CORAL Name: EBeam-AJA

Location: Bay U8
Tool Category: Deposition
Contacts: Gary Riggott, Kurt Broderick

Contents

Introduction 1
Safety 2
User Qualifications and Responsibilities: 2
Operations: 3
Sample Loading Procedure 3
Pumpdown Procedure 4
Deposition Procedure 4
Appendices 6

Introduction

The EBeam-AJA is used to deposit thin films, typically up to 1 micron thickness at normal or tilted angles, onto fixed or rotating substrates varying in size from millimeter pieces through 150mm diameter via electron beam (EBeam) evaporation. With a turret that can accommodate up to 6 crucibles per run, the EBeam-AJA can deposit a wide variety of materials. MIT.nano stocked metals are listed below:



Aluminum	Al
Aluminum Oxide	Al2O3
Chromium	Cr
Cobalt	Co
Copper	Cu
Germanium	Ge
Gold	Au
Iron	Fe
Molybdenum	Mo
Nickel	Ni

Palladium	Pd
Platinum	Pt
Silicon	Si
Silicon Dioxide	SiO2
Silver	Ag
Tantalum	Ta
Tin	Sn
Titanium	Ti
Titanium Dioxide	TiO2
Tungsten	W

Materials not listed here can be requested through the Process Technology Committee (PTC) as a “personal chemical”. Follow instructions here: Personal Chemical Request Form

A specially designed Shadow Fixture is available that allows multiple depositions to be done of different thicknesses or even of different deposition materials, during a single pumpdown process.

The substrate holder can be biased in order to back sputter the sample with O2 or Ar, either before the deposition to pre-clean the surface or during the deposition to change film density or oxygen content. A Kaufman Ion Mill is also available to etch the substrate at up to 30 nm/min. Ion milling may be used in a variety of different processes and substrates; self-aligned etch-depositions, simple masked substrates or bulk etching. All processes in the EBeam-AJA can be run at normal or tilted angles and with the sample stage rotating or in a fixed position.

Safety

The EBeam uses High Voltage (8.2kV) and High DC Current (=/< 500mA) in a vacuum chamber of <10-5 Torr to generate the electron beam which enables deposition. In addition, there are sources of lower, but still potentially lethal voltage (120, 220 VAC) within the cabinet of the tool. NEVER remove cabinet panels to attempt to fix a machine problem.

EBeam Specific Safety Considerations:

- Identify the Emergency Off on the front of the machine.
- Ground the crucible area with the Grounding Rod before touching the Pocket area.
- Only run approved materials and substrates in the tool.
- Always discuss material or process variations with staff before trying them.
- Never put low temperature materials such as adhesives, lab tape, liquids or unbaked resists into vacuum equipment as they can damage the pump.

User Qualifications and Responsibilities:

- Users seeking training on the EBeam-AJA must have a process approved by the PTC.
- Users requiring very low base pressure can load the tool and pump through the night and perform the deposition the next day. Users must remain engaged on the tool in CORAL throughout the pumpdown step.
- Normally, users should allow at least 1 hour of High Vacuum pumpdown to reach a base pressure of 1.0E-5Torr or less. Additionally, allow 30 min for sample preparation and unloading, plus deposition time, frequently at a rate of about 1-3 A/s.
- Tool users must be proficient at the Precious Metals Check-In/Check-Out process if applicable. Users are responsible for precious metals while they are engaged on the cabinet (while it is unlocked).
- Users must ensure that the front and side Viewport Shutters are closed immediately following use.
- When processing is complete and the system is ready for the next user, you may disengage from the tool in CORAL. Please be sure to enter accurate processing information into the CORAL dialogue as this is used for billing and tool maintenance.
- Users are deemed proficient at the discretion of MIT.nano Staff. Multiple training sessions may be required. Proficiency must be demonstrated in the tool operations of:
    - Chamber Venting
    - Sample Loading
    - Crucible Loading
    - Crucible Inspection/Turret Operation/Pocket Labeling

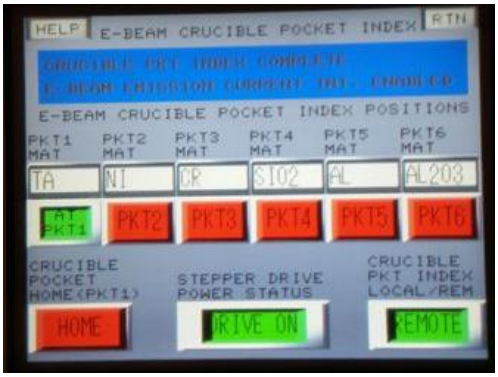
- Chamber Inspection & Cleaning
- Chamber Pumpdown
- Process Creation & Editing/Deposition Controller Operation
- Process Execution
- Completion of your process

Operations:

Sample Loading Procedure

Engage the tool in CORAL. Note: the tool will not vent the chamber unless engaged.

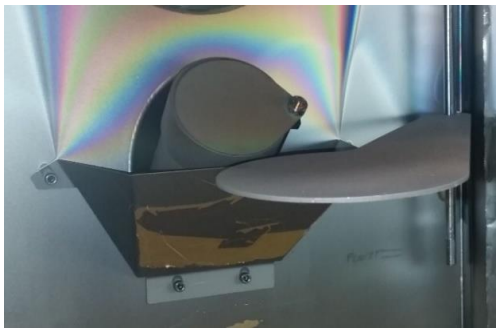
1. Vent the chamber. Select Auto/Pump from the main menu on the ProFace Display Computer (Appendix D), then choose Auto Chamber Vent, twice-and wait for the chamber to vent.
2. Open the Chamber.
3. Load and label crucibles under the "Crucible Index". There is a "Local/Remote" button, which will must be in local mode for loading. When a material is loaded, IMMEDIATELY label on the screen! Press Home once every run, then return to "Remote" or the crucible will NOT rotate when needed.



4. Crucible Information:
   a. Crucibles should be ½ to ¾ full, except materials that sublime (Cr, SiO2) which should be completely full. Fill or remove material from supplies cabinet as needed.
   b. Clean debris out of the hearth area with a razor and vacuum before and after every run to minimize cross contamination.



5. The proper height for the substrate shutter is shown in the photo. It should be flush with the top of the shield for the Ion Mill.



6. Load substrates onto one of the following substrate holders using either clips/screws or special high temperature Kapton tape,:
   a. Steel 8" perforated disks: the default sample holders, variety of clip positions for various sample sizes, can be tilted, easily cleanable with a razor blade and vacuum cleaner.

b. Aluminum 6" holder: magnetically attached, requires a Si dummy wafer installed to prevent its accumulation of excess material, can be tilted. This sample holder must be used for RF back sputtering.
c. Shadow Fixture: The shadowfixture blocks part of the substrate holder to provide selective deposition to samples. See Appendix C for details.
d. Extension Collar: attached in place before the magnetically attached Aluminum 6" holder with 3 short screws. This attachment doubles the efficiency over the normal position to save precious metal, but should not be used for liftoff.
e. Three wafer planetary: used for conformal coating of features and sidewalls. Attach with 3 long screws. Set rotation speed to 40 and set Shutter Delay (under Deposit Controls) to "0". The planetary has a lower height setting for the substrate shutter, of about 1 cm from the bottom of the shaft, and this position blocks the quartz crystal monitor when closed. ****always return to the normal upper shutter location when finished****

7. Test the substrate shutter by going to Local (vs remote) and tapping SHUT open and closed, return to Remote. Verify crucible index is in Remote.
8. Verify that no gas (Ar or O2) is flowing in the top left of the ProFace main menu.
9. Check Crystal Life: On the Inficon Controller (Appendix D), main menu, press "Next Menu" repeatedly until "Sensor Info" appears. Press "Sensor Info". If crystal "Life" reads less than 80%, change it (see Appendix E).

Pumpdown Procedure

1. Pump Down the Chamber: from the ProFace Computer (Appendix D) select Auto/Pump from the main Auto Pump menu, then choose Auto Chamber Pump down. Press once to select AutoChamber Pumpdown, which will display in red. Press again so the button switches to green.
2. The Foreline is pumped for <1 min, then the chamber is rough pumped for about 10 minutes, until the high vacuum crossover pressure of 100mTorr (1.0E-3Torr) is reached.
3. Then will switch to high vacuum. Total pumpdown time is typically 30 minutes to 3 hours.
   c. Turn on the high vacuum ion gage, "Sensor 1" on MKS gauge controller. The Ion Gauge On/Off switch is labeled. Once the vacuum level is displayed, turn the ion gauge off. This prolongs its life.

Deposition Procedure

While system is pumping down to desired base pressure, verify:

- Film Menu pockets on ProFace and Film Menu Match.
- ProFace is in Remote for Shutters and Crucibles, (buttons are green).
- Recipes for Films match the Film Condition Values table in Appendix B.
- See materials table in Appendix B for Shutter Delay, Error Percentage and Control Delay.
- If using Planetary, shutter has been lowered and shutter delay is "0".
- Tooling Factor is correct for substrate holder type. See Appendix D.
- Start is set to Automatic, not Manual
- Maximum deposition rate is 3 A/second. Use 0.5-1.0 A/s for thin films of 10nm or less. Use 2A/sec for films of 10-100nm.
- Note: Final Thickness is in KA: for example 100 nm is 1 KA.

Steps:

1. Press the Green "HV On" button on the Remote handset.
2. Press Start on the Inficon Controller.

3. The ProFace should indicate rotation to deposition material 1.
   Always watch to make sure the deposition starts, and the shutter opens. If there is an error the machine will shut off with only a transient error displayed.
4. Verify the current is going up on both the remote (shows up to 500 mA) and Inficon (shows % of max) proportionally.
5. Open the viewport 30 degrees and view the location of the crucible. As it heats and visible light will be emitted. If the beam position is incorrect abort the process with the Red Button on the Handset, or the Stop Button on the Inficon and notify staff immediately. The EBeam can melt itself easily, so pay attention!
6. Close the viewport after verifying correct beam positioning. Windows are expensive to replace if coated with metal!
7. Watch deposition rate during Ramp Ups and Soaks. When switching to Deposition Rate Targeting, look for the Deposition Rate displayed on the bottom of the Inficon, and beware of errors such as Maximum Power Reached.
   - **During ramp and soak 1 and 2, VIEW Deposition Rate!!**
   - **Make Sure Deposition Starts; if it aborts, it will only show the wrong thickness, no other error!**
   - **If Deposition Rate ever goes over 3A/sec, abort the run, and lower the soak power so Pre-Deposition Rate STAYS less than 3A/S, then PEN CHANGE the SOP!**

8. Parameters may be edited in-process: press the Inficon Next button to make the “Quick Edit” menu appear. You may change deposition rates and maximum power settings before the machine shuts off if these values are being approached.



9. Once deposition of the first material is complete, the ProFace will automatically rotate to each subsequent material. Steps 4-8 above should be repeated for all additional materials.
10. After the final material is deposited, WAIT 10 minutes for the crucibles to sufficiently cool. Failure to wait may oxidize target materials or damage system.
11. Vent the system: under ProFace Auto Pump, press Auto Chamber Vent twice.
12. Ground the hearth with the grounding rod. This will eliminate any residual static charge so that you don't get a shock.
13. Return metals to their storage area. Precious metals to be returned to the CORAL-interlocked cabinet.
14. Unload your samples.
15. Before and after every run: use the dedicated HEPA vacuum to clean any debris or flakes left in the chamber. Close the chamber.
16. Pump Down the chamber. Press Auto Pump, then press Auto Chamber Pump once to select it. Then press again to initiate pumping. The button will change to green.
17. Disengage from CORAL, enter your run data accurately.

Appendices

Appendix A: Common Failure Modes

- Caution: If Max Power exceeded error appears, STOP and THINK! Either you are on the wrong crucible, or your shutter is blocking the Sensor, or possibly a normal situation like heat loss out of the crucible from splashed conduction paths is occurring. Is Crucible index on REMOTE?

(Appendices continued on next page…)

Appendix B: Film Menu & Film Conditions Values list by Material

Material	Al fresh	Al (old)	Al2O3	Ag	Au	C	Cr	Co
Ramp 1 Pwr	10	15	10	6	15	15	5	10
Ramp 1 Time	3	4	2	2	3	2	2	5
Soak 1 Time	1	1	1	1	1	1	1	2
Ramp 2 Pwr	12	22	14	9	20	25	7	15
Ramp 2 Time	2	2	1	1	1	1	1	2
Soak 2 Time	1	1	1	2	1	1	1	2
UNUSED ROWS	X		X	X	X	x	X	X
Idle Power	0		0	0	0	0	0	0
Ramp Time	2	3	0	1	1	0	0	2
Notes: tooling factor, swept area								1hr min pumpdown 0.5A/s max
density	2.7	2.7	3.97	10.5	19.3	2	7.2	8.9
z-factor	1.08	1.08	.336	.529	.38	3.3	.305	.33
Process Menu/ Max Power	40	65	25	40	65	45	14	35
Shutter delay (max allowed) **	2	2	1	2	2	1	1	2
Capture (error allowed)	10	10	10	10	10	15	10	10
Control delay (gettering/ stabilizing time)	2	2 min	2 min	1 min	45s	1	1 min	1min

Film Conditions

Deposit Controls

** For extender or planetary sample loading, always use 0 shutter delay!

Appendix B: Film Menu & Film Conditions Values list by Material

Material	Cu	Ge	Fe	Mo	Ni		Pd	permalloy	Pt	Ru
Ramp 1 Pwr	10	8	7	30	18		9	12	25	20
Ramp 1 Time	2	1	2	2	2		2	2	3	3
Soak 1 Time	1	1	1	1	1		1	1	3	2
Ramp 2 Pwr	15	13	10	45	25		15	14	30	29
Ramp 2 Time	2	1	1	2	1		1	1	2	2
Soak 2 Time	1	1	1	1	2		1	1	2	1
UNUSED	X	x	X	X	X		X		X	x
Idle Power	0	0	0	0	0		0		0	0
Ramp Down	1 min	1m	1m	1m	2 min		2 m	3 min	2 m	2 m
Misc					**2A/sec max**				**0.7A/s max**	**0.5A/s max**
density	8.9	5.35	7.9	10.2	8.9		12	8.7	21.4	12.3
z-factor	.44	.52	.35	.257	.33		.36	1	.245	.18
*Process Menu*Max Power	60	40	65	70	70		35	35	65	50
Shutter delay max allowed**	2	2	2	2	2		2 m	2 min	2 min	2m
Capture %error allowed	10	10	10	10	10		10	10	10	10
Ctl delay - gettering	30 s	30 sec	1 m	1 min	1 min		30 s	30 s	30 sec	30 s

Film Conditions

Deposit Controls

** For extender or planetary sample loading, always use 0 shutter delay!

Appendix B: Film Menu & Film Conditions Values list by Material

Material	Si	SiO2	Ta	Ti	TiN	TiO2	W	WO3	Y
Ramp 1 Pwr	15	2	50	11	6	15	50	3	2
Ramp 1 Time	3	1	4	2	2	2	4	2	2
Soak 1 Time	1	1	1	1	1	1	2	1	1
Ramp 2 Pwr	20	3	30	16	8	20	60	4	4
Ramp 2 Time	1	1	1	1	1	1	1	1	1
Soak 2 Time	2	1	1	1	1	1	1	1	1
UNUSED	X	X	x	X	X	X	X	x	x
Idle Power	0	0	0	0	0	0	0	0	0
Ramp Down	1m	0	2min	1min	0	0	2 min	0	0
Miscnf, swept area			**½ area sweep**		**Store in N2!**	**1.39 tool factor**	**Smallest swept beam area**		**Store N2 box**
density	2.32	2.65	16.6	4.5	5.43	4.26	19.35	7.16	
z-factor	.71	1	.26	.63	1	.4	.163	1	
Process Menu/ Max Power	45	9	80	40	15	40	95	10	8
	.....	.....	.....	.....	.....	.....	.....	...	.....
Shutter delay(max allowed)**	90s	1min	90s	2m	2 min	1min	3min	30s	1min
Capture (error allowed, %)	10	10	10	10	10	10	20	10	10
Ctl delay (gettering stabilizing)	1	30s	30s	2	30s	30s	1min	30s	1min

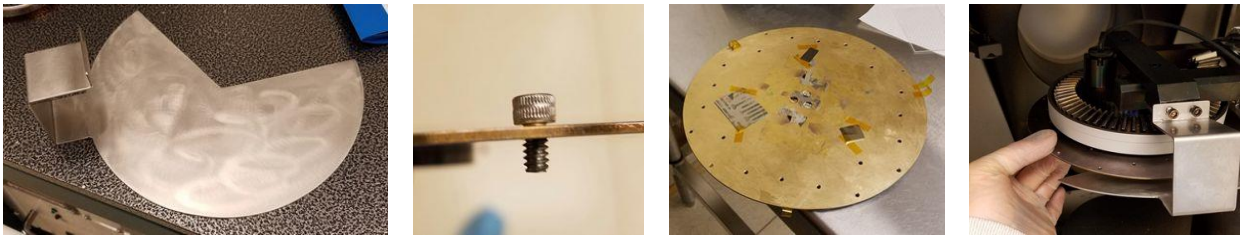
Film Conditions

Deposit Controls

** For extender or planetary sample loading, always use 0 shutter delay!

Appendix C: Shadow Fixture

The shadow fixture blocks part of the substrate holder to provide selective deposition to samples. It is recommended to get additional training from staff to use this feature. Use the steel perforated disk, with the sample positions marked in some fashion that will be visible from the side viewport when loaded. This can be done with tape or a screw.



Above: shadow fixture, marking screw, 3 different pieces, sample holder placed when fixture is loose, to allow loading room, then tightened last.

The sample holder is rotated, at slow speed (~20%) until the desired section is positioned in the shadow plate opening, then it's turned off. The sample can be viewed with the light, thru the opened shutter.



- Never leave the side viewport shutter open during deposition.
- Always test the system, as follows, before pumping down:
- Make sure that your markers can be seen from the side viewport.
- Make sure that the samples will be exposed to deposition when the marker is in the reference position.

Appendix D: Other Tool Operational Notes

If Max Power is exceeded; likely either shutter position closed is blocking sensor or wrong crucible is indexed. Watch during ramp 2 and soak 2!

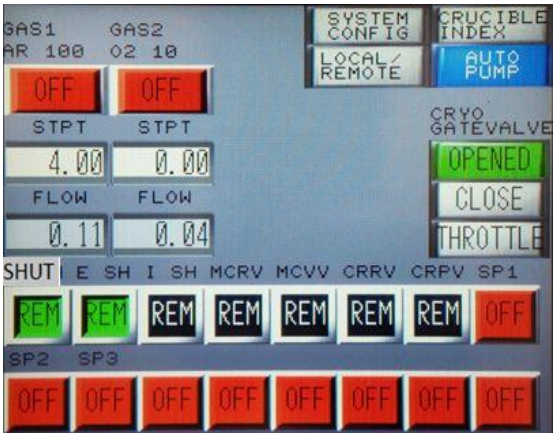
If Deposition rate is ***over 4A/sec, abort the run***, make *soak 2* power lower, and start again. Pen change this sheet too, or send a note.

Film Conditions = Preheating, Deposit Controls = Sensor feedback
PID values P=50, I=0.7, D=0.0, and Film Tooling=100%

ProFace Display Computer

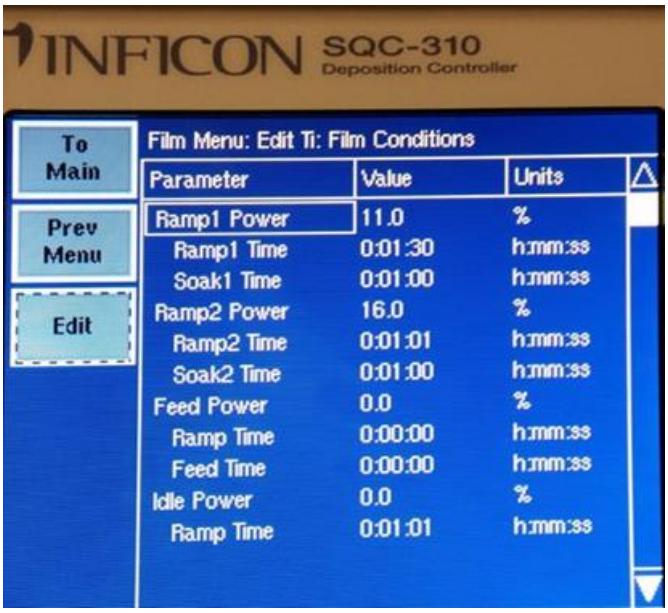
Controls pumping, crucible and shutter functions:

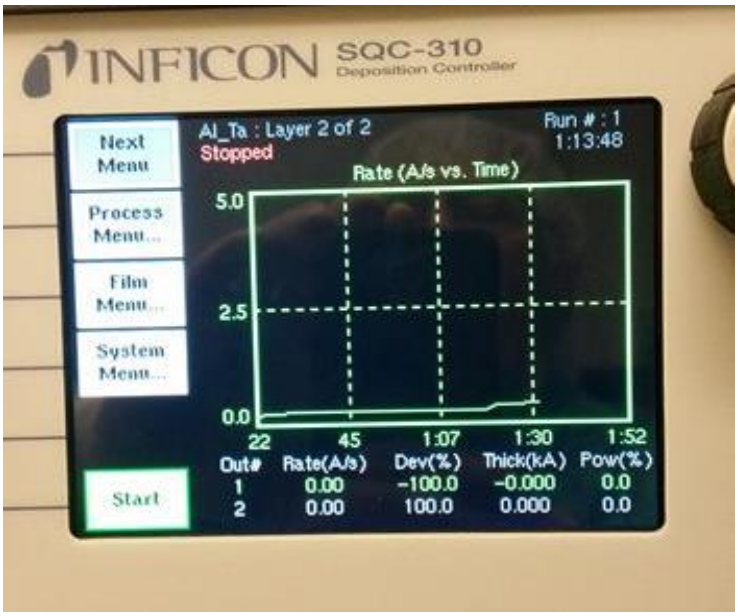
There are three functions from the ProFace membrane display, selectable from the Main Menu, in the top right of the display. You can always return to the Main Menu by touching the small "RTN" button at the top right corner.



Inficon Controller

Identifying materials' properties, deposition ramps and rates, pocket location, and feedback loops





Inficon Main Menu, Left, and Film Conditions, under Film Menu, Right

The Inficon controller is used as a material database interfacing with your specificrequirements, with menu choices following.

Film Menu:

Density and other standard values are stored, to which you assign a crucible pocket location;

- Select material from list, press Edit
- Turn wheel down to select Pocket # ; update correctly.

- Film Conditions**:** Material specific ramp up and ramp down heating profiles.
- Verify these are correct, compared to the *Film Condition Values* on last two pages of this SOP.

Deposit Controls: (under Film menu)

After ramp up 1 and 2 are done, either opening shutter immediately, if using 3 wafer planetary, or typically after 2 min under deposition rate targeting, the normal situation.

- **Shutter Delay** means "target the desired deposition rate", for the time listed, (typically 1 min)
- **Capture** means "allowable error % to end shutter delay time", (typically 10%) from targeted value. In not met, system shuts off.
- **Control Delay** means delay after deposition rate is reached, to improve quality of critical first layer interface. Use 2 min for first level adhesion layer, to allow gettering and moisture desorption; 1 min subsequent layers, minimum, more if high surface area crucible fill.

Process Menu:

- Start Mode Automatic
- Initial Rate = Deposition Rate (typ 1-3A/s)
- (faster rate is rougher, but slower rate has more time for contamination)
- Either Sensor 1 or Sensor 2 Must be ON
- Final Thickness = your required thickness
- Max Power from the table at end of this document
- (all unused fields are at value 0)

System Menu:

- **System Tooling** = ratio of material received at substrate to QCM sensor,depends on fixtures.
  - Standard 6" holder system tooling is 1.58
  - Extension is 3.75
  - 3 Wafer Planetary is 2.1
  - Caution!! system tooling can be adjusted at the film level as well.Leave that at 100% (unless otherwise specified) or the effects will multiply!!
- **Rate Filter Alpha** is similar to phase lead, or integration from PID, and can generally be set to .25 , although for materials which sublime, like Cr and SiO2, a smaller value like .1 is better

Genius Handset

Controls beam sweep area

The remote handset is used only for controlling the swept area and x, y beam positioning, with other functions such as power controlled by the Inficon or ProFace. Default is 8.2KV, with both left and right side in Automatic mode, and Pocket 1 material SiO2 displayed, with Data: Oxide 6KT. Default settings, not user adjustable. Normally beam swept area should be full sized, touching circle at the corners in display, but for refractory or high temperature materials, such as W, or Ta, the beam should be reduced to <25% of the area. Return to full sized after doing reduced area run, please!



To adjust swept area or beam positioning:

- Press Menu, making display offer Manual choice on left.
- Toggle down on left, causing Manual choice on right
- Toggle down on right
- Accept Manual mode by pressing Menu
- Adjust area with left toggle switch
- Adjust impact center with right toggle switch
- Press Menu, return to Automatic left and right, accept with Menu, when done

Appendix E: Changing QCM

Change the QCM as follows:



Verify the sensor 1 and 2 are operational, via the Inficon, From Main menu, press Next Menu, until you find the "Sensors Info". These Quartz Crystals are 6 mHz, declining frequency, and are replaceable by pulling down on the sensor face, and they should be replaced when less than 80% life is displayed, or if they are reporting failure.

Sensor 1 (back) and 2 (front) aiming down towards crucibles. Rings pull down for crystal replacement

Appendix F: Ion Milling

Kaufman Ion Milling:
To etch into your substrate, at the rate of perhaps 4-20 nm/min, use the 6" sample holder tilted towards the Kaufman Ion milling source, at 55 degrees. This will accelerate Ar into the sample, causing etching of the substrate. To protect crucibles from Ion Milled debris, leave an empty hearth pocket, without crucible, exposed during Ion Milling!

Ion Mill gun, with I-SH closed. Note Substrate Shutter is UNDER Ion Mill Gun.

To use this, after desired high vacuum base pressure is achieved:
Preset the voltage and current for approximately (record your values)

- set values on display by selecting the box with the button, ie "cathode" then spinning the "Setpoint Adjust" dial above the cathode display
- All parameters for Ion Milling are pre-set. If you need special process conditions, see Gary or Kurt.

*Accel display will flash when above 2mA(set) but will go to ~10mA.
** 30sec etch time, 30sec off for substrate cooling wait, repeat.

Driving voltages/currents and results: please update on paper or notify Kurt.

Cathode V/A	Discharge V/A	Beam V/mA	Accel V/mA(set)/ mA (actual)	Neutralizer V/A	Emission mA	Etch Rate film/mask nm/min
9/ 7	40/ 0.65	600/45	120/1.6/9	9/ 11.5	40-70	SiO2 10-25
8.5/1.16	40/0.59	600/46	120/2/8.0	10.7/12.1	46.2	Au/Ag 60 Resist 33

Operation:

1. Turn OFF the Ion Gauge and Turn ON the Ar at about 3.5 sccm.
2. CLOSE the Cryo Gate Valve for about 30 seconds, to allow pressure to increase to ~2mT, then go to THROTTLE to allow pressure to stabilize
3. Turn ON Kaufman Controller, see below, and check values. Adjust as required.
4. OPEN the I-SH, ion mill shutter then push BEAM ENABLE. If it doesn't ignite, briefly (1-2 sec) close I-SH to allow the Ar flowing through it to build local pressure, then open I-SH and proceed. Open the side viewing port if you wish to see the ion mill plasma.
5. Forgetting to open the shutter will cause an error and destroy the shutter!



Some notes on Ion Milling:

Accel mAmp has two displays: the Limit (bottom left) and the Set Value (bottom 2nd from right). The set value should be set to 4-15% of beam current, so about 2mA. Help 26 fault, pressure too low. Is gas flowing and throttle valve active?

To proceed with EBeam evaporation at this point:

- Close I-SH
- Return to normal substrate holder angle
- Turn off Ar
- Open Cryo
- Turn on Ion Gauge

Back Sputter RF

Substrate sputtering can be done with either O2 or Ar, to remove organics or etch slightly, respectively. This is ONLY available with the standard Aluminum 6" holder!

Operation

After achieving desired base pressure, flow desired gas, from ProFace main menu, Top Left. On same menu, Top Right, is option to close the pump or close partially (Throttle). Ideally, the Back Sputtering is done at ~3-5mT, so if throttle is selected with gas flowing, the chamber pressure should be about in this range. Gas flow may be adjusted if needed.



Main Menu, ProFace, L, showing gas, and RF Generator, R, for Back sputtering

To light plasma:

1. Flow gas as desired, sufficient for 3-6 mT on Throttle mode
2. Close cryo gate valve, causing pressure to rise.
3. When about 20 mT chamber pressure, rotate dial to FP, press to change, and set FP RF Power value to about 25W, and press to accept setpoint.
4. Light Plasma with RF Output button. Look in side window to verify plasma.
5. Switch immediately to Throttle valve on the ProFace.
6. Organic strip is often 1 minute, although significant process variations are used.
7. Turn off Gas, RF Power, and open cryo gate valve when finished, and proceed to normal evaporation

When processing is complete and the system is ready for the next user, you may disengage from the tool in CORAL. Please be sure to enter accurate processing information into the CORAL dialogue as this is used for billing and tool maintenance.