STS DRIE User SOP

Location: NRF Cleanroon, Dry Etch Bay

STS DRIE SOP

The STS DRIE is an Inductively Coupled Plasma Process etcher designed and configured to etch deep high aspect ratio features in silicon only. The process provides high selectivity for etching Si with most common photoresist and SiO_2 masks. ICP RIE uses RF magnetic field to further excite electron cloud and reactive ions and increase density of ions and neutrals which increases etch rate. By combination of alternate SF_6 etch and C_4F_8 protection (deposition) process cycles with ICP RIE, high etch rate, high directionality silicon etch is realized.

Please be aware, EXPOSED METALS AND METAL MASKS ARE MOT ALLOWED IN THE CHAMBER. This will create etch-related micromasking and extensive system maintenance issues.

Prerequisites for operating the Solaris RTA system:

a) Obtain a NRF ID (if you do not already have one) by completing the NRF Lab Use Request Form and safety training.

b) Receive “one on one” training and certification from NRF Staff. Discuss your process with a staff member.

Safety

DANGER! Do not remove the covers of the instrument. Do not modify the instrument.

- There are several hazards associated with the DRIE. It is a high voltage device so no operation of the machine is allowed unless all of the interlocks and safety measures are intact.

- **Pinch Hazard** - The loadlock lid is extremely heavy; keep your hands clear when opening and closing the lid.

- **HOT Components** - The User must observe caution when loading/unloading samples from the sample stage or graphite susceptor. Samples are very hot when immediately removed from the process chamber. Sufficient cooling time must be allowed prior to sample handling.

1.0 Sample Restrictions

1.1 Absolutely no exposed metal is allowed in the process chamber. Any metal on your substrate must be COMPLETELY covered by photoresist.

CAUTION CAUTION

METALS AND METAL MASKS ARE NOT TO BE EXPOSED TO PLASMA IN THE CHAMBER.

1.2 No silicone based thermal compounds are allowed. Use only staff approved thermal compounds for carrier wafer mounting.

1.3 No wet samples are allowed in the chamber. All wet processed samples must be completely dry before placing inside the tool.

2.0 Pre-Operation

2.1 Tool Reservations may be made via the NRF Reservation Page. http://nimet.ufl.edu/servicecenter/resources/default.asp

2.2 Change gloves. WARNING No solvents or liquids are allowed near the machine, change your gloves before operation!!

2.3 Log into the tool by using the TUMI computer in this cleanroom bay.

3.0 System Checks And Layout

3.1 System hardware checks

3.1.1 Check that the LCD display on the ILD module is not showing any coolant errors.

3.1.2 Check that the lid temperature is at setpoint, 45°C.

3.1.3 Check that the turbo pump is in rotation and showing an amperage range of between 1.8 and 2.8.

3.2 Software checks

3.2.1 If the operator station software is not running then double click on the operator station icon on the bottom windows launch bar and allow the software to boot up.

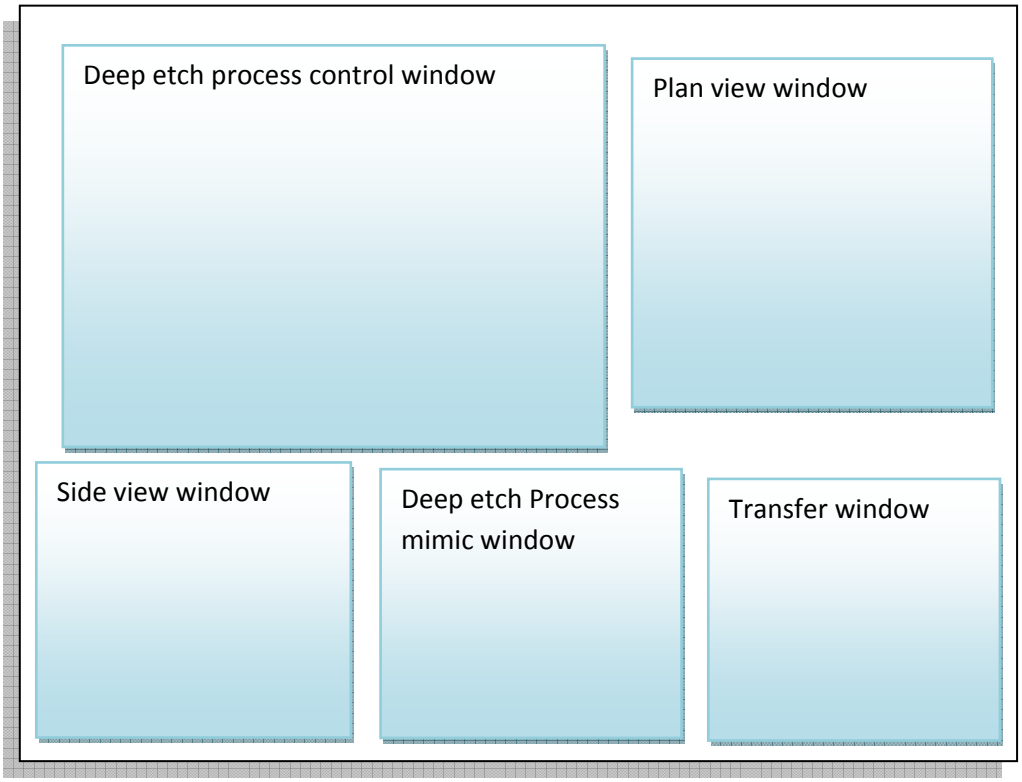
3.2.2 If the Operators Station is closed open it and log on to the software as Administrator; the Password is “adm”. If the Operators Station Mode is “active” the tool is ready to process; if it is “Unknown” press the mode button and take the machine to Inactive then to active. Never go to active mode from any state other than “inactive” mode.

3.2.3 The lower bar of the operator’s station window should not be RED; if it is, click in the red and a pop up window will appear that describes the problem(s) in detail. SEE SPECIAL OPERATIONAL SEQUENCES SECTION FOR DETAILS.

3.2.4 Check that all five windows are present on the operators screen; if not the Plan view, Side view and Process windows can be activated by clicking Mimic and selecting them.

3.2.5 The deep etch process control and Load Lock transfer windows are activated by clicking control on the menu bar and selecting them.

The software window should be arranged as shown below:



4.0 OPERATION

4.1 Select a mode from the **Operator Mode** dialog and enter mode password

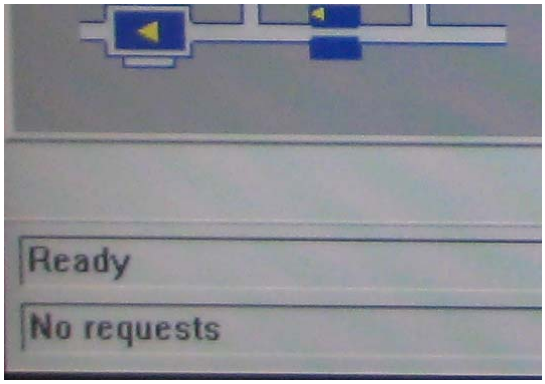
4.2 At the Operators Station “process control” window press SELECT button to select your recipe, or create a new recipe from one of the basic template recipes. The basic recipes are BAO, O2CLEAN; all others are either user modifications of the basics or maintenance recipes.

NOTE: No user will ever modify and save a recipe and fail to rename it unless they created the recipe in the first place.

NOTE: Critical operation parameters (**Appendix** section **3.0**) should not be changed.

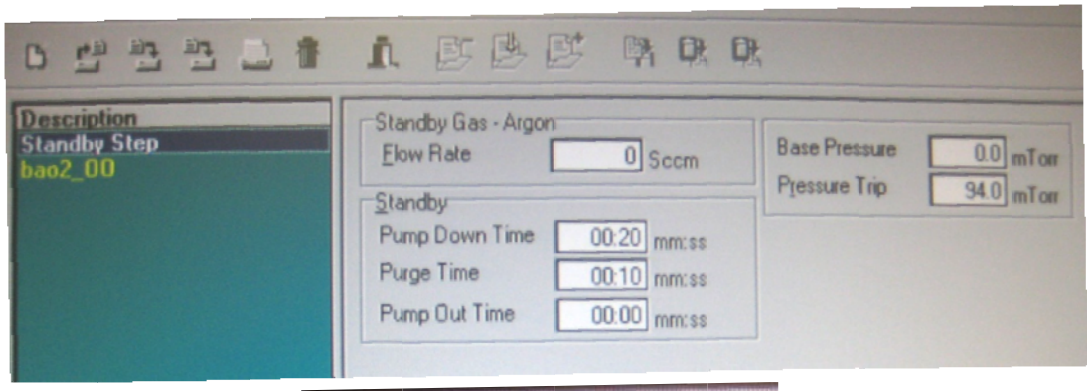
Once a recipe is highlighted, press SELECT and the machine will load the recipe and prepare the etcher to run it. The recipe name will appear in the process window.

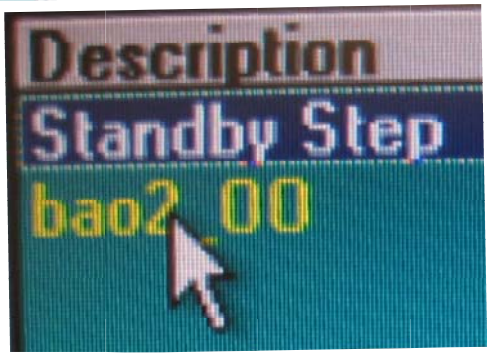
NOTE: Never command the machine to do anything unless the word “READY” appears in the lower left part of the Operators Station window. Failure to do so will cause the software to lock up.



Click on the recipe button to bring up the Recipe editor and display the recipes parameters.

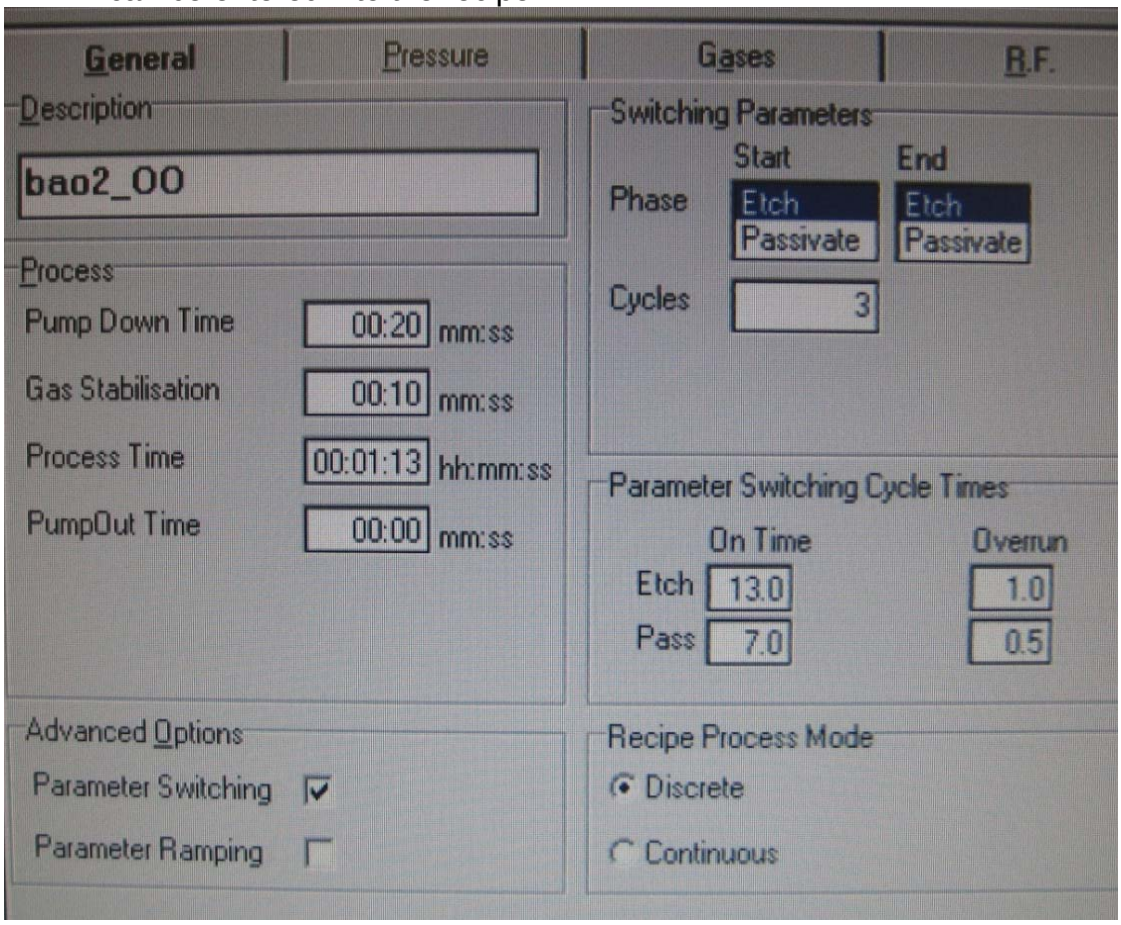
The first window displayed by default shows the Stand by Step; never modify this.



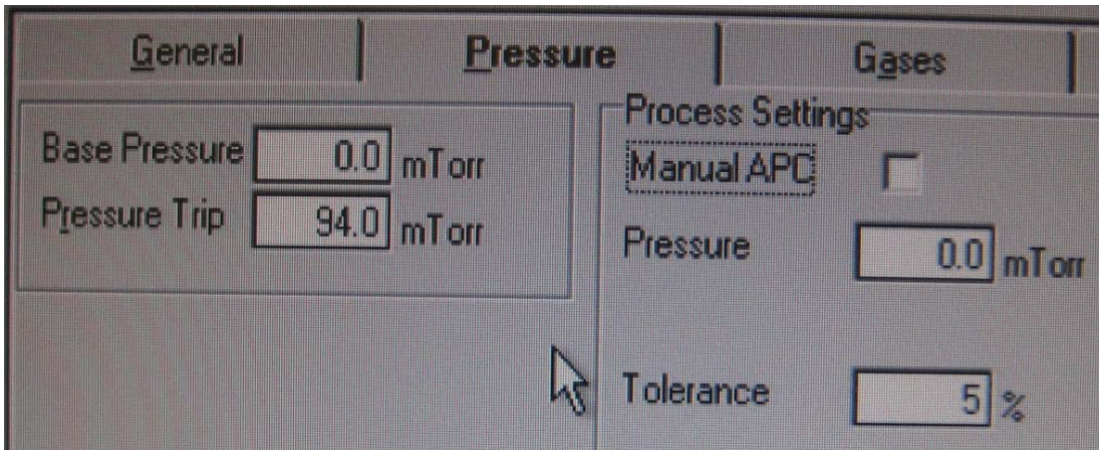


The recipes process tabs will be displayed; General, Pressure, Gases, RF, HBC and HLUR.

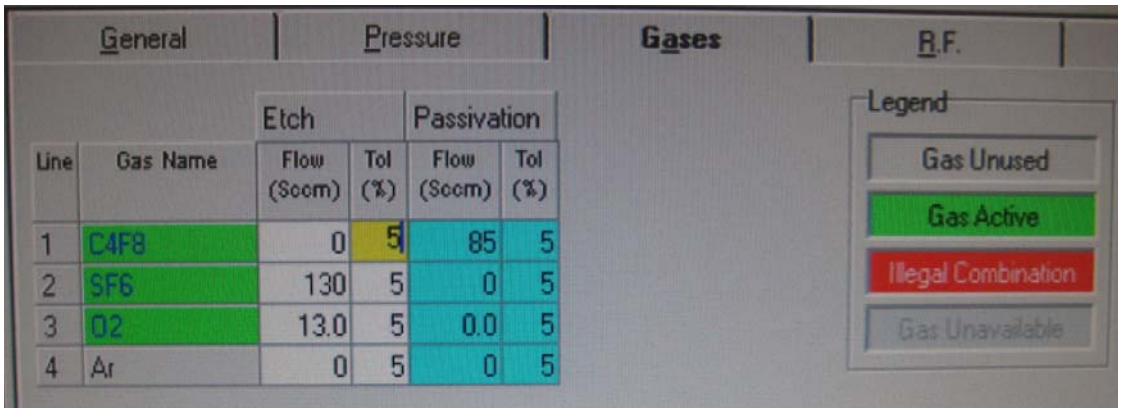
On the General tab process time, cycle phase times, and process modes can be entered into the recipe.



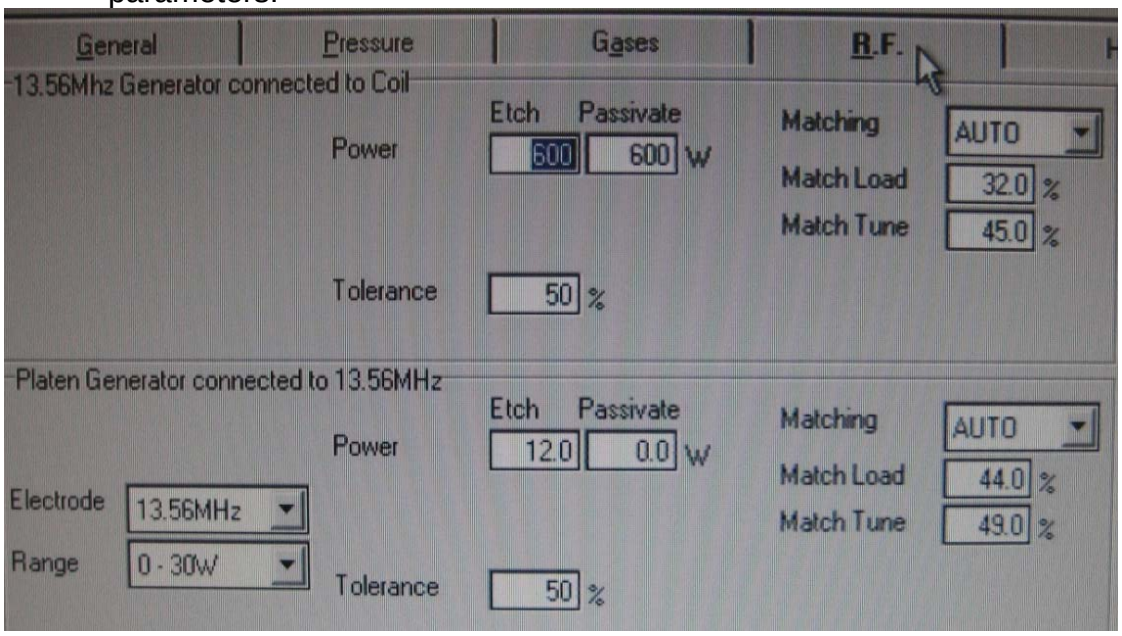
In the pressure tab the chamber pressure and APC valve mode can be set. Tolerances in the recipe should be 5%



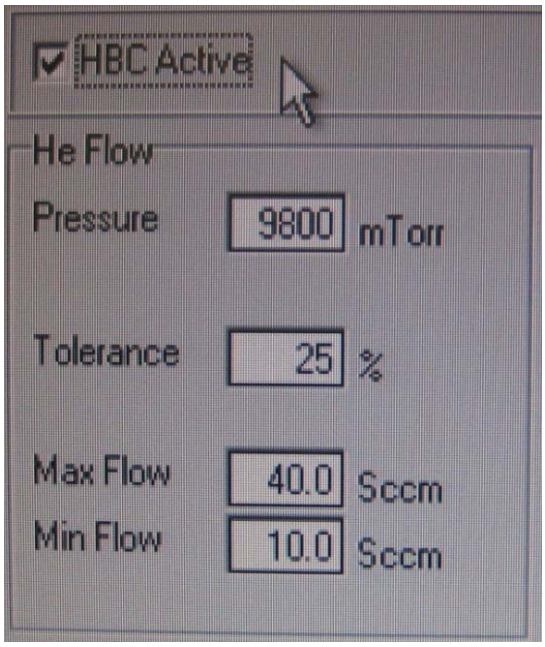
The gas flows and mixtures are set on the Gases tab



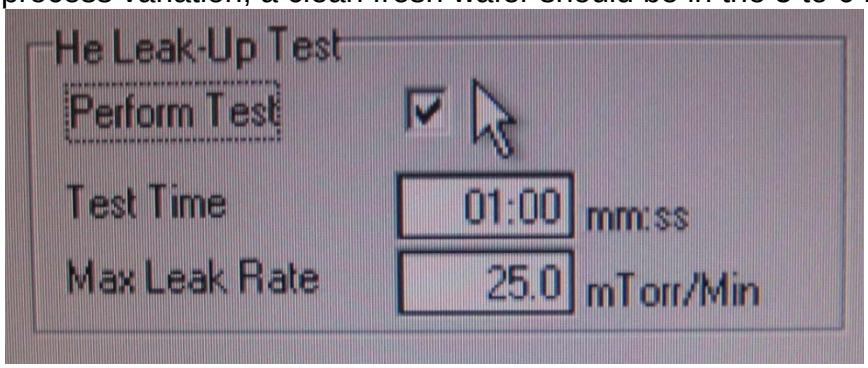
The RF energy tab allows the RF wattage to be set do not change the other parameters.



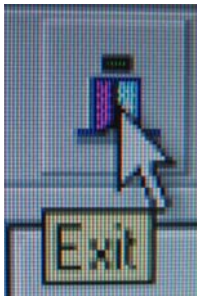
The parameter for Helium Backside Cooling can be set on the HBC tab; adjustments are device specific.



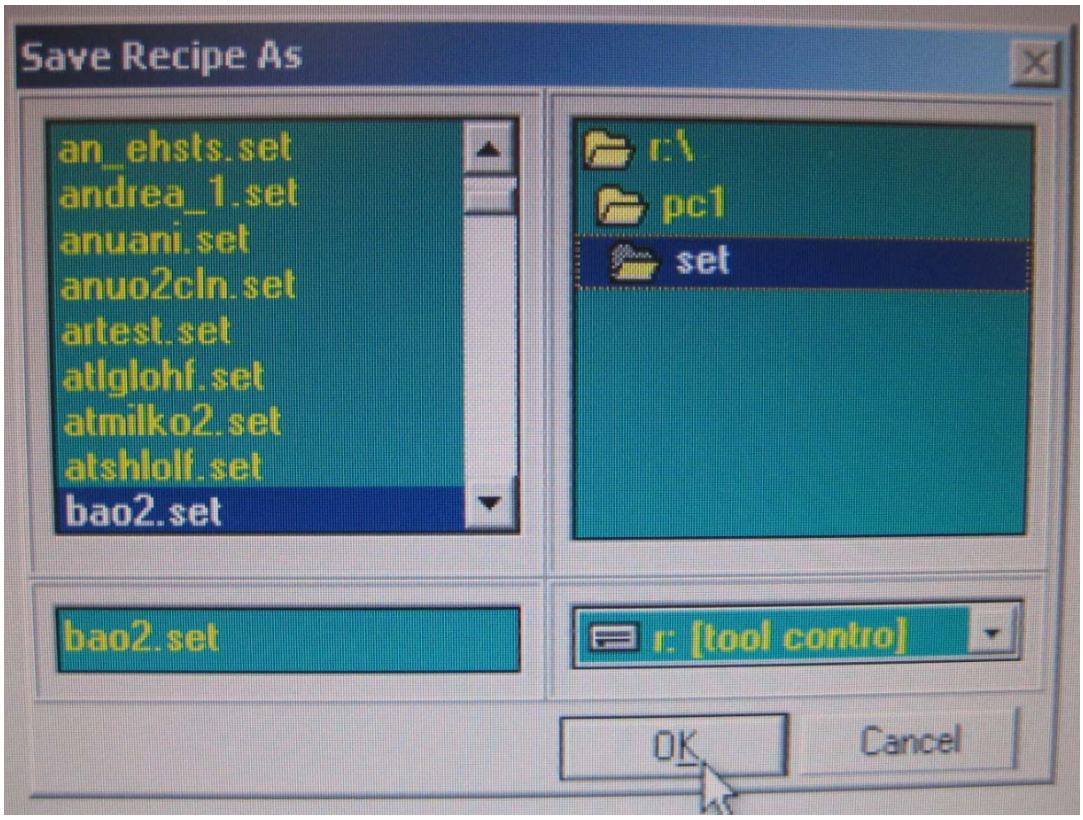
The helium leak up rate test parameters are set in the HeLUR tab; max should be 20 to 25 mTorr/min. LURs over 10 will however will cause process variation, a clean fresh wafer should be in the 5 to 6 range.



After editing is finished click on the exit icon.



Save the recipe using a personal file name if the originals was one of the basic recipes or was authored be someone else.

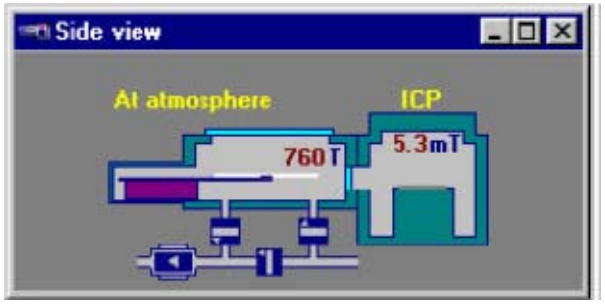


4.3 After the recipe loads and the machine is in a “ready” condition, click on the recipe button to check that the recipe parameters are correct or to modify the recipe. NEVER modify the parameters of a recipe that are a part of the default line of the recipe.

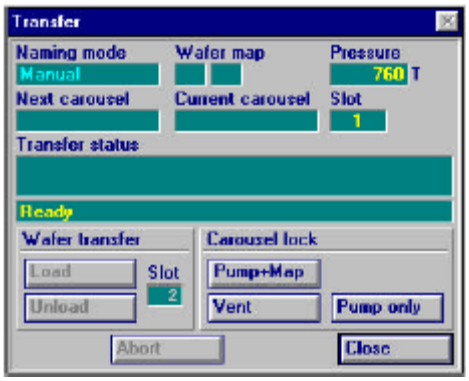
REMEMBER TO SAVE THE RECIPE IF YOU MADE CHANGES. Click exit to return to the operators station.

4.4 To load the properly prepared wafer (See Sample Preparation in Appendix section 1.1) , follow the procedure below.

4.4.1 Select **Mimic** > **Side View** to display side view of chamber and wafer position



4.4.2 Select **Control** > **Transfer** to open the Transfer dialog. Select '**Vent**'.



The carousel loadlock will vent to atmospheric pressure. When the carousel loadlock is at atmospheric pressure, the operator will be prompted to open the carousel loadlock lid and load the carousel

4.4.3 Lift up on the lid handle. The lid is heavy and must be held open while placing the wafer on the carousel; be careful.

Place your wafer in any open slot on the carousel (removal of maintenance wafers may be necessary, remember to replace them when finished). It is good practice to align the wafer flat with the flat markers.

Take care when placing wafers in the carousel slots that you do NOT press down on the carousel arm. Doing so could put the

loader arm out of calibration and cause a miss-load, destroying your sample and causing machine damage.

NOTE: Maintenance wafers are NOT to be used by users for any reason.

Close the lid and pull the latch handle forward, it will click closed locking the lid shut.

CAUTION  **CAUTION**

Always check the underside of the wafer for particulate debris and irregularities just before loading to prevent contamination of the o-ring and a high HLUR.

4.4.4 Select '**Pump+Map**'. Carousel loadlock will be pumped.The status will change to '**Acquisition of * (wafer) complete**'

4.4.5 Select wafer slot number (1 or 2) and select '**Load**'. The wafer will be transferred to the process chamber. The status will change to '**Transfer of * (wafer) from carousel to ICP complete**'

4.5 In the "Process Control" window, click on PROCESS and your recipe will run until complete showing a green wafer icon. If the process aborts for any reason the wafer icon will be red

4.6 Unload by pressing UNLOAD in the transfer window, wait for the unload process to complete and the machine to be in the ready state and then venting the load lock.

Lift the lid and remove your samples. Remember to '**Pump+Map**' the Loader afterwards, failure to do so can cause an overload and possibly severe damage to the turbo pump.

5.0 SPECIAL OPERATIONAL SEQUENCES:

In the eventof:
Serial Communications Error
In the event of a Red box error of serial communications error use the following procedure to re-establish communications between the system computers.

1. If the error interrupted an active process during any plasma phase record the process times and conditions at the time of the failure so that the process can be restarted where it left off.

2. Reset and accept any process errors that are active and allow the machine to reach ready state.

3. Take the system to inactive mode. (click the mode button and select inactive)

4. Open the door of the computer located in the upper third of the Electronics Control rack on the wall behind the operator's computer. Behind the door you will find some storage drives, a red "reset" button and a black power switch. Turn the switch to off. This will shut down the machine control computer and the Operator's computer. After 30 seconds turn the power switch back on. The two main control computers will reboot; wait for the Operator Station to come up to the Windows desktop, as always sign on as "Administrator" password= adm. If the system fails again to establish communications then a staff engineer must be called to reset other systems.

6.0 Shutdown

The user will never shut down the system. In the case of fire in the machine hit the EMO button.

APPENDIX

1.0 Pre-Run Considerations

1.1 Sample preparation

All loose materials (small pieces, partial wafers) must be secured to a 4" carrier wafer (user provided) so there is no possibility of the material leaving the carrier and falling in to the chamber; small unsecured items will be sucked into the chamber when the gate valve opens because of the pressure differential.

1.2 Mask considerations

Wafer preparation as outlined in the wafer preparation section (page 4) is extremely important; please read that section carefully and discuss variations or questions with a staff member.

The user should design the patterning and etching process so that etches of similarly sized features are done at the same time while vastly different features are protected and etched together. It helps to determine ahead of time which features require the greatest precision and which ones are less important to the overall design.

Uniformity is best achieved on the inside 3 inches of a 4" (100mm) wafer and so it is best to eliminate all patterning and on the outside ½" of the wafer. Characterization of process results in this region will be invalid due to the wide variation that can be present.

1.3 The etch process and effects

The use of discrete cycles in the process to achieve a stepwise etching of deep features (greater than 10 µm) is a balance between the etch phase and the passivate phase. The use of a continuous process where etch and passivate are simultaneous can achieve shallow scallop free sidewalls.

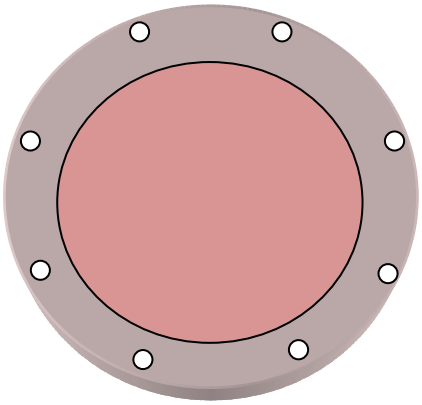
	To increase the etch	To increase the passivation
Platen power	Increase	decrease
Etch : passivate ratio	Increase	decrease
Chamber pressure	Increase	decrease
Total cycle time	Increase	decrease
Passivation gas flow	decrease	Increase
Etch gas flow	Increase	decrease

These parametric changes are completely dependent on the specific configuration of the pattern being etched and can only achieve balance when all are characterized in multiple runs and inspection using the SEM.

1.4 Sample Heating

In addition to the basic process parameters, wafer temperature is a major factor in uniformity and etch rate. The higher the wafer temperature, the more aggressive the etch phase and the less resistive are the passivation layers and masks.

The wafer heats up on the outside rim where cooling is less effective. The heat travels toward the center of the wafer where the wafer back side cooling removes the heat. The clamp fingers act as heat sinks and remove heat from the edge but to a lesser degree as longer process times occur.



This has the effect of creating a flower petal pattern outside the uniform zone. The center area is the most uniform. The white dots are where the wafer clamp contacts and are slightly cooler than the outside edge. The hottest portion of the wafer is the outside edge at the midpoint between the wafers clamps.

2.0 WAFER / SAMPLE PREPARATION

The DRIE is a Silicon only etcher all other materials are to be etched in one of the other etchers. PR, PMMA, Polyimide, SiO_2, and Si_3N_4 are appropriate pattern masking materials for high aspect ratio etching. Silicone adhesives, oils and greases are not to be exposed in the chamber. No exposed metal masks.

The DRIE is designed to hold 4“ wafers only. Small pieces must be secured to a user supplied carrier wafer; the method of securing the samples should contain no metal or silicone and should aid the removal of heat from the sample. The removal of heat from the sample is critical to etch rate

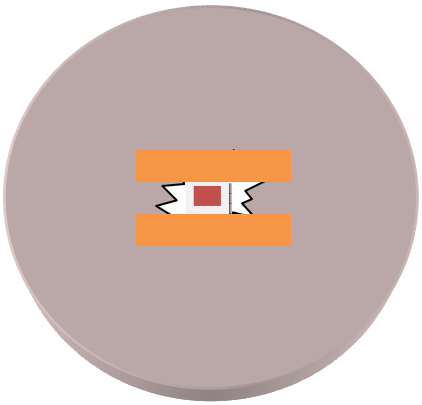
uniformity so the method of attachment that is used should have good thermal conduction.

Very high aspect ratio etches of isolated structures may not have enough mass left to conduct heat well and so will etch faster. Air voids and entrapped solvents from uncured PR can cause structures to explode under vacuum if the etch is so deep as to cause the wafer to weaken.

If the adhesion material used does not conduct heat well then the process parameters will have to be changed to deal with the difference. The total area of exposed silicon should be controlled and standardized as any changes in the area will change the process.

Mask off any areas of exposed Si that do not need to be etched (including adhesive material) so that they do not affect the process. Mask off and protect the handling area of the wafer with polyimide tape to protect the wafer from tweezer marks. Through and through etches require special considerations, please consult NRF staff.

A well prepared process wafer: the outside ring should be masked off and not processed. The underside of the wafer should never have anything on it.



Example of a carrier wafer with the small piece is adhered with heat sink compound and two of the four needed pieces of polyimide tape are in place.

There is also a roll of heat transfer two sided tape that can be used in the same way, see staff on its use.

To insure the integrity of the Helium Backside Cooling (HBC) the underside of the wafer should be free of anything that will inhibit cooling. Wafers with etched patterns all the way to the outside will never seal.

NOTE: Always check the underside of the wafer for particulate debris and irregularities just before loading to prevent contamination of the o-ring.

3.0 Critical Operation Parameters for the STS DRIE

3.1 MFC Deviation Alarm
Gas flows thould have a tolerande of no greater than 5 %

3.2 HeLUR Interlock
Are set between 20 and 25 mTorr / min, but rates over 10 will effect process stability.

3.3 Lid Temperature Interlock
Lit temp is critical to the process and will stop the process if off by +/- 2 C.

4.0 Basic Recipes from the STS Company – the chiller setpoint for the NRF system is 20°C

4.1 3 µm Wide Trench to 60 µm Depth
130 sccm SF6 + 13 sccm O2 (9+0 s)
85 sccm C4F8 (7+0 s)
Fixed APC 40 mT (e) / 25 mT (d)
Coil 600 W (e) / 600 W (d)
Platen 12 W (e)
Chiller 20°C

Etch rate 2.5 µm/min for < 10 % exposed Si area. Selectivity Si:PR 100:1. Profile 90°.

4.2 5 µm Wide Trench to 100 µm Depth
130 sccm SF6 + 13 sccm O2 (11+0 s)
85 sccm C4F8 (8+0 s)
Fixed APC 28 mT (e)
Coil 600 W (e) / 600 W (d)
Platen 12 W (e)
Chiller 20°C

Etch rate 1.9 µm/min for < 20 % exposed Si area. Selectivity Si:PR 70:1. Profile 90°.

4.3 5 µm Wide Trench to 30 µm Depth – SOI
130 sccm SF6 + 13 sccm O2 (7+0 s)
120 sccm C4F8 (5+0 s)

Auto APC 15 mT
Coil 600W (e) / 600 W (d)
Platen 25W (e), LF pulsed @ 5 ms, 33 %
Chiller 20°C

Etch rate ~ 1 µm/min with < 50 nm scallop

4.4 50 µm Wide Trench to 100 µm Depth

130 sccm SF6 + 13 sccm O2 (9+0 s)
85 sccm C4F8 (7+0 s)
Fixed APC 25 mT (e)
Coil 600W (e) / 600 W (d)
Platen 13.5 W (e)
Chiller 20°C

Etch Rate 2.60 µm/min with 90.4° profile. Selectivity Si:PR 80:1. Scallops 180 nm.

4.5 500 µm Square Holes to 500 µm Depth

130 sccm SF6 + 13 sccm O2 (12+0 s)
85 sccm C4F8 (8+0 s)
Fixed APC 40 mT (e) / 22 mT (d)
Coil 600 W (e) / 600 W (d)
Platen 12 W (e)
Chiller 20°C

Etch rate 4.1 µm/min for 30 % exposed Si area. Selectivity Si:PR 70:1.
Profile 92°.

4.6 Photoresist De-scum

40 sccm O2
Pressure 40 mT
Coil 800 W
Platen 25 W

Time ~20 secs (etch rate quite high)

4.7 ASE Oxide Etch

28 sccm C4F8
6 sccm SF6
5 mT auto APC
Coil 800 W
Platen 130 W

E/Rate = 0.2 um/min
Selectivity = 2:1

4.8 ASE Nitride etch

120 sccm C4F8 + 130 sccm SF6
50 mT auto APC
800 W coil
30 W platen

4.9 SiC Etch

40 sccm SF6 + 10 sccm O2
10 mT auto APC
Coil 800 W
Platen 15 W

Expect an etch rate of ~4500A/min

4.10 Ge / SiGe Etch

Regular ASE process

4.11 Si Mask Etch (shallow "poly etch") good to ~ 15 μm

50 sccm SF6 + 90 sccm C4F8
15 mT auto APC
Coil 800 W
Platen 14 W
Chiller Temperature 20 °C
Process Time 5 mins

Expect etch rate > 0.4 μ/min for 2 μm wide trench and ~10 % exposed Si area
Selectivity Si: Photoresist > 5:1 and profile 89 – 91 °

4.12 Chip Scale Packaging (positive profile for dicing)

200 sccm SF6 + 20 sccm O2 + 80 sccm C4F8
60 mT auto APC
Coil 950 W
Platen 0W
Chiller Temperature 20°C

If base of feature is very rough, increase platen power to 10W. If profile curves inwards at the top of the feature increase C4F8: SF6 ratio.

OR

96 sccm SF6 + 24 sccm O2
30 mT auto APC
Coil 800 W
Platen 0 W

Chiller Temperature 20°C

Can adjust profile changing SF6: O2 ratio, can also add ~15 % C4F8 of SF6 flow if required.