University of Minnesota Nano Center

SPTS Rapier Standard Operating Procedure

Badger Name:	P1 Etcher SPTS	**Revision Number:**	1
Model:	Omega LPX Rapier	**Revisionist**:	Wanjohi Kimani
Location:	Bay 1, PAN	**Date:**	July 13, 2021

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SPTS Rapier Standard Operating Procedure

1 Scope

1.1 This document provides detailed instructions on how to operate the Omega LPX Rapier Etch tool.

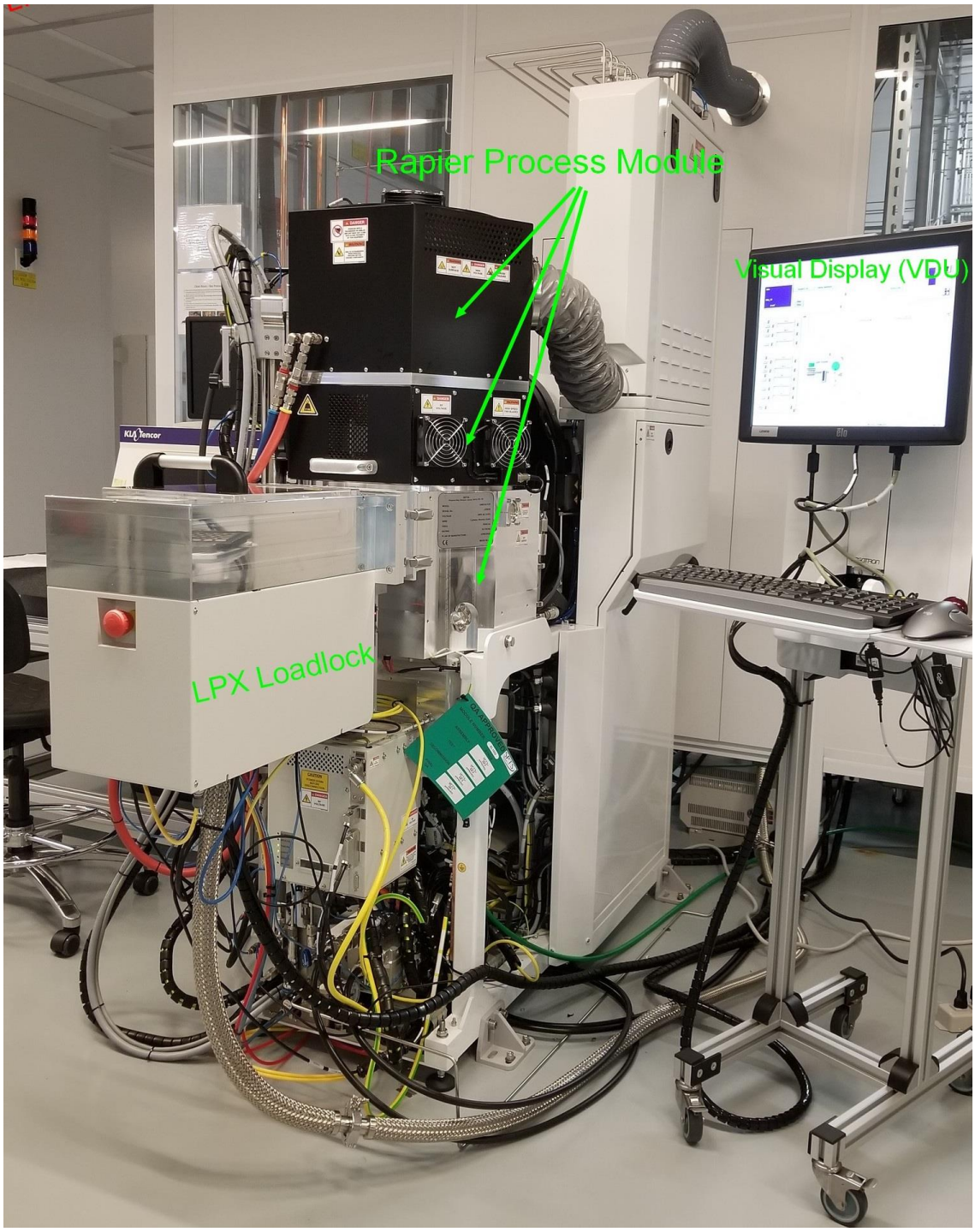

Fig 1: SPTS Rapier tool

2. Tool Description

2.1 The following are the systems features.

2.1.1 The machine configuration comprises of the LPX Load Lock single wafer Module and one Rapier 100mm Process Module (Bosch process deep Si module).

2.1.2 The Load Lock Module is an integrated vacuum Load Lock and Transport Module

2.1.3 The Rapier module comprises upper and lower chamber assemblies with dual plasma sources and dual gas inlets

2.1.4 Source RF - 6kW (TruPlasma)

2.1.5 Source 2 RF - 3kW (TruPlasma)

2.1.6 Bias RF - 2kW (TruPlasma)

2.1.7 Process gases and max flows:- SF6 (720sccm), C4F8 (500sccm), Ar (500sccm), O2 (1000 sccm), N2 (100 sccm)

2.1.8 The Rapier 100mm Process Chamber comes with an Electrostatic Chuck (ESC - ±2kV - ±6kV static voltages) wafer clamp, He backing (max 15 Torr) and chuck thermal control

2.1.9 Filter endpoint system for inter-wafer cleans only (SPTS 440nm)

2.1.10 Operator controls is provided in the form of a trolley mounted user interface keyboard and Visual Display Unit (VDU)

2.1.11 Touch screen or mouse click control VDU

2.1.12 Etch rates from 3µm/min to 23 µm/min depending on process

2.1.13 Broad features from nm to mm lateral dimension

2.1.14 High aspect ratio etching

2.1.15 No metal masks, no metal stop layer, no metal backside exposed to the ESC

2.1.16 Silicon etching only

2.1.17 Photoresist like AZ 1500 series or AZ 9260 or other approved PR; and SiO2 masks only. SU8 PR is not allowed in the system.

2.2 Mimic Displays

2.2.1 Operational control of the tool is provided via a graphical user interface (GUI) with “mimics” showing either the complete system or an individual module.

2.2.2 The interface can be alternated between three “Mimic” displays (**Control (F3)**, **Transport (F4)** and **Process (F5)**). Each display has a specific function. The menu bar options will vary depending on which mimic is on display. Most menu items can also be accessed on the mimic display. The following images show the three mimic displays.

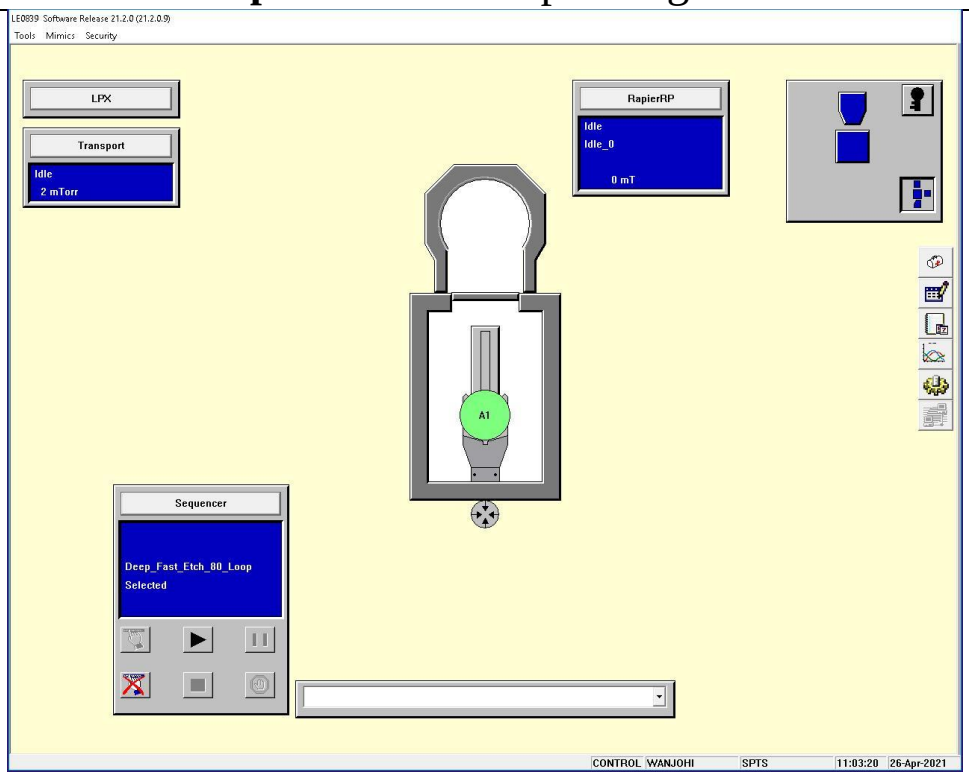

Fig 2: Control Mimic display (F3)

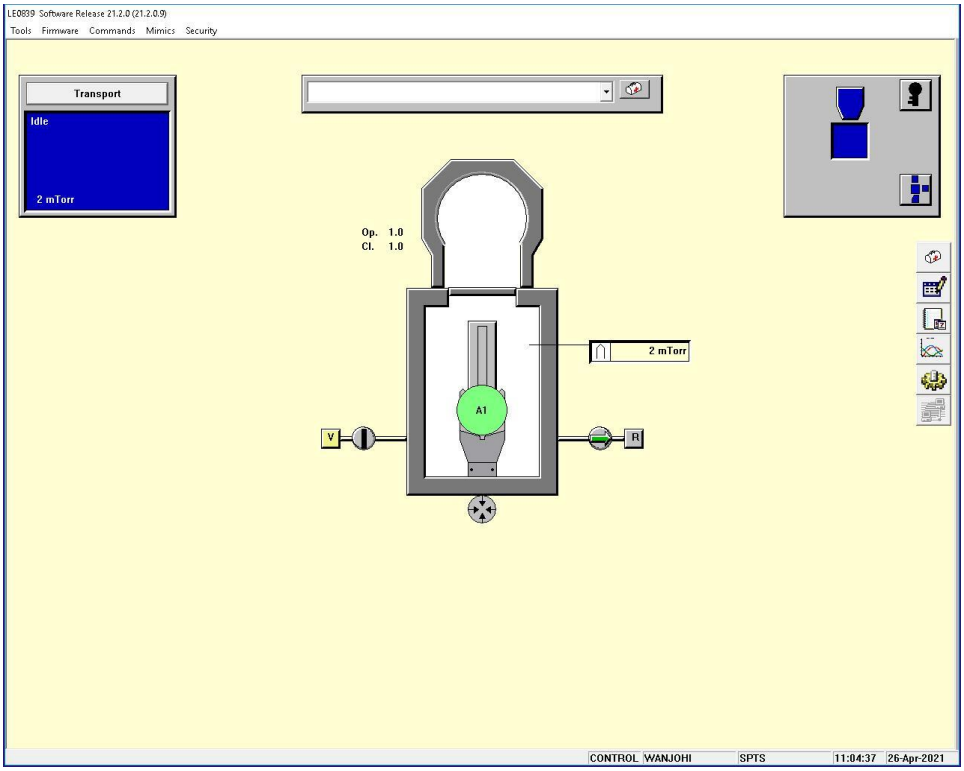

Fig 3: Transport Mimic display (F4)

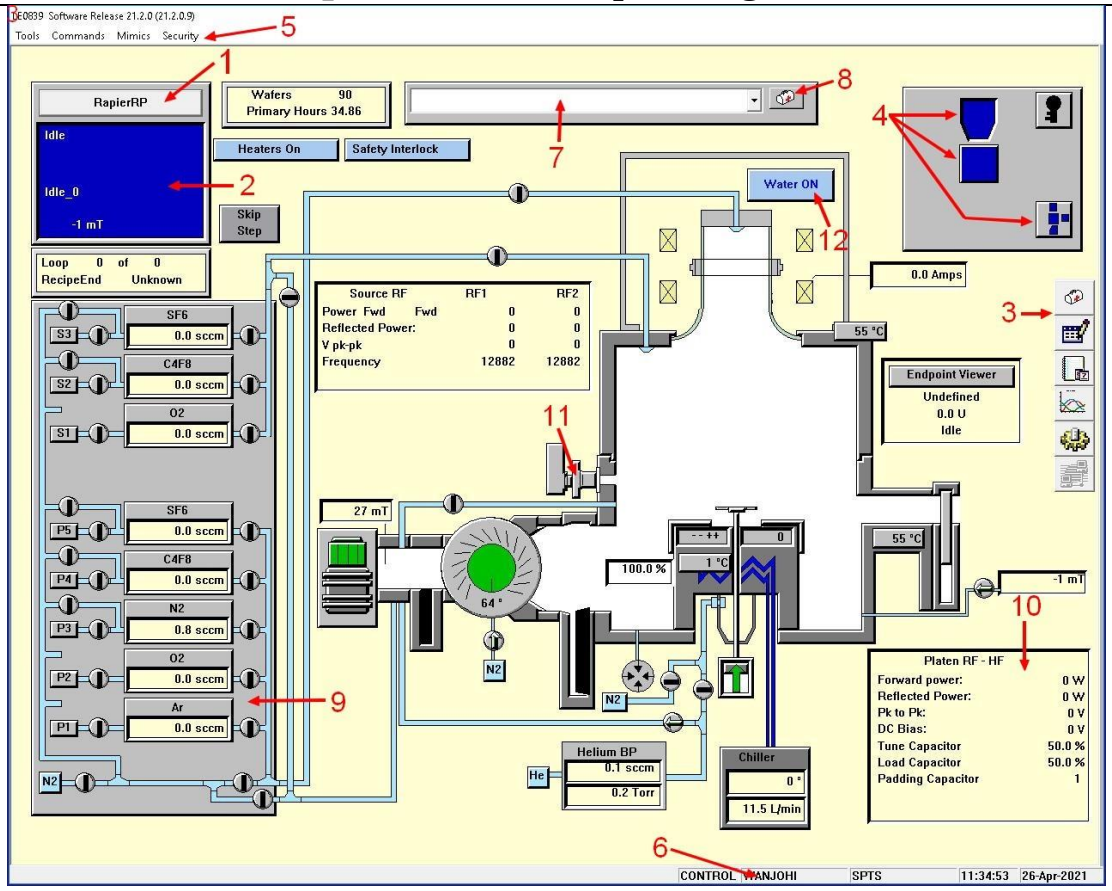

Fig4 : Rapier Mimic display (F5)

2.3 Description of labelled items

2.3.1 (1) State Control Box Message Window – displays state of the concerned module i.e. Abort, Idle, Ready, Process, etc.

2.3.2 (2) State Control Button

2.3.3 (3) Item Toolbar – Provides six buttons for quick access to a) Fault response b) Recipe Editor c) Event log viewer and d) Data viewer and two other inaccessible items

2.3.4 (4) Navigators Icon – Provides a plan view of the systems and its modules and a quick way of selecting each display

2.3.5 (5) Menus – Drop-down menus. Vary depending on which mimic is selected

2.3.6 (6) Status Bar

2.3.7 (7) Fault Message Box – Shows module warnings and faults as they appear.

2.3.8 (8) First Aid Button – If a fault occurs on the system, the user can view details by touching or clicking on this box

2.3.9 (9) Process Gas Lines – Gives status of all process gas control valves and measured flows of any active gas lines

2.3.10 (10) RF System Data – For the source RF; displays the Forward power, Reflected power, Peak-to-Peak voltage, and frequency. For Platen RF-HF; displays Forward power, reflected power, peak to peak voltage of the RF supplies to the module, DC bias generated at the platen, tune capacitor (relay

position of the tune capacitor as a %), load capacitor (relay positions of the relay capacitor as a %) and padding capacitor (one of the 4 step values of the padding capacitor)

2.3.11 (11) Endpoints – provides a simple plot of the latest endpoint trace

2.3.12 (12) Bell Jar Cooling Water

3 Safety

3.1 RF power may be present in some areas of the equipment. All enclosures inside which RF power may be present are clearly marked and the covers are fitted with electrical interlocks.

3.2 The system uses electrical power and runs under vacuum. High voltage electricity exists within most areas of the equipment and ancillaries.

4 Restrictions/Requirements

4.1 Must be a qualified user on the "**P1 Etcher SPTS**"

4.2 For etching Silicon only

4.3 Acceptable masks: Photoresists like AZ 1500 series and AZ9260 and SiO2

4.4 No metal exposure to plasma. Metal features shall be completely covered with sufficiently thick photoresist or dielectric (SiO2 or Si3N4) to prevent them being exposed to plasma. Review selectivity data to determine what thickness photoresist to use.

4.5 No metal exposure to the Electrostatic chuck (ESC). If there is metal on the backside, a carrier wafer must be used. Exceptions can only be made by MNC staff.

4.6 Thermal bonding materials are highly recommended for deep/long etches. Santovac 5, cool grease and crystalbond 555HMP are readily available in the cleanroom. Photoresist may be applicable for short or shallow etches. See appendix for bonding instructions on selected materials

4.7 Tool is for etching 4-inch Si wafers or smaller substrates. Smaller substrates need to be mounted on a carrier wafer

4.8 If you will be performing, a through-wafer etch or the remaining thickness after etch is 100um or less, your wafer will need to be mounted on a carrier wafer.

4.9 Generally, larger features etch faster than smaller features. Keep that in mind as you estimate your etch depth especially with rapid etching recipes like "**DeepFast**"

Fig 5: CRYSTALBOND 555HMP

Bond Material	Temp range (ºC)	Thermal conductance	Solvent	Application	Comments
Santovac 5		Good	Acetone	Room temp bonding	Can be messy
Cool Grease		Excellent	Acetone	Extreme thermal requirement	Generates particles
Crystalbond 555	< 50	Good	DI/1165/Acetone		
Photoresist		Poor	1165 remover		Least recommended

5 Required Facilities

5.1 Compressed air (CDA)
5.2 Nitrogen
5.3 Chiller/Recirculator (SMC HRZ001 with HT170 fluid)
5.4 Roughing and backing pumps
5.5 Pump and Enclosure Exhaust
5.6 400 VAC

6 Definitions

6.1 Process – Runs the selected process in the module (a wafer must be loaded)
6.2 Idle – Pumping, awaiting next command
6.3 Abort – Aborts current command
6.4 Restore – Restores the module from Hold to the previous state
6.5 Manual – Available for manual commands. Cannot use sequencer in this mode
6.6 Automatic – Available to Sequencer but not available for manual command
6.7 Module recipe – Defines the processing activity that takes place within the module process chamber.
6.8 Sequence recipe – Control the movement of the wafer from Loadlock, through processing in the module chamber and back into the Loadlock.

7 Operating Instructions

7.1 LOGGING ON

7.1.1 Check Badger for other reservations for the “P1 Etcher SPTS” system first
7.1.2 Enable " **P1 Etcher SPTS**” on Badger if not reserved or in use
7.1.3 Click on the log in key **(Ctrl O)**

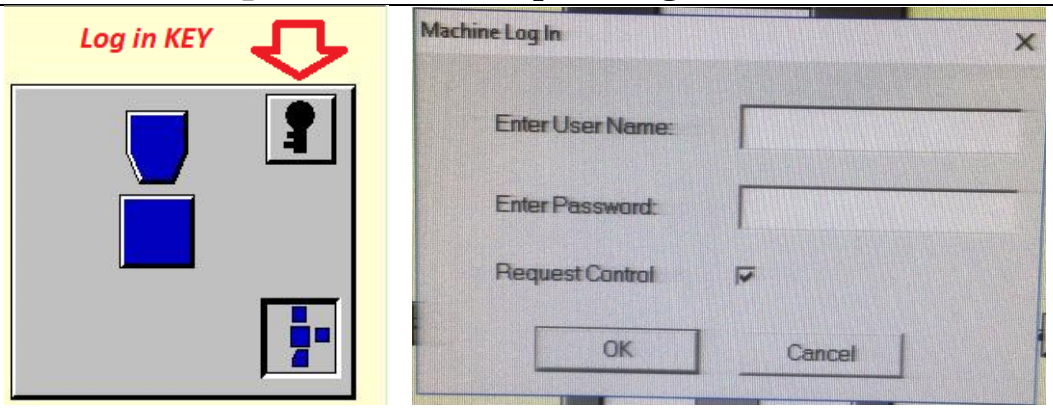

Fig 6: Login icon and login screen

7.1.4 Login with the username "**oper**" and password "**1234**" and click login. Username and password are not case sensitive

7.2 SAMPLE LOADING - Vent Chamber and load sample(s)

7.2.1 To vent the system, click on **Transport** (in **F3** or **F4** mimic mode) and then on **Vent button** then **OK**. The LPX Loadlock will vent quickly. The State control box will go green showing venting is in progress. When done venting the transport mimic will return to idle mode with a message "LPX is at atmosphere so please remove wafer".

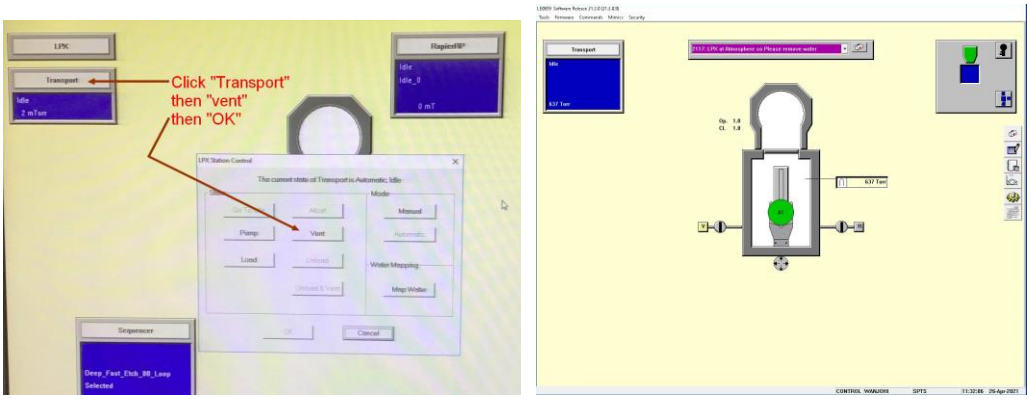

Fig 7: Vent buttons and view

7.2.2 Lift up the lid and position your substrate on the Loadlock arm as shown below:

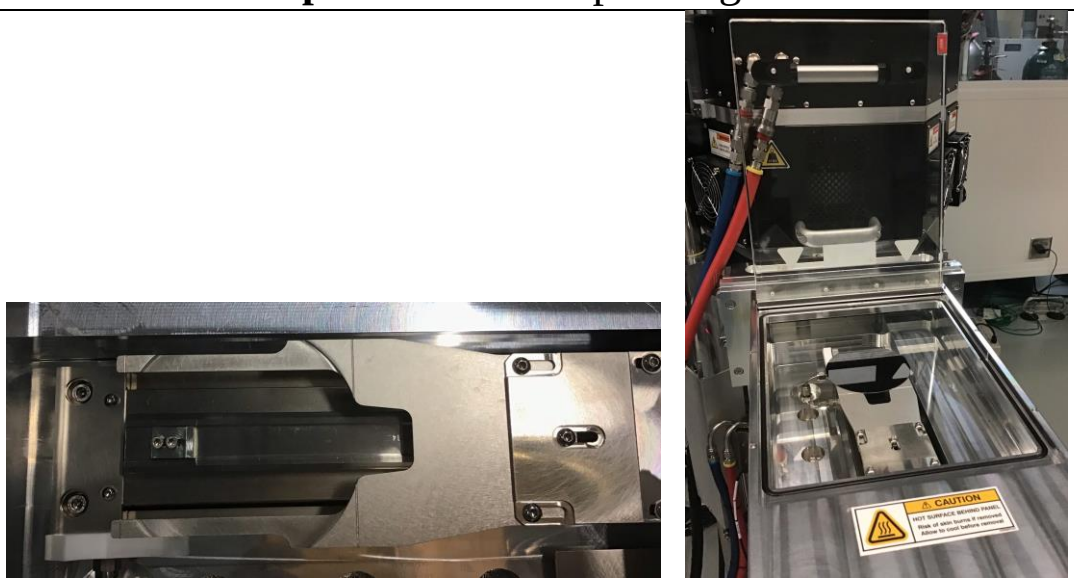

Fig 8: Loadlock arm /wafer positioning

7.2.3 The wafer's major flat needs to align to the major flat mark on the Loadlock (Fig 9)

Fig 9: Wafer position on arm

7.2.4 Close the lid

7.2.5 If you will be running a sequence recipe, it is not necessary to pump down at this point.

7.2.6 Click on transport mimic, then on "Map Wafer" then "OK". Use Un-Map wafer if this is your first wafer and you need a reset the count; or "Next Wafer" if you are doing multi-wafer etch or just click OK. A grey color wafer image should show up on the LL arm.

7.3 STARTING PROCESS – Recipe Editing (if needed)

7.3.1 If a recipe already exists with your desired number of loops, skip this recipe-editing step.

7.3.2 On the "Item Toolbar" (3 in Fig 4) click on the icon with a pencil to open the recipe editor 

7.3.3 Click on module in the Recipe Type box. The following steps show how to edit a **"Module recipe".**

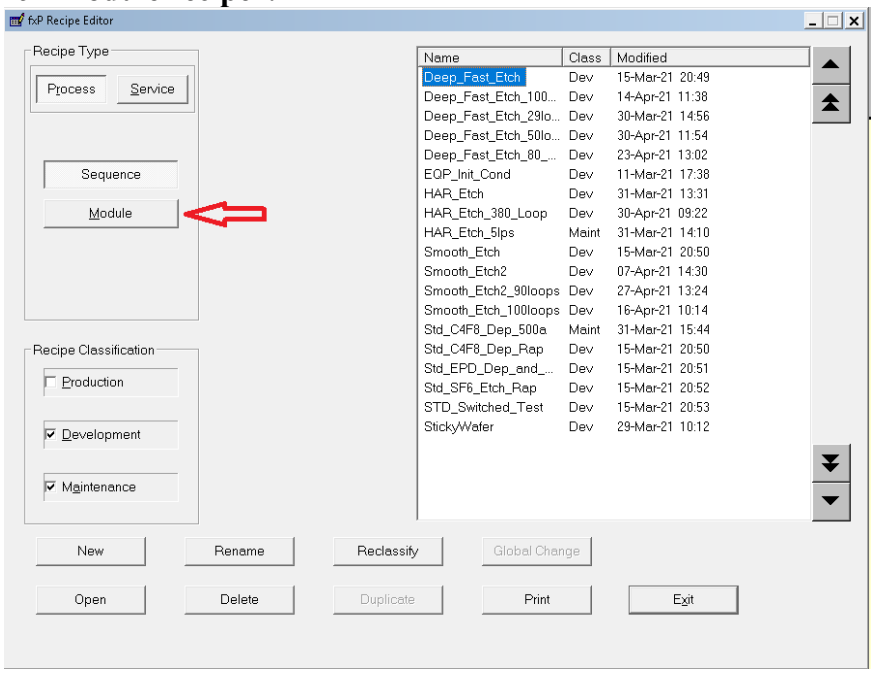

Fig 10: Module selector button

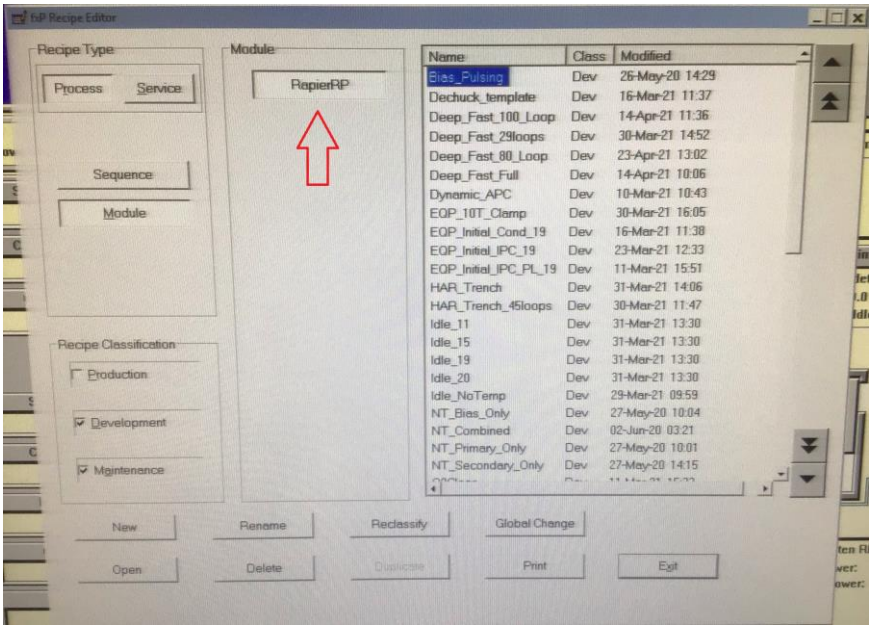

Fig 11: Rapier RP selector button

7.3.3.1 Click on **RapierRP** in the module box
7.3.3.2 A list of all recipes appears to the right of the module box
7.3.3.3 Select the recipe you want to edit and click "Open"
7.3.3.4 The ONLY thing you should change, if necessary, is the "**number of loops**". If a recipe already exists with your desired number of loops, skip recipe editing step
7.3.3.5 Locate "**number of loops**" row under the "**Etch**" tab. Do not change anything else in the "**Etch**" tab or in the other tabs (Version, General, etc)
7.3.3.6 For the number of loops your may have to scroll to the right to get to the last column comprising the number of loops

		1	2	3	4
Step Name		Strike1	Dep	E1	E2
Process Time	Secs	1.0	2.4	1.2 1.2	6.0
Process Pressure	mTorr	80.0 ± 0 %	80.0 ± 30 %	25.0 25.0 ± 35 %	200.0 ± 35 %
APC Setpoint Position	%	0.0	0.0	0.0	0.0
APC Mode		Automatic	Automatic	Automatic	Automatic
Source 1 power	Watts	2500 ± 0 %	2500 ± 20 %	2500 2500 ± 20 %	3500 ± 20 %
Source 1 AFT On		Disable	Enable	Enable	Enable
Source 1 AFT Frequency	KHz	12882	13560	13560	13560
Source 1 RF Control Mode		Load	Load	Load	Load
Source 2 power	Watts	1100 ± 0 %	1100 ± 20 %	1100 1100 ± 20 %	1100 ± 20 %
Source 2 AFT On		Disable	Enable	Enable	Enable
Source 2 AFT Frequency	KHz	12882	13560	13560	13560
Source 2 RF Control Mode		Load	Load	Load	Load
Platen HF Power	Watts	0.0 ± 0 %	10.0 ± 75 %	135.0 152.0 ± 20 %	0.0 ± 20 %
Platen HF Capacitor Adjust		Preset	Automatic	Automatic	Automatic
Platen HF Tune Capacitor	%	20.0 ± 20 %	46.0 ± 5 %	50.0 ± 5 %	45.0 ± 20 %
Platen HF Load Capacitor	%	15.0 ± 20 %	40.0 ± 5 %	50.0 ± 5 %	40.0 ± 20 %
Platen HF Padding Capacitor		2	2	2	2
Platen HF Control Mode		Load	Load	Load	Load
Platen HF Modulation Enabled		Enable	Enable	Enable	Enable
Platen HF Modulation Frequency	Hz	150	150	150	150
Platen HF Modulation Duty Cycle	%	50	50	50	50
Helium pressure	Torr	15.0 ± 20 %	15.0 ± 20 %	15.0 15.0 ± 20 %	15.0 ± 20 %
Helium Flow Warning Level	sccm	8.0	8.0	8.0	8.0
Helium Flow Fault Level	sccm	12.0	12.0	12.0	12.0
Coil current	Amps	10.0 ± 0 %	10.0 ± 20 %	10.0 ± 20 %	10.0 ± 20 %
Loop destination		0	0	0	2
Number of loops		0	0	0	85
Loop Variation Parameter		0.0	0.0	0.0	0.0
ESC Voltage	Volts	5000 ± 10 %	5000 ± 10 %	5000 ± 10 %	5000 ± 10 %
Gas Line Config		Flow	Flow	Flow	Flow
P1 Ar	sccm	200.0 ± 20 %	0.0 ± 5 %	0.0 0.0 ± 5 %	0.0 ± 5 %
P2 O2	sccm	0.0 ± 5 %	1.0 ± 0 %	130.0 130.0 ± 20 %	1.0 ± 0 %
P3 N2	sccm	0.0 ± 5 %	0.0 ± 5 %	0.0 0.0 ± 5 %	0.0 ± 5 %
P4 C4F8	sccm	200.0 ± 20 %	500.0 ± 20 %	1.0 1.0 ± 0 %	1.0 ± 0 %
P5 SF6	sccm	1.0 ± 0 %	1.0 ± 0 %	1.0 1.0 ± 0 %	720.0 ± 20 %
S0 O2	sccm	0.0 ± 5 %	1.0 ± 0 %	70.0 70.0 ± 0 %	1.0 ± 0 %
S1 C4F8	sccm	120.0 ± 5 %	160.0 ± 20 %	1.0 1.0 ± 0 %	1.0 ± 0 %
S2 SF6	sccm	0.0 ± 5 %	0.0 ± 5 %	0.0 0.0 ± 5 %	0.0 ± 5 %

Only change number of loops under etch tab

Fig 12: Typical etch recipe (multiplexing or Bosch type)

7.3.3.7 Make the desired change to the number of loops on the last column (can be etch1, etch 2, etc.)

7.3.3.8 Click "**Save As**"

7.3.3.9 Retain "**Development**" classification and click "**OK**"

7.3.3.10 Rename the recipe with the new number of loops. Keep the same general name so other users can easily identify the recipes.

7.3.3.11 Click OK. For some recipes like **DeepFast**, there may appear a warning about the gas flow range. Ignore by clicking on "**OK**"

7.3.3.12 Your new module recipe is now saved

7.3.3.13 Exit the module recipe editor

7.3.4 The following steps show how to edit a Sequence recipe (i.e., apply the module recipe you edited earlier into a sequence recipe).

7.3.4.1 Under the recipe type box, click on "Sequence"

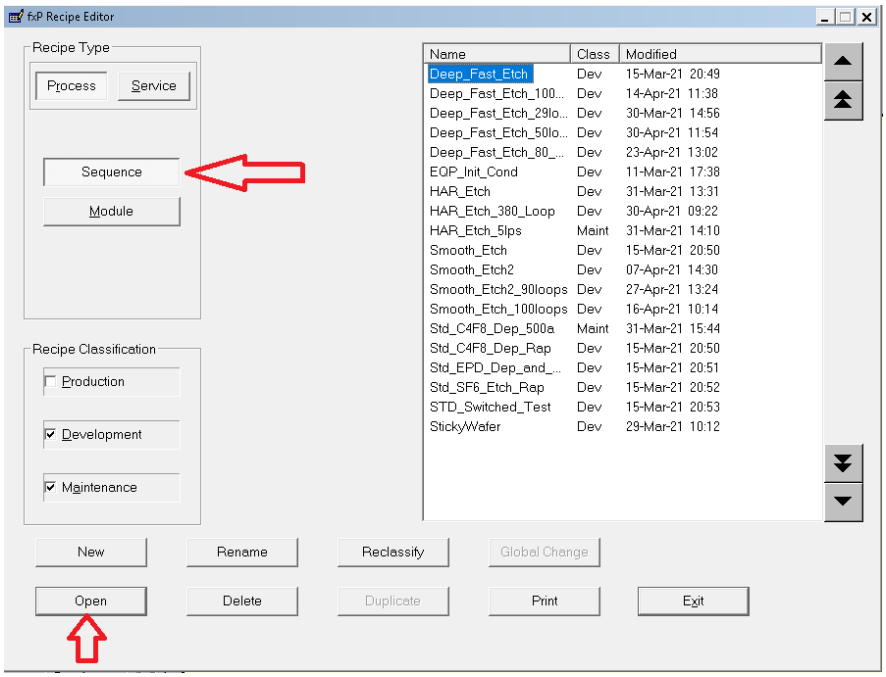

Fig 13: Recipe editor selector

7.3.4.2 Open a "**sequence recipe**" with similar identity to a "**module recipe**" that you previously edited (Double-click or click "Open")

7.3.4.3 Under the LPX Sequence tab, locate the process row corresponding to the module recipe earlier edited (most likely row 5)

7.3.4.4 Under the "**Module Recipes**" column, click inside to open a drop-down list of module recipes

7.3.4.5 Select the module recipe you previously edited. Remember it may be up or down from your current view

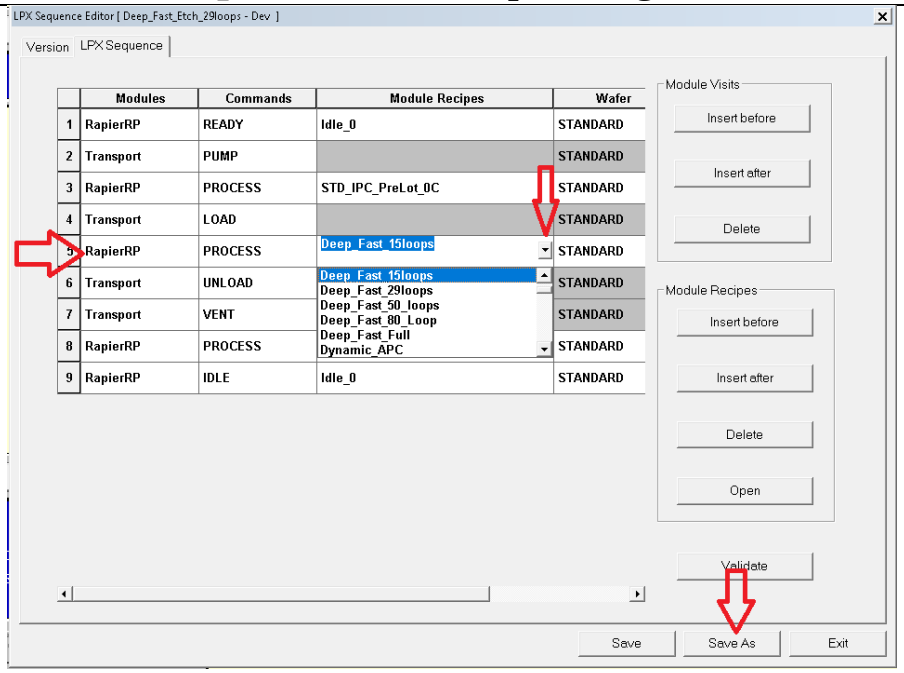

Fig 14: LPX sequence editor

7.3.4.6 Click "**Save As**"
7.3.4.7 Retain "**Development**" classification and click "**OK**"
7.3.4.8 Rename the Sequence recipe with the new number of loops. Keep the same general name so other users can easily identify the recipes
7.3.4.9 Click "**OK**" and exit (twice)
7.3.4.10 Both Module recipe editing, and Sequence Recipe editing are now complete

7.4 Etching

7.4.1 Load the Control mimic (F3)

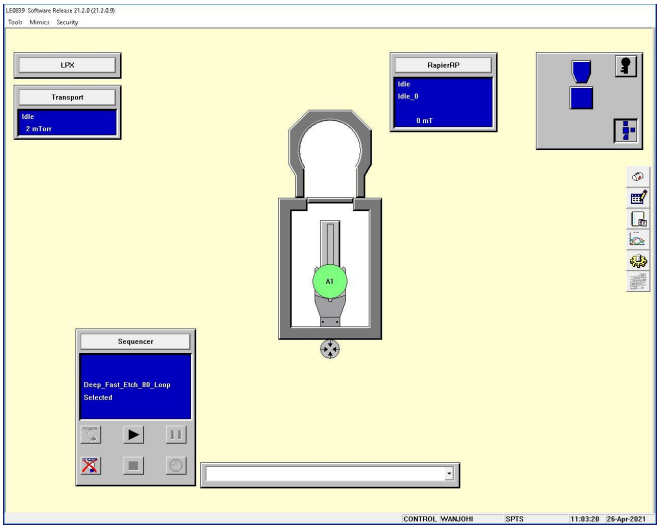

Fig 15: Control Mimic

7.4.2 On the lower left side is the **Sequencer (shown below)**

1. Select Recipe 2. Cancel 3. Start 4. Stop 5. Pause 6. Resume

Fig 16: Sequencer buttons

7.4.3 On the Sequencer, if the previous sequence recipe is different from your desired sequence recipe, click on "**2**" (**Cancel**) and acknowledge.

7.4.4 Ensure that the "**RapierRP**" is at "Idle". If it is not and shows "**Ready**", click on the "**RapierRP**" bar and "**Idle**". Select idle recipe that corresponds to the chuck temperature of your recipe or select "**Idle_NoTemp**" to idle at the current temperature.

Fig 17: Ready and Idle modes

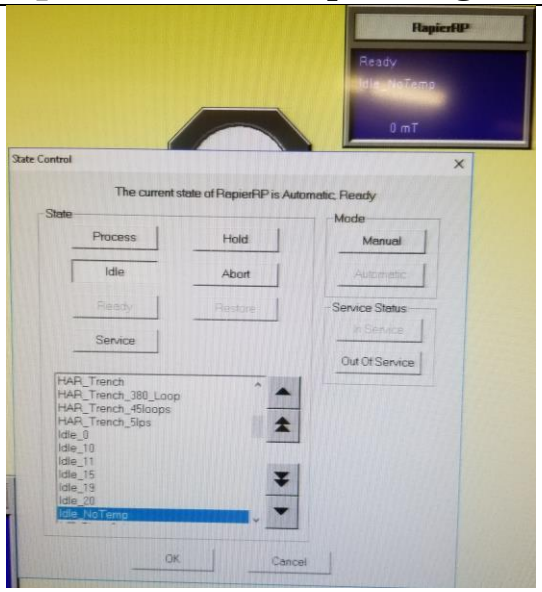

Fig 18: Selecting "Idle" mode (If necessary)

7.4.5 Click on "1" (Select Recipe), select the sequence recipe to run (E.g. **Deep_Fast_Etch_50loops or HAR_Etch**) and load it by clicking "**OK**".

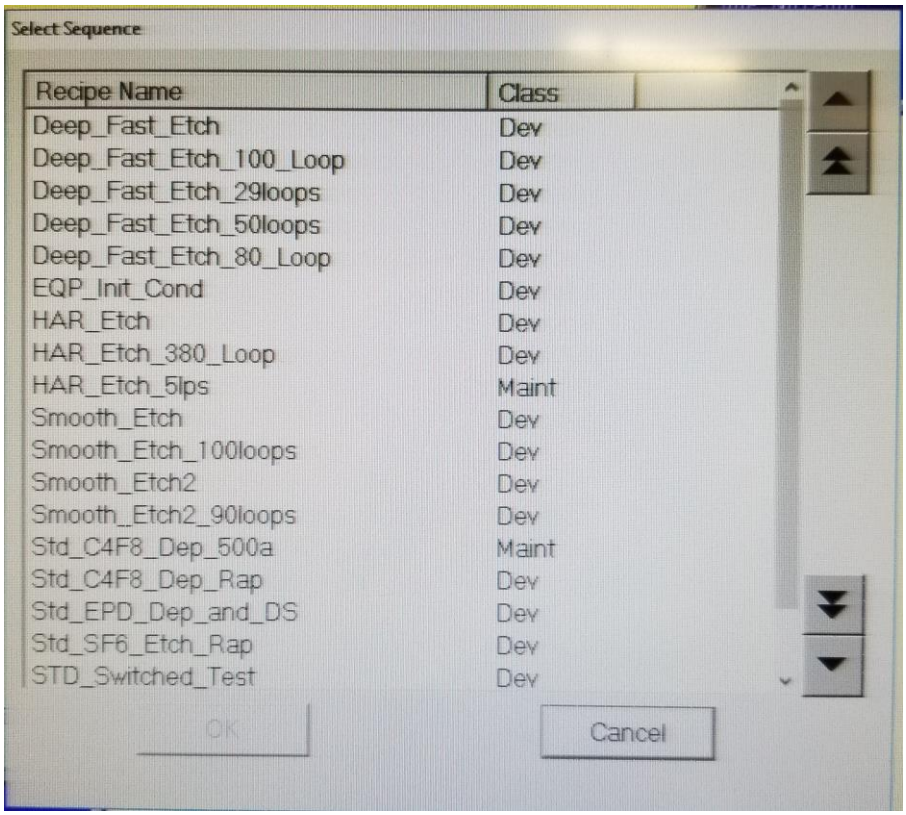

Fig 19: Sequencer Recipes

7.4.6 Click on "**3**" (**Start**) to run the selected sequence recipe. A "**Start LPX Sequence**" box appears. You can Enter a wafer ID or click "**Next Wafer**" if not

done earlier. Leave the select Wafer Type as "**Standard**". Acknowledge with "**OK**".

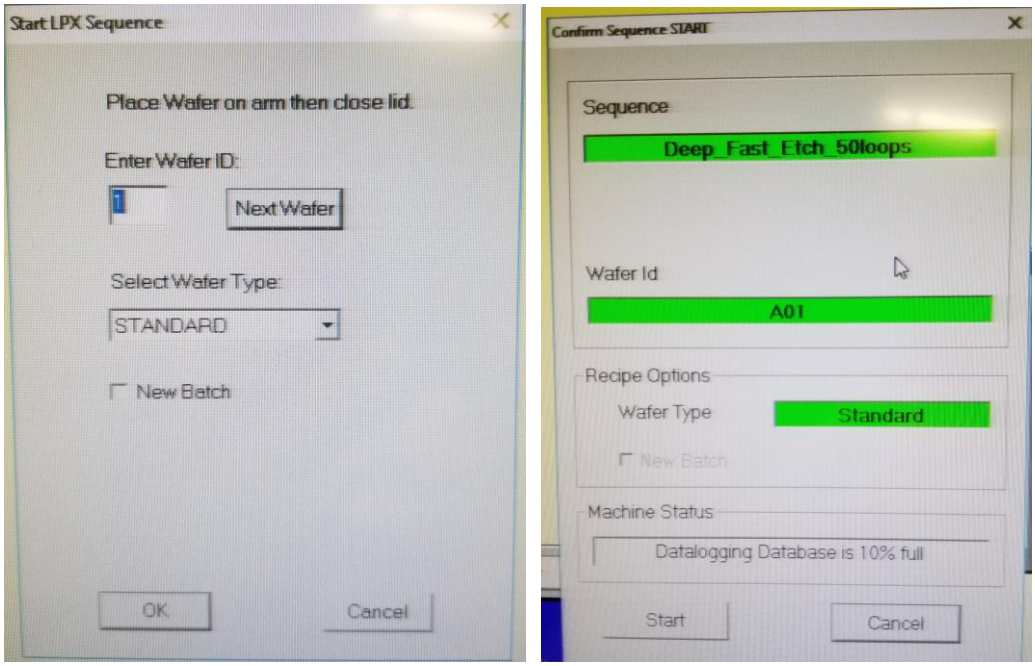

Fig 20: Sequence recipe start buttons

7.4.7 Confirm the Start sequence by clicking on "Start"

7.4.8 The process proceeds automatically from hereon. Proceeding steps are as follows:

7.4.8.1 A Pre-clean process step "**STD-IPC-Prelot-^{oo}C**" will begin. '**^{oo}C**' refers to the chuck temperature corresponding to the sequence recipe. If your recipe temperature is different from the current chuck temperature, the process will not start immediately until the chuck warms up or cools to the loaded recipe's temperature.

7.4.8.2 There are two clean steps (**Clean1, Clean2**). No wafer is present in these pre-clean runs. Your wafer will be in the Loadlock under vacuum during these clean steps.

7.4.8.3 A quick Dechuck step (8s) follows.

7.4.8.4 The slot valve opens, and the transport arm loads the wafer into the etch chamber.

7.4.8.5 The transport mimic is green colored during the load step

7.4.8.6 Etching will commence and run to its conclusion unless skipped or aborted. View progress of Etch (loops, RF, gas flows, pressure) in the Rapier Mimic (F5)

7.4.8.7 During etching, the Status box is green colored and shows the process steps. The number of loops show right below the status control box.

7.4.8.8 If user misjudged the number of loops or need to stop the etch process earlier than the pre-determined loops, click on "**skip step**" once. Your etch

run will complete all the remaining etch steps in that loop/cycle and then jump out of the loop (to base pressure, unload, etc.)

7.4.8.9 Reflected power in the Source RF1, RF2 and Platen RF is not necessarily zero. Safe levels will be emphasized in training

7.4.9 Another Dechuck step follows

7.4.9.1 Transport arms retrieves wafer back into the Loadlock and the Loadlock vents to atmosphere. Wafer can be retrieved as soon as Transport mimic (F3 or F4) goes into **IDLE** mode.

7.4.9.2 A post-clean process "**STD-IPC-Fast_ººC**" will also begin while venting is in progress. It is also a two-step clean process.

7.4.9.3 Once the post clean process is complete, the Rapier mimic will go into "**Idle**" mode (Blue color).

7.4.9.4 If you have another wafer to etch, repeat from **7.4**

7.4.9.5 If you have already retrieved your wafer and have no further etching to do, close the lid and pump down the Loadlock by clicking on "**Transport**" and then "**Pump**" in the LPX Station Control box.

7.5 SAMPLE UNLOADING

7.5.1 Open the lid and remove your wafer

7.5.2 Close the lid

7.5.3 Click on **transport > pump > OK**

7.5.4 Log off by clicking on the "**key**" icon and acknowledge

7.5.5 Disable in Badger

7.6 WARNINGS

7.6.1 All pre-clean and post clean steps should run to completion

8 Problems and Solutions

8.1 If the machine aborts for any reason or you encounter an unexpected situation, report the issue on badger immediately

8.2 The system logs out a user when an etch sequence is complete. To regain control, simply log in again (CTR+O or use the KEY icon)

9 Appendix

9.1 Bonding instructions: Application and removal – Crystalbond 555HMP

9.1.1 Using a hot plate or oven, heat a ceramic or glass-mounting block to the flow temperature of the selectedCrystalbond555 adhesive. Make sure to work in a well-ventilated area, and do not overshoot the flow temperature, otherwise, the adhesive will begin to decompose, degrading its strength.

9.1.2 Apply a uniform layer of adhesive to the heated mounting plate and place the substrate over the adhesive.Using a weight, apply even pressure to the substrate to remove air bubbles and to ensure that the substrate is parallel to the plate. Apply a fillet of adhesive around the perimeter of the substrate to increase the holding strength.

9.1.3 Remove the mounting plate from the heat source and allow it to cool slowly to room temperature until theadhesive is hardened. Cool for 20-30 minutes before processing.

9.1.4 Process the substrate as required, and then remove the parts by reheating the mounting block to theflow temperature. Use a tool to slide the substrate off the mounting plate.

9.1.5 Clean off the adhesive using hot water. Immerse parts for a minimum of 5 minutes until Crystalbond 555 dissolves. As adhesive residue begins to concentrate in the stripper, 20% of the stripper should be replaced with fresh material.

9.1.6 Rinsing: After removing the adhesive, a step-wise warm rinsing process is recommended. Rinse in a dilute, non-ionic surfactant or liquid detergent system, followed by a final rinse in de-ionized water to eliminate water spots due to hard salts and contaminant redepositing

9.2 Bonding instructions: Application and removal - Santovac 5

9.2.1 Place the sample on a hotplate at ~80°C

9.2.2 Dispense a small amount (depending on the size of substrate being mounted) of Santovac 5 using a pippete

9.2.3 Place sample on top of the carrier wafer and wait for a few minutes. Use of a vacuum jar can help reduce air bubbles

9.2.4 Wipe off any excess with an acetone soaked cleanroom cloth

9.2.5 To remove Santovac 4; Sample should slide off the carrier wafer. If it does not, place wafer on a hot plate at ºC and try sliding the sample. Alternatively soak the wafers in acetone.

9.3 Bonding instructions: Application and removal - cool grease

9.3.1 COOL-GREASE™ (CGR7016) is a re-workable, boron nitride filled, electrically insulating and thermally conductive paste

9.3.2 Dispense adhesive on a clean substrate/carrier

9.3.3 Place target substrate on the carrier and apply pressure at various points

9.3.4 Process wafers. Process temperature not to exceed 150C

9.3.5 To detach wafers, rinse or soak in IPA

9.4 Bonding instructions: Application and removal - photoresist

9.4.1 dehydrate bake a silicon wafer at 150C for 1 minute

9.4.2 Spin coat AZ 1505 or AZ 1512 at 3000 rpm 30 sec

9.4.3 Place your target sample on the freshly coated carrier wafer; apply pressure at perimeter points

9.4.4 Bake at 115C for 2 minutes as you apply light pressure intermittently to minimize bubbles/air gaps.

9.4.5 Wafer is ready.

9.4.6 Because of poor thermal transfer, use this method for shallow/shallow or non-aggressive etch processes.

9.4.7 To detach wafers, rinse or soak in 1165 remover or acetone