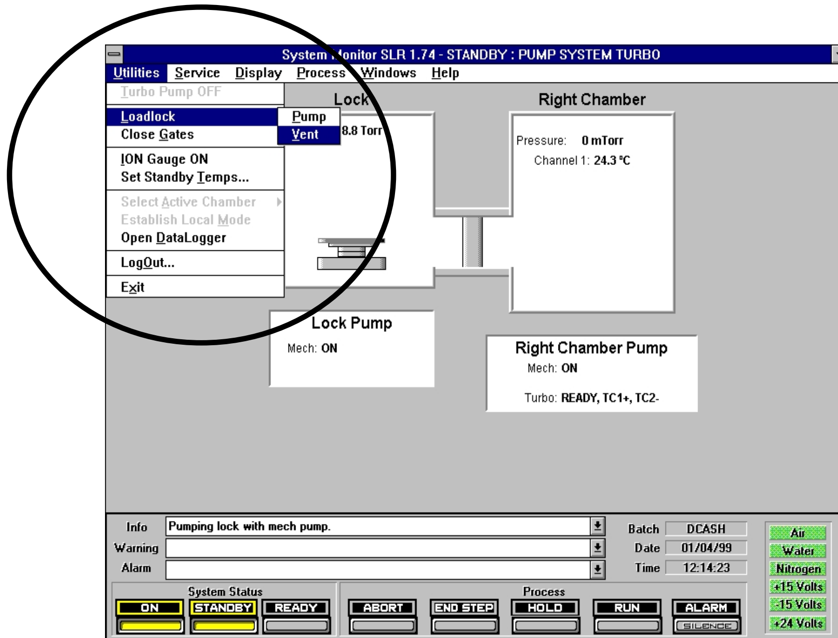
b. Sign into the User Process Logbook
   a) In order to gather information for process development in the lab we require users to log information about their processes in the user process logbook. There are several blocks in the log book to record information. The logbook should be self explanatory but if you have any questions please ask
   b) There are a large number of important parameters to look at when performing dry etching and not enough space in the log to record all of them. Because of this we ask users to provide any and all pertinent information acquired (Selectivity, Side wall profiles, CD, Surface roughness, …) as you record it in you notebook. This will enable the Nanofab to put together a resource guide regarding different etch recipes for a variety of different materials. This information can be sent to Guy Lavallee at the following email address: ***glavallee@psu.edu***

If the previous user did not log their information in the logbook please make a note of this in the process log book.

## 2. Loading Samples

a) With the system in the Standby mode:

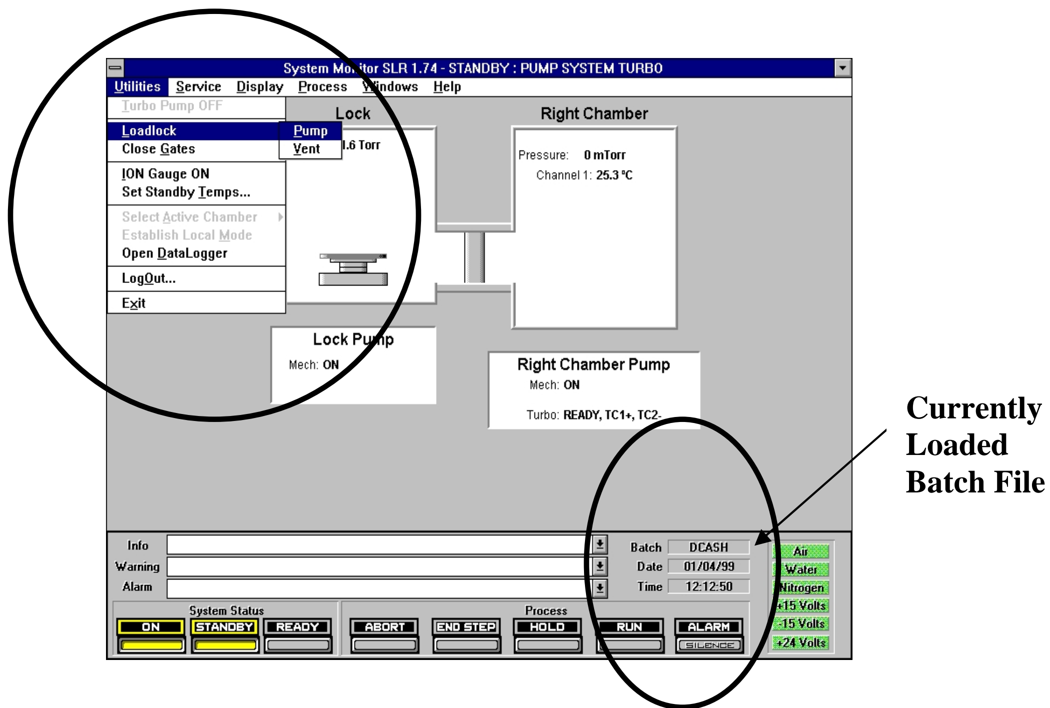
1. Go to the **Utilities** menu select the **Loadlock → Vent**
    a. It should take approximately 2 minutes to vent the loadlock.




2. Once the system is vented (LoadLock diagram will turn red) open the loadlock and place your samples on a 6" carrier wafer.
3. The 6" carrier wafer is used to protect the system electrodes from being damaged.
    a. NOTE: If you are etching a 6" wafer you do not have to use the carrier wafer.
4. The standard carrier wafer for the system is a 6" anodized aluminum plate. If you find that this creates a problem for you during your etch we can provide you with another 6" carrier wafer that will be compatible with your process.
    a. There are 3 separate anodized aluminum carrier wafers. If your process turns them black please be considerate and clean them.

b. To clean the carrier wafer scrub it using a green scrub pad (from the top drawer of the tool box) and a mixture of Acetone and water. After it is clean use a clean wipe and IPA to wipe it down. After the IPA wipe down use another clean wipe with DI water and wipe it down again. Then place it on a hot plate at 125°C for approximately 15 minutes. Then remove it from the hot plate. Be very careful as the wafer will be ***very hot***!

b) Once you have your samples loaded go to **Utilities**→***Loadlock*** → ***Pump***.



## 3. Creating and Loading Batch/Process files

In order to run an etch process on the Plasma Therm 720 a Batch file must be loaded into the computer. The following is a description of how to **Open/Create/Modify** and **Load** Batch files.

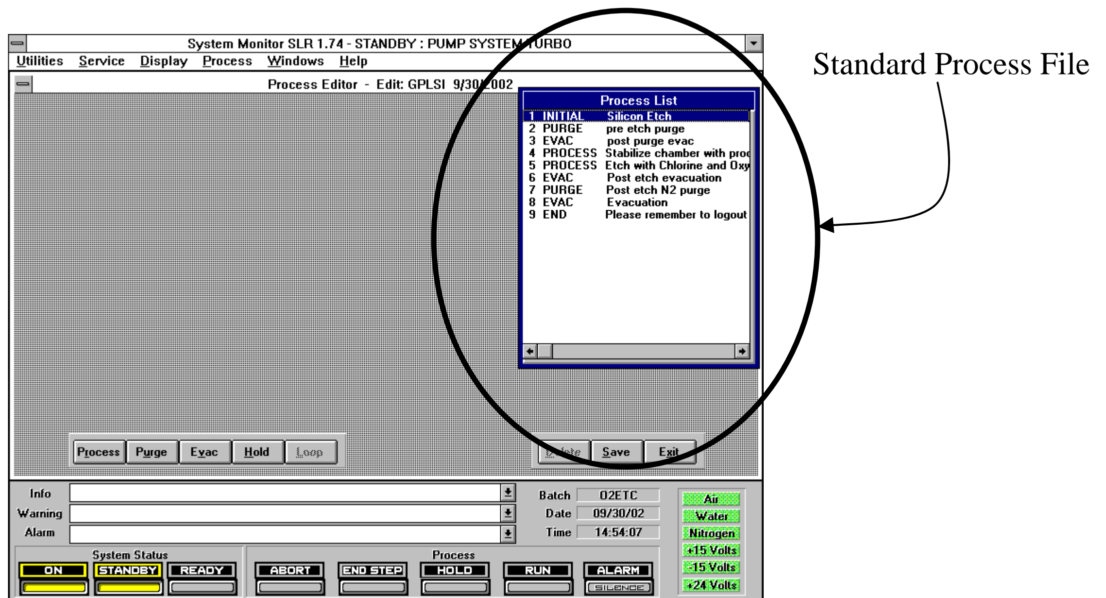
a) In order to open a batch file go to the ***Process*** menu and select ***Batch***. This will open a batch file editor window.

Note: The purpose of the batch editor is to allow for automatic processing of wafers in a single automated task. This is accomplished by programming a routine using a list of predefined functions. These functions allow for the transfer of samples from the load lock to the processing chamber,

b) Once the batch file editor is open go to the ***File*** menu and select ***Open*** and select the appropriate batch file from the list of batch files.
   1. Users should always create their own batch and process files. This is so that users don't change other user's recipes.

   NOTE: You may use an existing user file to create your own file. The procedure for doing this will be discussed in the following sections.

c) Before running a Batch file make sure that your process file parameters have not been changed. In order to verify this ***Double Click*** on the ***Process Step***. This should bring up the following Process file editor.



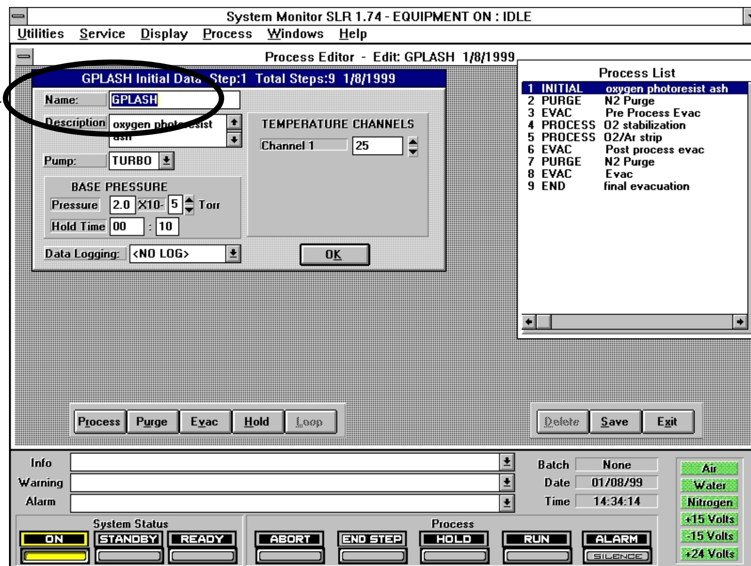

NOTE: In order to maintain a clean system it is very important to design a proper process file. All process files (with the exception of processes that use $O_2$ should have pre and post process evacuation and purge steps.

1. Every process file should consist of several processing steps: Initial, Purge, Evac, Process, Evac, and Loop (when needed).
   a. Initial Step:

      The main purpose for the initial step is to pump down the system to a low base pressure. For most applications $5X10^{-5}$ Torr should be adequate. The hold time should be ~1 minute.

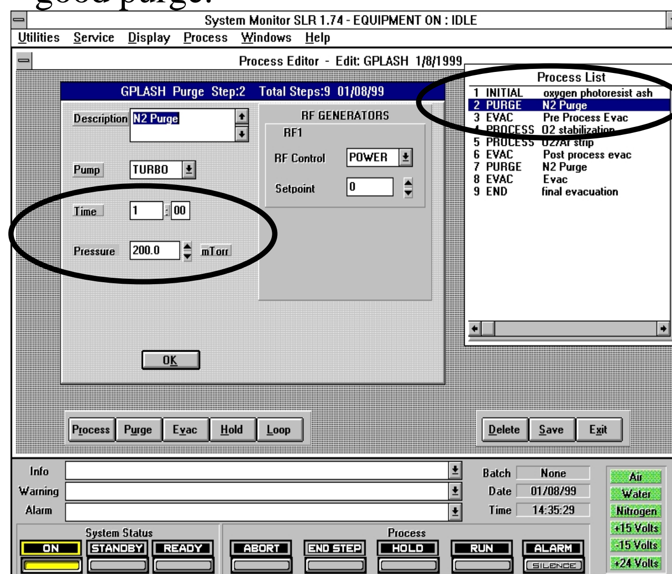
   NOTE: When opening another user's process file make sure that you change the name of it before you save the file. In order to change the name of the file **Double Click** the ***Initial step***. This should bring up the following screen. The ***Name*** block is where you will rename the ***Process File***. The protocol for renaming the file is to use your first three initials and then a qualifier for the type of material being etched.

**Process File Name**




**NOTE:** In the example above I am doing a DC Ash so I named the process file ***GPLASH.*** Once you have this step setup properly select **OK**.

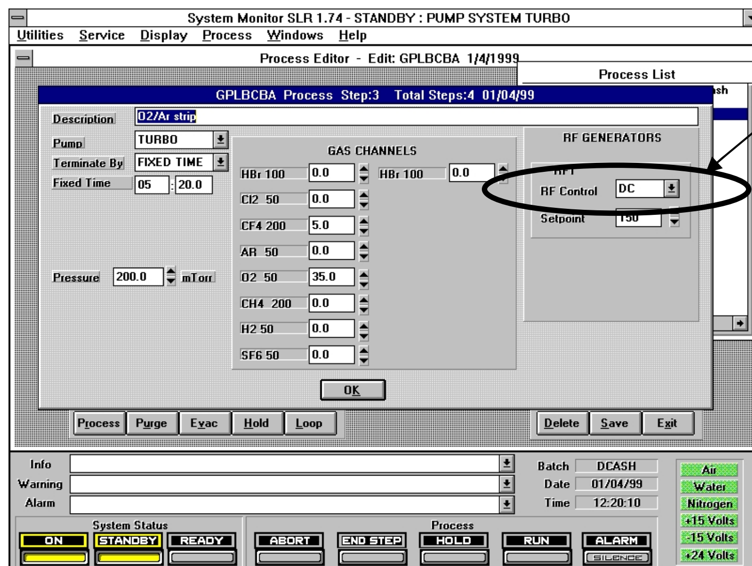
b. Purge Step:
   i. The purpose of the purge step is to allow the nitrogen to permeate into the chamber which will assist in removing any residual gases in the chamber. The pressure should be set between 15-200 mTorr and should be run for a minimum of 45 seconds to ensure a good purge.



c. Evac Step:
   i. After a nitrogen purge you want to run a chamber evacuation to remove the nitrogen and any other residual gas from the chamber.

d. Process Step:
   i. Each recipe should have two process steps.
      1. The first process step is where you set the following parameters: etch pressure, etching gas(es) flow rates, choose the pressure that you want to perform the etching. The setpoint for the RF Control should be zero.
      2. The second process is where you will set the RF Control for the etching. Here you will have two options to choose from; Power or DC.

      NOTE: There are actually three options for RF Control; Power, DC, and RF. The RF option is not used on our system



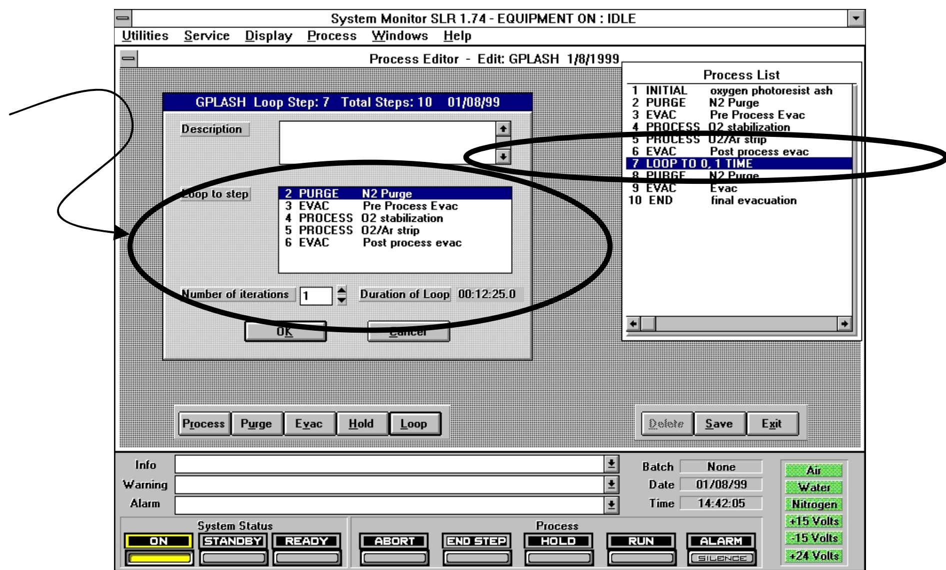
e. Evac Step:

   i. After a process step you want to run a chamber evacuation to remove the any residual process gas from the chamber.

f. Loop Step:

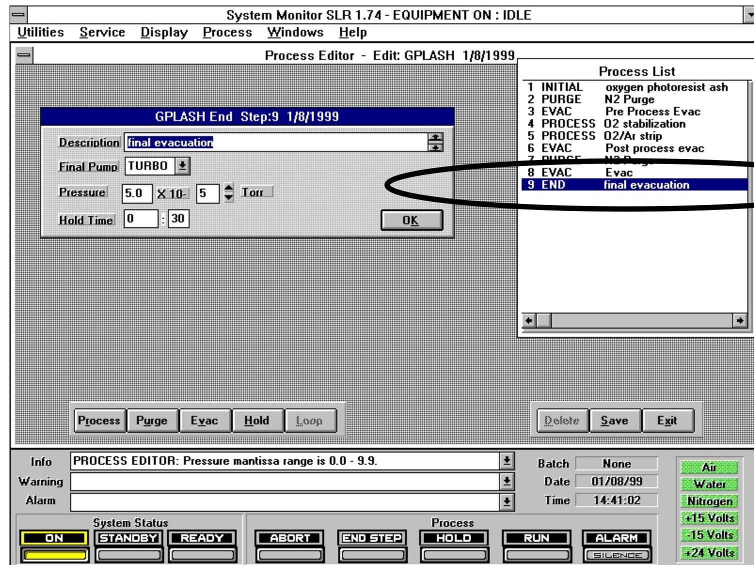
   i. This system doesn't have affective temperature control for the substrate during the etching process. So depending on your process parameters you sample will see temperatures that can affect your resist and make it hard to remove. In order to control the temperature you can use the loop function.

**Select the Step you want to Loop back to and the number of times you want it to loop.**




   ii. Here you select the step that you want to go back to in order for the loop to begin. Once you have chosen the step then enter the number of times to repeat the steps.

g. The final step in the process file should be an evacuation. This step will automatically be named **END**. It should be setup just like all the previous evacuation steps. The Hold time for this step should not exceed 30 seconds.

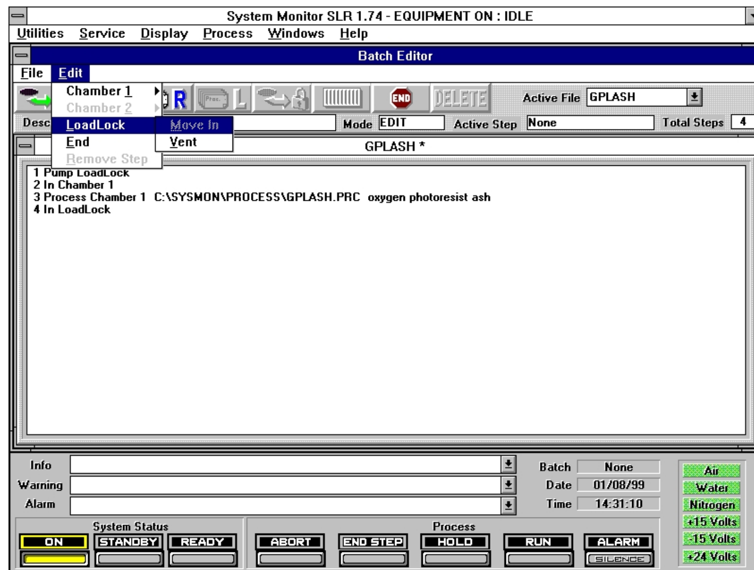



d) Once you have completed this you can hit **SAVE** or **EXIT** both will ask you to save the file.

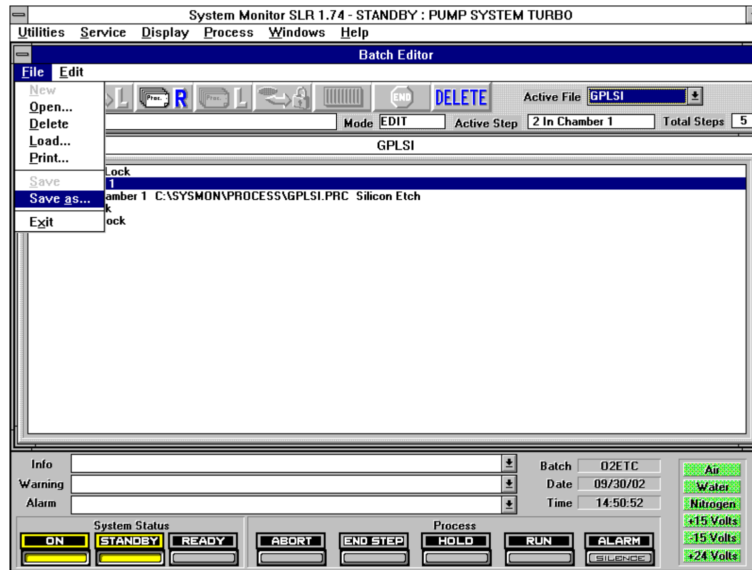
e) When it asks you to save make sure it the file has the correct name. If it doesn't and you had selected **EXIT** do not save (you will have to go back and redo everything again). If you selected **SAVE** then just hit cancel and go to the ***INITIAL step*** and change the name to the appropriate one and select **SAVE** again.

f) After you save the file you should be returned to the Batch editor screen. The next step in the batch file should be *In Loadlock*. This takes the wafer from the process chamber and returns it to the Loadlock chamber. And the final step should be either *End* or *Vent Loadlock*.

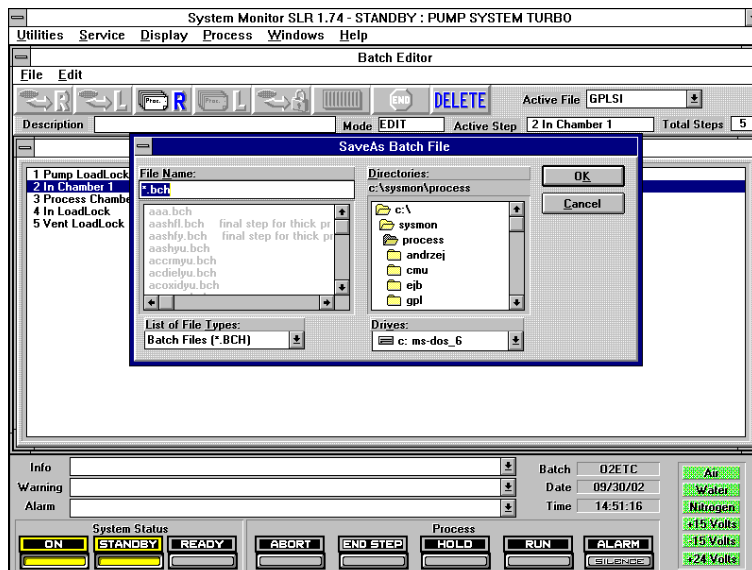
   1. If the last step is *End* then you will have to vent the loadlock using the **Utilities→Loadlock→Vent** menu options. If the last step is *Vent Loadlock* this will be done automatically.



g) Once the **Batch file** is completed you should save it using the same file name as the **Process file** (your initials followed by a qualifier)**.** In order to save the file go to the File menu and select the **Save As** function.

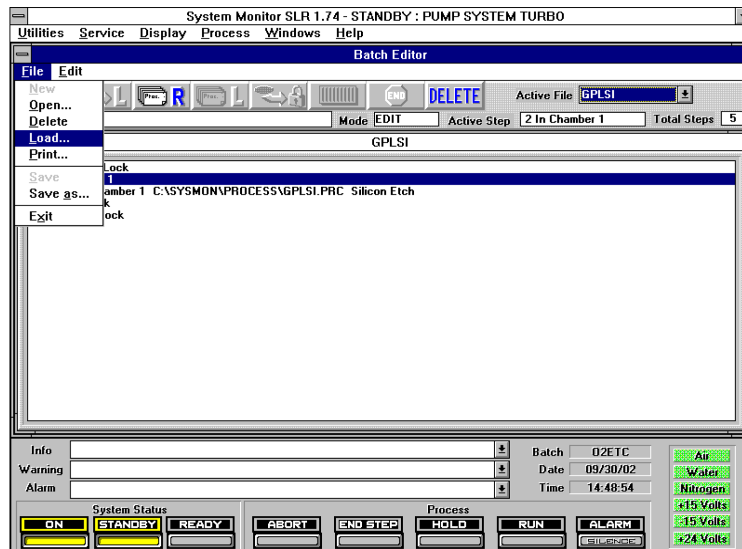



Then the following screen will display:

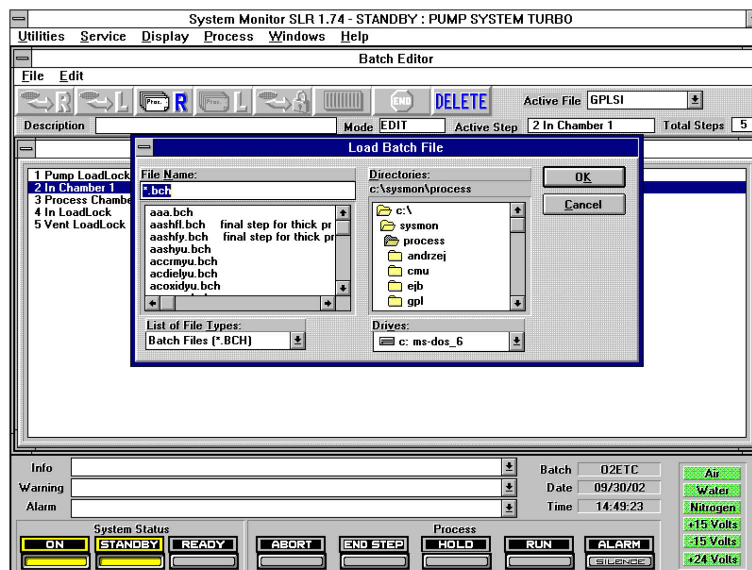



**NOTE:** The files should be located in the process directory. If you would like to setup your own directory for saving your processing files please contact the Engineer who is in charge of the tool.

h) The next step is to **Load** the Batch File you want to run. To load a batch file select ***File→Load***




i) This will ask you to enter the batch file you want to load. You can either type it in or select it from the list of files.



j) Once you have loaded the **Batch file** then the next step is to put the system in the **READY** state.  You can tell what the current system status is by looking at the bottom of the screen. The system will be in one of two conditions: **STANDBY** or **READY**

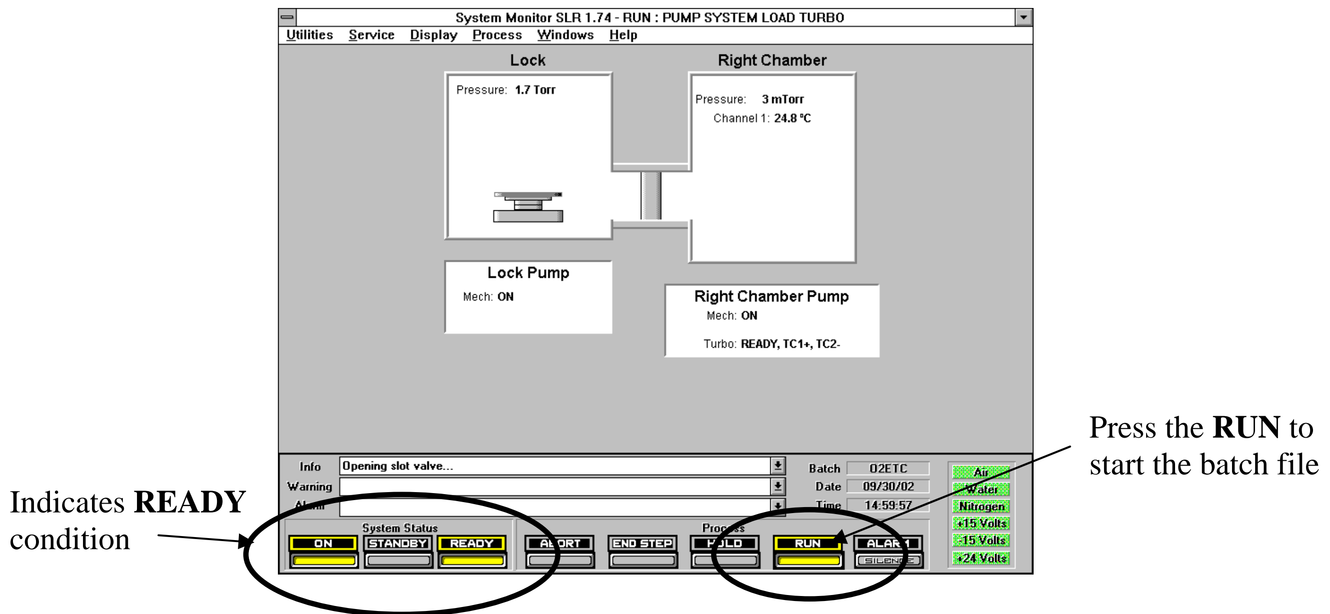
**STANDBY condition**

**READY condition**

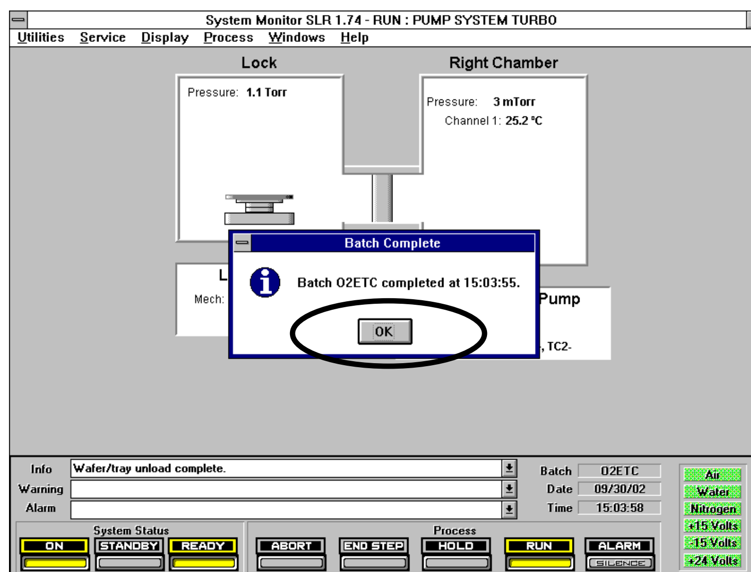
**NOTE:** If in **STANDBY** then select the **READY** condition by clicking on it.

# 4. Running a Batch File

Once you have your batch file loaded you can run the file. Verify the system is in the **READY** condition (if not select **READY**). Once the system is in the **READY** condition you then press **RUN**

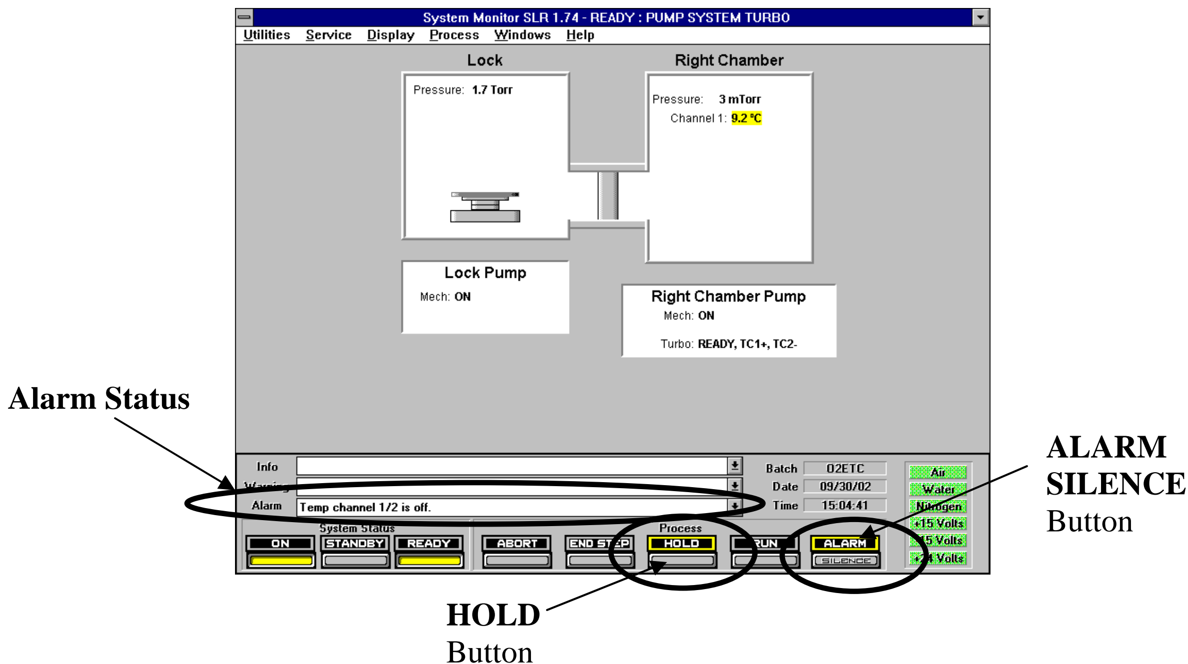



When the **Batch file** is complete a dialog box while pop up and tell you. You will have to select **OK** before doing any other step.



## 5. Clearing Alarms

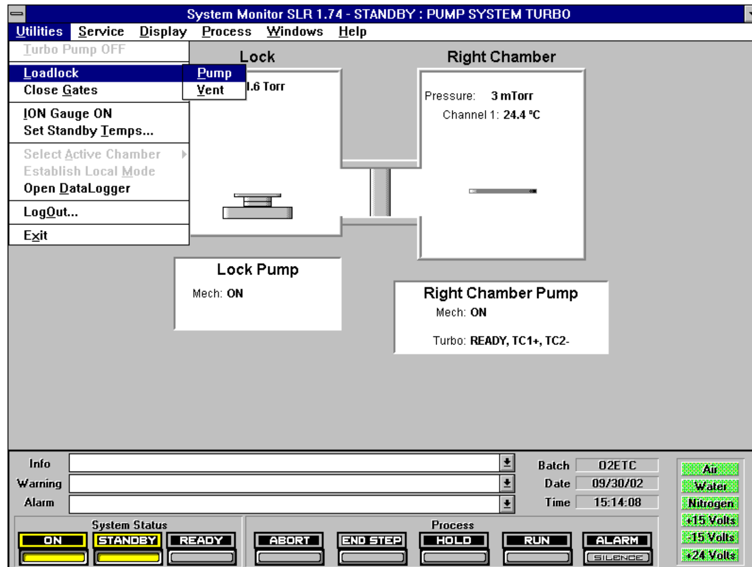
If you encounter a situation where the system begins to alarm (this can happen for a variety of reasons). Look in the Alarm box to determine why the system is in an Alarm condition. In order to get the system out of an Alarm condition you must press the **HOLD** button. This will temporarily reset the system which will take care of some problems. However, other alarms will only temporarily clear and if this happens you will have to contact the Engineer in charge of the tool.



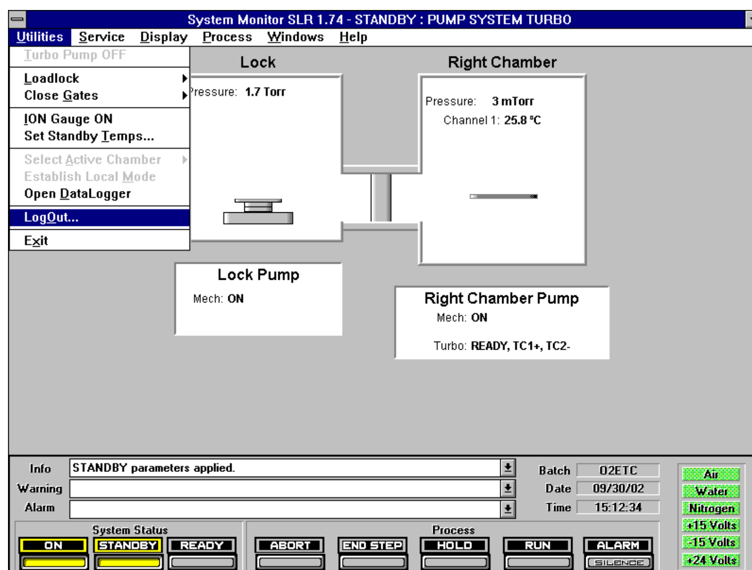

**NOTE**: To disable the audible alarm press the **ALARM SILENCE** button. Some of the typical Alarms would be:

## 6. Log Out of the System

When you are finished using the tool you should logout of the system. In order to logout verify that the system is in the **STANDBY** condition and that the loadlock is pumped down (Load Lock should be White). If the loadlock is not pumped down then go to ***Utilities→LoadLock→Pump***




Once it is pumped down you can then go to ***Utilities→LogOut***



## 7. Additional Information

Unfortunately, we have found numerous bugs with the software on the RIE. One such issue is if you hit the return key on the keyboard it has a tendency to lock the system up. Another issue is the system becomes unstable (stops displaying information properly in the different windows) if you move the smaller popup windows around. If and when you begin to notice that the system is becoming unstable please reboot the system using the following steps:

a) Press **CTRL-ALT-DEL** twice in succession to restart the system. When the system reboots enter the username and password.
b) On the chiller unit (back right corner of RIE) toggle the **START** switch up.
c) Press the **ON** button located in the bottom left corner of the windows display.
d) Since the Turbo Pump is reset during the power reset it must be turned back on. To do this go to ***Utilities →TuboPump(ON)***
e) Once the turbo pump comes back online (as indicated in the Info window at the bottom of the screen) you then put the system in **STANDBY**.
f) The next step is to clear the warning (Gas suspected in process chamber) on the system. This is accomplished by going to ***Service →Maintenance →Pump →System(Turbo)***
g) ***WAFER RETREVAL:*** If your wafer is stuck in the process chamber you will have to manually retrieve it by doing the following: ***Service →Maintenance →Wafer Handling***

    1. From here select the **UNLOAD** option and the wafer should be returned to the loadlock. Once the wafer is back in the loadlock press the **EXIT** button .
        a. If the unload option is not available click the **RIGHT CHAMBER** button on the bottom of the screen. This will let the system know there is a wafer in the chamber that needs unloaded.