CORAL: RIE-PlasmaTherm-210RL-A

Location: Bay 6L
Purpose: Plasma Etcher
Contacts: Cody Corey, Bob Bicchieri

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Introduction:

The RIE-PlasmaTherm-210RL tools are Reactive Ion Etchers (RIE) that use plasma to etch a wide variety of semiconductor materials including dielectric thin films, compound semiconductors and III-V materials, metal and metal-oxide thin films, and more. The Plasmatherm A is primarily used for RIE processes and the Plasmatherm B is primarily used for sputter etching. Both tools are capable of both methods of etching, but the processes are separated to simplify and minimized maintenance. Each system has a Loadlock (named 'AL' in the tool software) for faster sample loading, and reduced pump-down times. The AL also improves safety by preventing accidental exposure to hazardous gases and etch byproducts. There are 8 process gases available on this tool: BCl3, Cl2, CH4, H2, SF6, CF4, O2, and Ar.
The RIE-PlasmaTherm-210RL-A creates a plasma with a single 600W Radio Frequency (RF) power supply (13.56 MHz) attached to the lower electrode. The lower electrode has a heat exchanger with a temperature range of -20°C-150°C. The system also has a Laser Interferometer Endpoint System which can be used to determine when a film is etched. The Plasmatherm can etch pieces as well as whole wafers up to 8" (200mm).



Figure 1: Plasma-Therm A in bay 6L

Safety:

Under normal operating conditions, the user is protected from these hazards. Any attempt to bypass interlocks or modify the system may result in accidental exposure to the following:

- Hazards contained within the system:
  - Oxidizing gases – Oxygen (O_2), Chlorine (Cl_2)
  - Corrosive chemicals (skin, eyes, nose, and lung irritant) --Chlorine (Cl_2), and Boron Trichloride (BCl_3)
  - Flammable gases – Methane (CH_4) and Hydrogen (H_2)
  - Inert gases (asphyxiation hazard) –Carbon Tetrafluoride (CF_4), Sulfur Hexafluoride (SF_6), Argon (Ar), Nitrogen (N_2), Helium (He)
  - High power (600W) RF energy and temperatures
  - Laser (wavelength 671 nm)
  - Pneumatics –Compressed Dry Air (CDA) at 100 psig
- If you encounter any equipment problems while operating the system, contact the technical staff in charge of the system and flag a problem in CORAL/NEMO. Do not try repairs on your own.
- Do not try to force the door open. Forcing the door open while the system is under vacuum can damage the tool and/or cause harm to the operator or other users.
- **Use caution when running at elevated temperatures!** The shuttle, and samples may be hot after a process.
- Be cautious when loading/unloading samples and carriers. There are mechanical pinch/crush points at the Loadlock and the robot arm.
- Make note of the large, red **EMO** button to the left of the Loadlock. If the system is behaving erratically, press this button to immediately shut the system down.
- Do not attempt to run any recipes while the Loadlock is vented (at atmosphere). The AL serves as an additional vacuum barrier between the hazardous gases and the User.

User Qualifications and Responsibilities:

To be considered qualified you need to be trained by the staff in charge of the equipment, be up to date with your safety trainings, and have a PTC approved process. Running processes/materials that have not been approved by the PTC may lead to disqualification from the tool.

- If you encounter any problems while operating the machine, report them immediately in CORAL/NEMO so that the staff can address them in a timely fashion.

Operating Procedures:



Reserve and engage the RIE-PlasmaTherm-210RL-A (or B) in CORAL. Engaging CORAL enables the tools computer monitor, so you need to do this before running any process on the tool. Verify that the system is not being used. If necessary, you'll logon as Operator, Password: **user.**

Loading a Sample:

Manually Vent the Loadlock (AL in the tool software): Click TRANSFER (if the quartz carrier is not in the load lock), then VENT LOCK.
Load your sample onto the quartz shuttle.

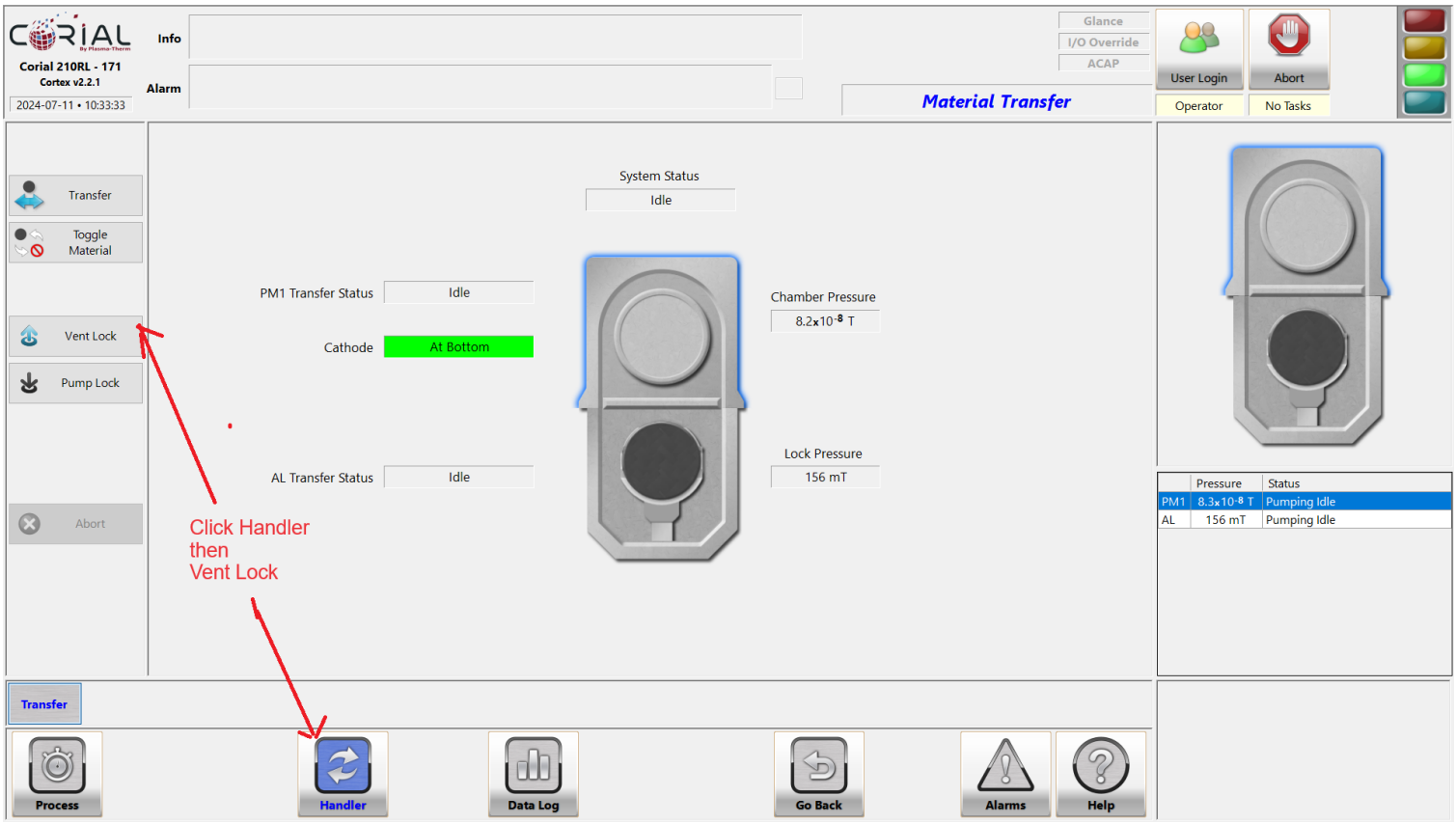


Figure 2: Tool screen while venting load lock (AL)

Note there are 4 different shuttle sizes:

a) 100mm square
b) 100mm round
c) 150mm round
d) 200mm round *

- The designated Sputter Tool, Plasma-Therm-B, (PT-B) has a 200mm round in the AL to accommodate all samples. Please do remove it as it is considered **contaminated** with metals or other non-desirable particles.!

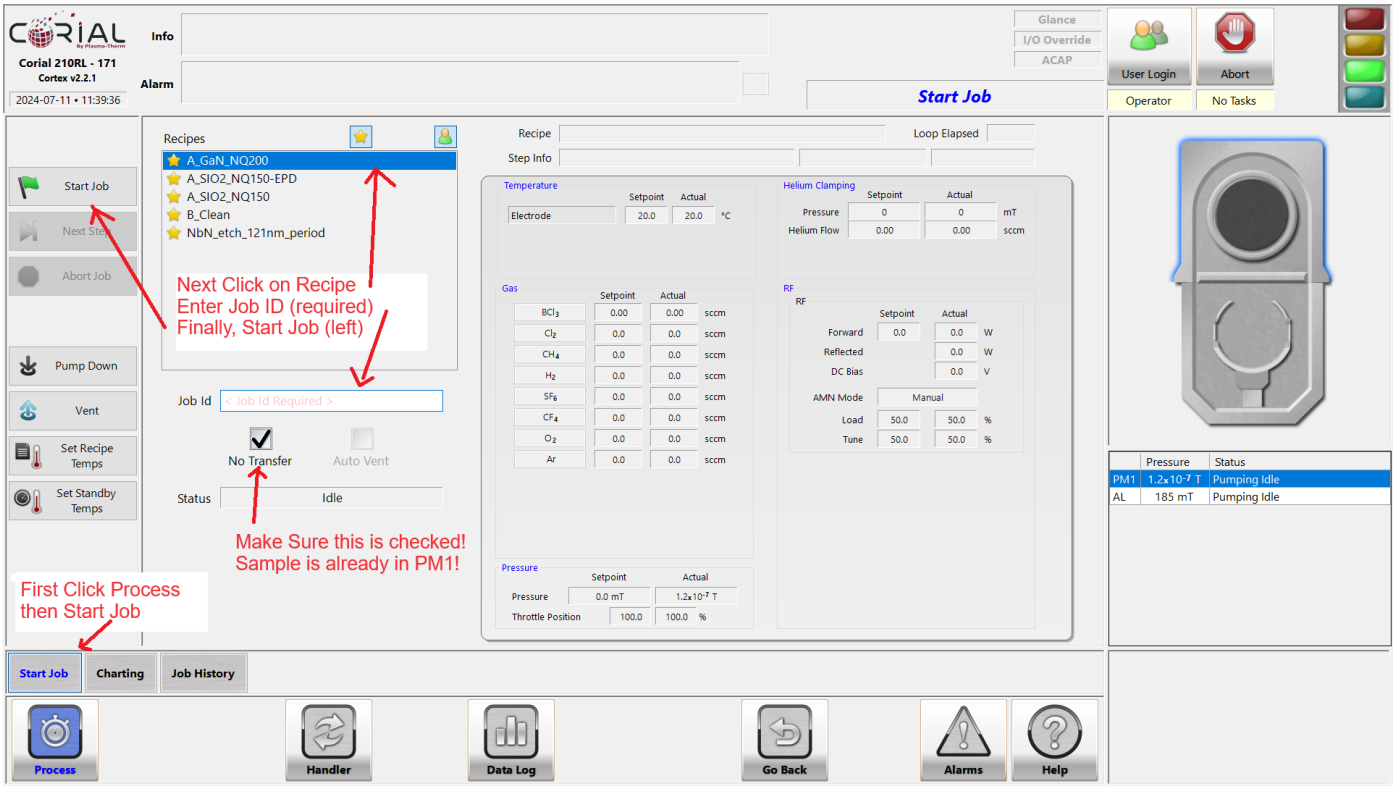
If you need to switch quartz shuttles, remove the one from the AL in Plasma-Them-A, (PT-A) and carefully place it on the plastic rack next to the tool. Carefully place the desired shuttle on the arm. Properly installed it should rotate freely on the arm. This is also helpful as it is easier to rotate the shuttle to align the wafer flat.

Running a Recipe:

The tool can be operated in either AUTO or Manual Mode. NOTE the camera/laser cannot be used in the AUTO Mode. Typically, the AUTO Mode will be used mainly for the CHAMBER CLEAN and Sputtering. Currently, sputtering is confined to PT-B ONLY, as both quartz viewports are physically blocked to protect them from the deposition of sputtered material.

For AUTO Mode:

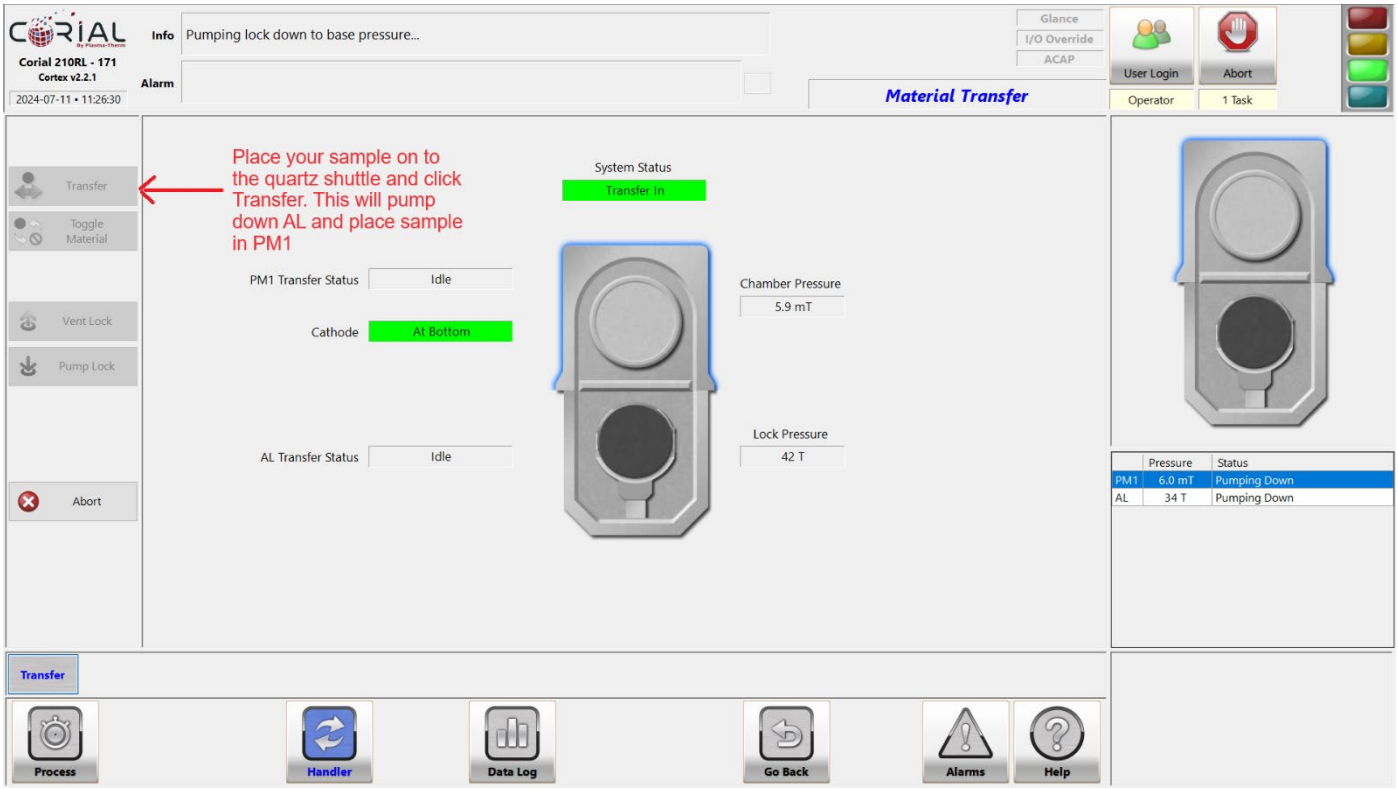
1. Click START JOB on the bottom tabs. Click CHOOSE RECIPE and select desired recipe. Enter JOB ID (required). Do not check NO TRANSFER, but check AUTO VENT. Click START JOB on the side tabs.



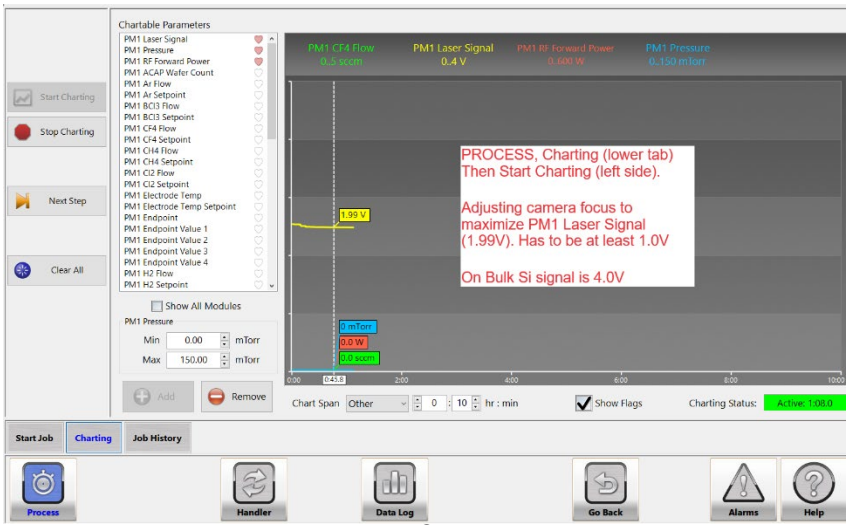
2. Stay on this page until all the necessary parameters change from yellow to green (see Appendix).
3. Click CHARTING, it should start automatically. You can select the parameters you wish to monitor. For example, Pressure, Forward RF Power, gas flows etc. When the recipe is finished, the sample will be unloaded from PM1, returned to AL and vent automatically. Repeat until all samples are processed.
4. Then Click HANDLER, PUMP LOCK wait for it to display pump idle and disengage from CORAL/NEMO.
5. If you ran the clean, and now plan to use the camera/laser then proceed to MANUAL MODE.

For MANUAL Mode:

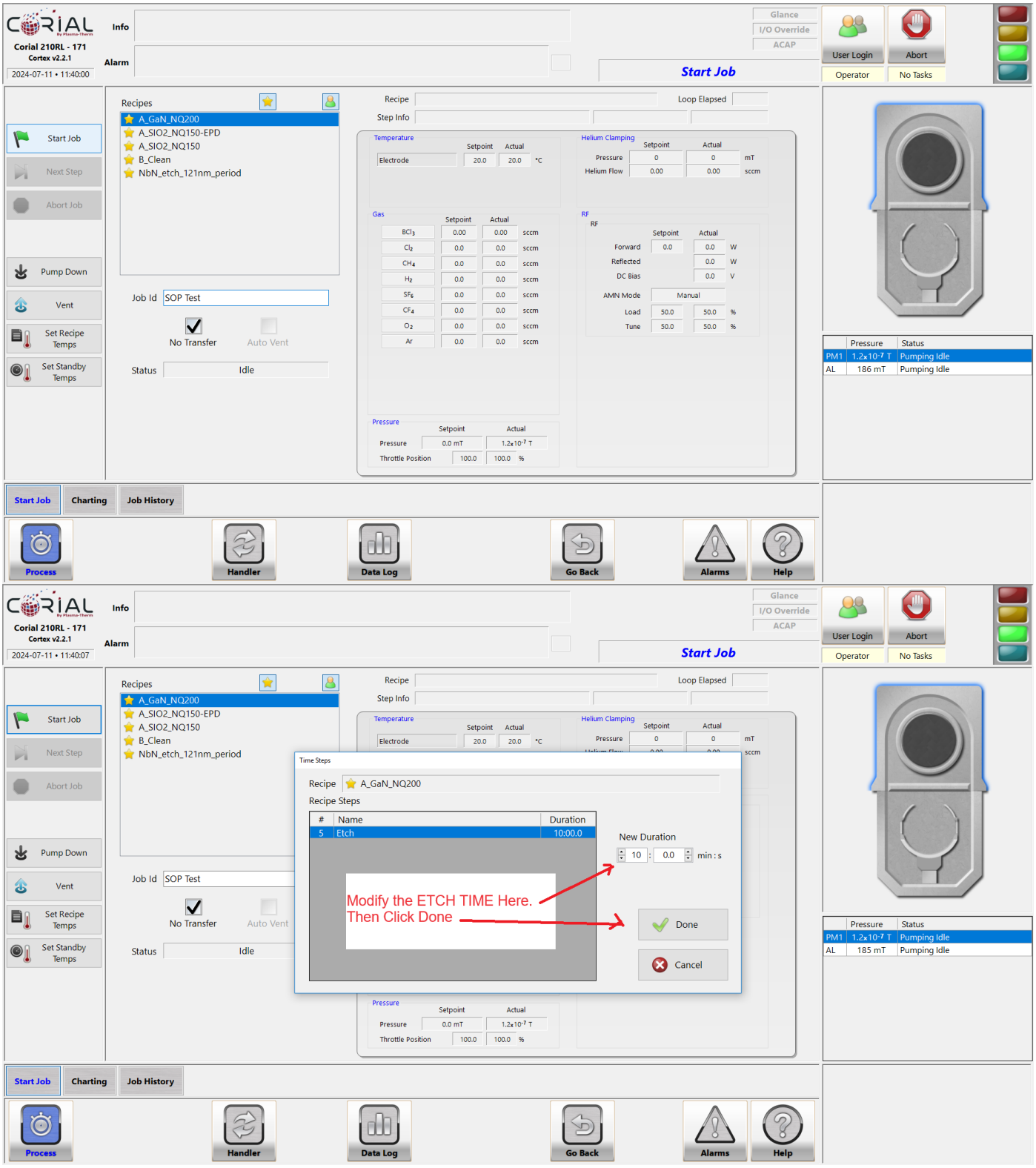
1. Click TRANSFER, the AL will pump down and transfer the sample into PM1.



2. Open the Plexi-glass door above the AL. Ensure the Laser is on (red light is lit on left side of laser). Ensure the Upper Monitor is on (red light off). Turn the Focus Ring on the camera to get the best focus spot on the Upper Monitor. If you can't see a spot then either you're on the quartz shuttle and not your sample or the laser is not over the viewport. Use the Joystick to move your sample under the camera and repeat focusing. You can also go to PROCESS, CHARTING, START CHARTING. If you do not see a parameter for laser voltage, ensure that SHOW ALL MODULES is checked. Rotate the lower monitor so you can see it while you adjust the focus. Select and double click on the Laser Voltage to see the voltage value for the laser—try to maximize the voltage by focusing, (needs to be greater than 1 V). Then click STOP CHARTING and rotate the lower monitor back to its original position.

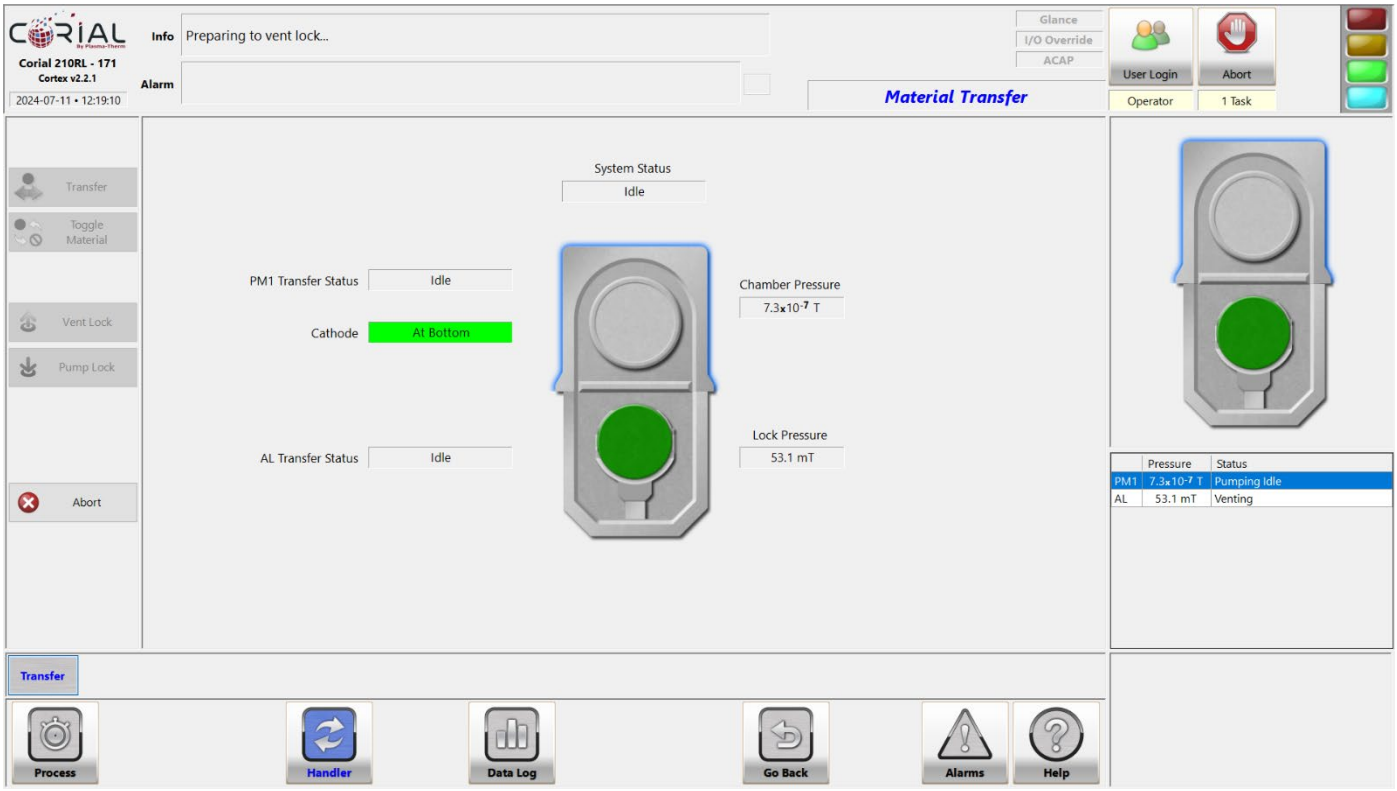


3. Click START JOB (lower tab) and click on desired recipe. Enter JOB ID (required). Ensure you select NO TRANSFER, as the sample is already in PM1! Click START JOB on the side tabs. Smaller window opens and you can change the etch time. Click OK and the recipe begins.



4. Stay on this page until all the necessary parameters change from yellow to green (see Appendix).

5. Click CHARTING, it should start automatically. You can select the parameters you wish to monitor. For example, Laser Signal, Pressure, Forward RF Power, gas flows etc. When the recipe is finished, Click HANDLER, TRANSFER. Wafer will be transfer from PM1 to AL. Then click VENT LOCK. Remove your sample when vented. Repeat procedure until all your samples are finished.



6. When finished, click PUMP LOCK wait for it to display pump idle and disengage from CORAL/NEMO.
7. Record data in the LOGBOOK at the tool.

Appendix:

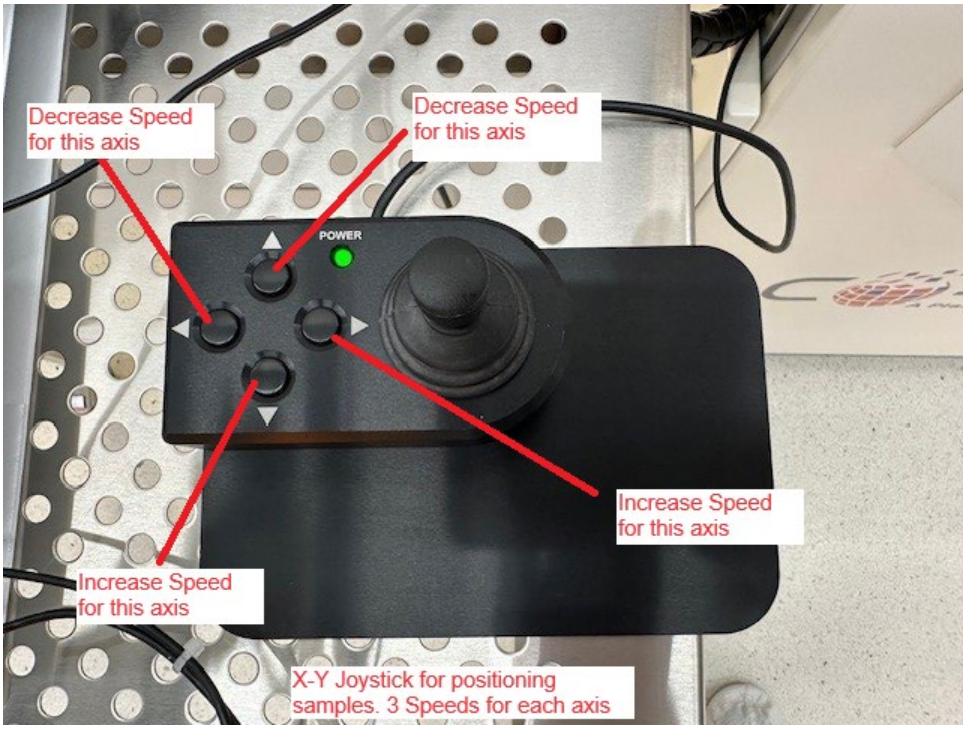


Figure 3: Camera joystick controls

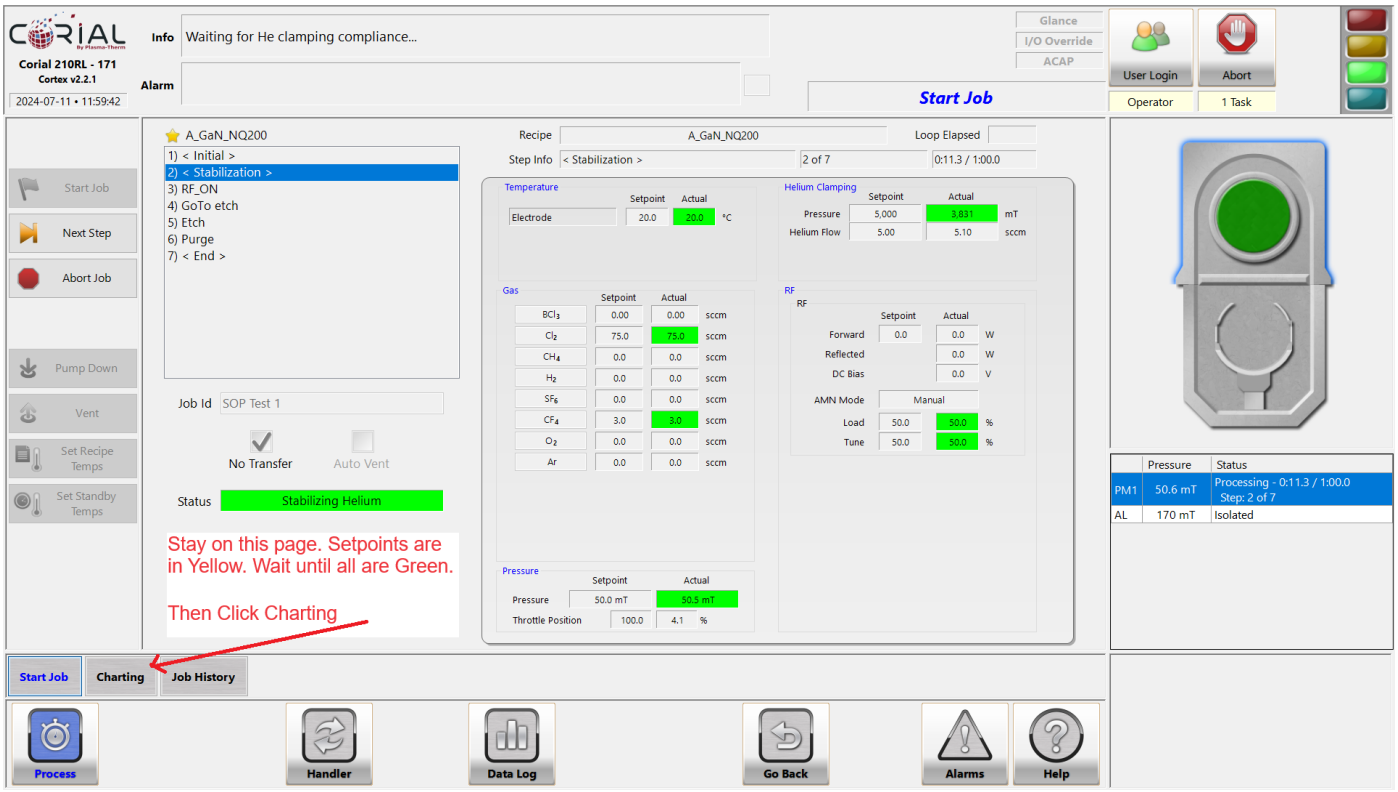


Figure 4: System parameters highlight in green after they reach their setpoint

Table 1: Process and non-process gasses used in the tool

Plasmatherm Process Gasses	
Gas	**Max Flow Rate**
BCl_3	50 sccm
Cl_2	100 sccm
CH_4	100 sccm
H_2	100 sccm
SF_6	100 sccm
CF_4	100 sccm
O_2	100 sccm
Ar	100 sccm
Non-Process Gasses	
Gas	**Function**
N_2	TMP purge, chamber vent, MFC bypass
He	Backside cooling
CDA	100 psig - valve actuation

Table 2: Common films and their etching gasses for the Plasmatherms. Note, this is a short list of common compatible films. This is not the extent of materials that can be used in these tools

Plasmatherm Common Etchable Films	
Fluorine Etched films	
Silicon Oxide (SiO_2)	Silicon Nitride (SiN_x)
Amorphous Silicon (a-Si, Si, etc)	
Chlorine Etched Films	
Gallium Nitride (GaN)	Aluminum Gallium Nitride (AlGaN)
Aluminum (Al)	Amorphous Silicon (a-Si, Si, etc)
Sputter Etched (Argon) Films	
Gold (Au)	Platinum (Pt)
Nickle (Ni)	Copper (Cu)
Methane/Hydrogen Etched Films	
Indium Arsenide (InAs)	Indium Phosphide (InP)
Gallium Arsenide (GaAs)	Gallium Antimonide (GaSb)

Refractive Index Lookup:

Use the following link to find the refractive indexes of different materials to use the endpoint detection system.
https://refractiveindex.info/?shelf=main&book=GaN&page=Barker-o#google_vignette

Endpoint Detection System:

Laser endpoint detection (laser interferometer) allows real-time control over deposition/etching rate, thickness/etched depth, and process end pointing. In the “Step Termination” window of the etching step, select ‘Endpoint Detector’ and the recipe that you have created in the software EndpointWorks III. It is needed to determine the maximum and minimum time and appearance of an alarm if the endpoint detector is unable to process the signal. The refractive index of the material must be programmed.
Refractive index versus the wavelength is reported in table 2, and the exact value for given films can be determined by ellipsometry. Typical wavelength of the laser diode of the system is 675 nm, exact value can be read on the endpoint detector case.

Table 3: Refractive index of materials

Wavelength (nm)	254	405	436	546	675	905
Photoresist	/	/	/	/	1.64	1.62
Si	1.608	5.42	4.831	4.106	3.815	3.67
SiO_2	1.5	1.469	1.466	1.46	1.455	1.451
Si_3N_4	2.27	2.07	2.06	2.03	2.02	2.005
SiO	2.01	2.12	2.09	2.01	1.948	1.913
TiO_2	2.37	3.2	3.0	2.8	2.6	2.7
SiC	/	/	/	/	2.621	2.592
GaAs	2.89	4.44	5.06	4.07	3.79	3.57
GaN	/	/	/	/	2.36	2.34
AlN	/	/	/	/	2.145	2.131
Sapphire	/	/	/	/	1.764	/
Perylene-C	/	/	/	/	1.64	/
InP	/	/	/	/	3.504	3.047
$Al_{0.2}Ga_{0.8}As$	/	/	/	/	3.676	3.455
$Al_{0.4}Ga_{0.6}As$	/	/	/	/	3.522	3.301
$Al_{0.6}Ga_{0.4}As$	/	/	/	/	3.361	3.177
$Al_{0.8}Ga_{0.2}As$	/	/	/	/	3.215	3.097
AlAs	/	/	/	/	3.213	3.096

Deposition/etching rate, thickness/etched depth during recipe adjustment can be estimated 'on the fly' using the relation between the thickness per interferogram period and optical parameters of the film:

$$Period = \frac{\lambda}{2n}$$

where λ: lager wavelength (nm), n: film refractive index.

Table 4: Materials with their refractive indexes, and thickness per endpoint system period

Material	RI	Wavelength (nm)	Thickness per period (nm)
Photoresist	1.64	675	205.8
Si	3.815	675	88.5
SiO2	1.455	675	232
Si3N4	2.02	675	167.1
SiO	1.948	675	173.3
TiO2	2.6	675	129.8
SiC	2.621	675	128.8
GaAs	3.79	675	89.1
GaN	2.36	675	143
AlN	2.145	675	157.3
Sapphire	1.764	675	191.3
Perylene-C	1.64	675	205.8
InP	3.504	675	96.3
Al0.2Ga0.8As	3.676	675	91.8
Al0.4Ga0.6As	3.522	675	95.8
Al0.6Ga0.4As	3.361	675	100.4
Al0.8Ga0.2As	3.215	675	105
AlAs	3.213	675	105